THE DEVELOPMENT OF A FRAMEWORK FOR AN INTEGRATED LOGISTICS SUPPORT SYSTEM WITHIN A HIGH TECHNOLOGY INDUSTRY IN A DEVELOPING COUNTRY

by

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ABSTRACT

Competitive and high-risk environments require complex high technology systems, which need to be supported and maintained over their respective life cycles. These systems often have a significant consequence of failure, and require complex management systems to achieve their operational objectives. Significant leadership and management challenges exist, not only in South Africa, but also in other developing countries, where systems may be utilised beyond the lifespan they were designed for and are susceptible to obsolescence.

This study was conducted by following a structured process; the research consisted of three stages. The first stage dealt with the research problem, including the delimitations of the study. The second stage was further divided into three phases. The first phase deconstructed the appropriate literature, which included the interpretation of numerous definitions of logistics, integrated logistics support, and the integrated logistics support elements. In addition, the research was grounded in the fields of operations management, supply chain management and integrated logistics support. The second phase focused on the deconstruction of six case studies from four different high technology complex systems. From the analysis of the first two phases followed the third phase of research, which focused on the identification of areas requiring further research. Further research was conducted by means of a questionnaire, the results of which were analysed for variable dependency and variable association. The third stage of the research included the collation and analysis of the findings of the first two stages of research. The analysis utilised the principles of Mode 2 research and design science research, whereby an ILS framework and associated grounded technological rules have been recommended.

These recommendations are robust in nature, as they can be applied in the most challenging environment and circumstances as identified. Furthermore, by grounding the theory in the disciplines of operations management, supply chain management and integrated logistics support, the reliability, validity, relevance, and applicability of the study could be substantiated. This implied that the generated theoretical knowledge could be transferred to and applied in practice, and as such, an organisation can reap substantial value added benefits, and gain considerable competitive advantage in the market place by applying this developed ILS framework and associated ILS grounded technological rules.

KEY TERMS

Integrated logistics support (ILS); integrated logistics support system (ILSS); high technology; developing country; systems beyond designed life; obsolescence; operations management; training, manpower and personnel; maintenance; technical data and documentation; support and test equipment (S&TE); supply support; packaging, handling, storage, and transportation (PHS&T); reliability, availability, and maintainability (RAM); supply chain (network); supply chain management.

DECLARATION OF OWN WORK

"I declare that

THE DEVELOPMENT OF A FRAMEWORK FOR AN INTEGRATED LOGISTICS SUPPORT SYSTEM WITHIN A HIGH TECHNOLOGY INDUSTRY IN A DEVELOPING COUNTRY

is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references."

________________________ __________________

Keith Richard Lambert Date

Student no.: 3088-783-6

'Always bear in mind that your own resolution to succeed is more important than any other.'

– Abraham Lincoln.

'Do not go where the path may lead, go instead where there is no path and leave a trail.'

– Ralph Waldo Emerson.

PREFACE

During the process of completing this doctoral degree, many people have asked me why I want to complete a doctoral degree and why anyone in their right mind would want to do so. From the start to the finish of the process the answers have differed. The answers differed for various reasons depending on the stage of my life I was in at the time. My reasons were self-actualisation fulfilment, contribution to the body of knowledge of management and leadership theory, and last but not least because I enjoy a challenge. It was a seminal, life-changing experience, as you not only grow as a person, but also learn a lot about yourself. There have been many challenges during the process of completing this degree; despite these challenges it was worth the effort, time and sacrifices that had to be made. Fortunately there were many encouraging words along the way.

'I'm doing it because I choose it. And if it's not working, I can make a change.'

– Alanis Morissette.

'As long as I have the feelings that I can improve and I will learn and be better I will continue.'

– Ayrton Senna.

'In reading the lives of great men, I found that the victory they won was over themselves. Self discipline, with all of them, was first.'

– Harry S Truman.

'Really big people are, above everything else, courteous, considerate and generous – not just to some people in some circumstances – but to everyone all the time.'

– Thomas J. Watson.

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Additional acknowledgements are provided in Appendix J.

'As we express our gratitude, we must never forget that the highest appreciation is not to utter words, but to live by them.'

– John F. Kennedy

THE LOGISTICIAN

'Logisticians are a sad and embittered race of men who are very much in demand in war, and who sink resentfully into obscurity in peace. They deal only in facts, but must work for men who merchant in theories. They emerge during war because war is very much a fact. They disappear in peace because peace is mostly theory. The people who merchant in theories, and who employ logisticians in war and ignore them in peace, are generals.

Generals are a happily blessed race who radiate confidence and power. They feed only on ambrosia and drink only nectar. In peace, they stride confidently and can invade a world simply by sweeping their hands grandly over a map, pointing their fingers decisively up terrain corridors, and blocking defiles and obstacles with the sides of their hands. In war, they must stride more slowly because each general has a logistician riding on his back and he knows that, at any moment, the logistician may lean forward and whisper: "No, you can't do that." Generals fear logisticians in war and, in peace, generals try to forget logisticians.

Romping along beside generals are strategists and tacticians. Logisticians despise strategists and tacticians. Strategists and tacticians do not know about logisticians until they grow up to be generals – which they normally do.

Sometimes a logistician becomes a general. If he does, he must associate with generals whom he hates; he has a retinue of strategists and tacticians whom he despises; and, on his back, is a logistician whom he fears. This is why logisticians who become generals always have ulcers and cannot eat their ambrosia.'

– Author unknown, Made available by Major William K. Bawden, RCAF.

(Bowersox, Closs and Helferich. 1986:iii).

'My logisticians are a humorless lot…they know that if my campaign fails, they are the first ones I will slay.'

– Alexander (Logistics World, 2005).

'Behind every great leader there was an even greater logistician.'

– M. Cox (Logistics World, 2005).

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TABLE OF CONTENTS

CHAPTER 1 THE PROBLEM AND ITS SETTING 1

1.1 INTRODUCTION 1

1.2 STATEMENT OF THE PROBLEM 3

1.3 SCOPE OF STUDY 4

1.4 RESEARCH PROBLEM 5

1.5 RESEARCH QUESTION AND REQUIREMENTS TO ANSWER 6

1.6 PROPOSITIONS 7

1.7 ASSUMPTIONS 8

1.8 DELIMITATIONS 9

1.9 RESEARCH OVERVIEW 10

1.10 IMPORTANCE OF THE STUDY 12

1.11 CHAPTER OUTLINE 15

1.12 SYNOPSIS OF THE PROBLEM AND ITS SETTING 17

CHAPTER 2 LITERATURE REVIEW 18

2.1 INTRODUCTION 18

2.2 SEMINAL LITERATURE – OPERATIONS MANAGEMENT 18

2.2.1 TAYLOR – SCIENTIFIC MANAGEMENT 18

2.2.2 FAYOL – PRINCIPLES OF MANAGEMENT 19

2.2.3 DRUCKER - MANAGEMENT BY OBJECTIVES 19

2.2.4 WOODWARD – PRODUCTION MANAGEMENT 20

2.2.5 SCHEIN – ORGANISATIONAL CULTURE 20

2.2.6 SENGE – LEARNING ORGANISATION 20

2.2.7 ALLISON – ‘ESSENCE OF DECISION: EXPLAINING THE CUBAN MISSILE CRISIS’ 21

2.2.8 RELEVANCE TO INTEGRATED LOGISTICS SUPPORT SYSTEMS 21

2.3 SUPPLY CHAIN, SUPPLY NETWORK AND SUPPLY CHAIN MANAGEMENT 22

2.3.1 DEFINITIONS OF SUPPLY CHAIN, SUPPLY NETWORK AND SUPPLY CHAIN MANAGEMENT 23

2.3.2 LOGISTICS AND SUPPLY CHAIN MANAGEMENT 25

2.4 INTRODUCTION TO INTEGRATED LOGISTICS SYSTEMS 25
2.5 BRIEF HISTORY OF LOGISTICS..... 27
2.6 DEFINITIONS OF LOGISTICS 29
2.7 DEFINITIONS OF INTEGRATED LOGISTICS SUPPORT 35
2.8 EVOLUTION OF THE INTEGRATED LOGISTICS CONCEPT 40
2.8.1 DEVELOPMENT OF INTEGRATED DISTRIBUTION 40
2.8.2 EVOLUTION OF INTEGRATED LOGISTICS MANAGEMENT..... 41
2.9 AVAILABLE MODELS OF INTEGRATED LOGISTICS SUPPORT – MILITARY 42
2.10 MILITARY EXPENDITURE 44
2.11 DEVELOPING WORLD CONTEXT 45
2.11.1 ENVIRONMENTAL FACTORS 49
2.11.2 POLITICAL ENVIRONMENT..... 50
2.11.3 LANGUAGE PROFICIENCY AND THE HUMAN DEVELOPMENT INDEX 51
2.12 HIGH TECHNOLOGY 53
2.13 KNOWLEDGE MANAGEMENT 56
2.14 INTEGRATED LOGISTICS SUPPORT ELEMENTS (DISCIPLINES) 57
2.14.1 MAINTENANCE SUPPORT – FAILURE AND MAINTENANCE 59
2.14.2 SUPPORT AND TEST EQUIPMENT..... 63
2.14.3 SUPPLY SUPPORT 65
2.14.4 PACKAGING, HANDLING, STORAGE, AND TRANSPORTATION..... 66
2.14.5 TECHNICAL DATA AND DOCUMENTATION..... 68
2.14.6 FACILITIES..... 69
2.14.7 MANPOWER AND PERSONNEL 70
2.14.8 TRAINING AND TRAINING DEVICES..... 73
2.14.9 COMPUTER RESOURCES 74
2.14.10 RELIABILITY, AVAILABILITY, AND MAINTAINABILITY..... 75
2.14.11 CONFIGURATION MANAGEMENT 77
2.14.12 SYSTEM OPERATIONAL REQUIREMENTS..... 79
2.14.13 EQUIPMENT BREAKDOWN STRUCTURE 79
2.14.14 OBSOLESCENCE 81
2.14.15 DISPOSAL OF MATERIAL/SYSTEM/EQUIPMENT 82
2.14.16 RISK MANAGEMENT PLAN 83
2.15 TRANSFER OF TECHNOLOGY FROM MILITARY TO INDUSTRIAL SYSTEMS..... 85

2.16 FINANCIAL/BUDGET CONSTRAINTS FOR LOGISTIC SUPPORT 86
2.17 SUMMARY OF LITERATURE REVIEW – CURRENT RELEVANT LITERATURE 88
CHAPTER 3 RESEARCH DESIGN 90
3.1 INTRODUCTION 90
3.2 APPROACH TO RESEARCH 94
3.3 PHASE 1, PHASE 2 AND PHASE 3 RESEARCH 96
3.3.1 PHASE 1 RESEARCH 98
3.3.2 PHASE 2 RESEARCH 102
3.3.3 PHASE 3 RESEARCH 104
3.3.4 STATISTICAL ANALYSIS 108
3.3.5 DESCRIPTIVE AND INFERENTIAL STATISTICS 109
3.3.6 PARAMETRIC AND NONPARAMETRIC STATISTICS 109
3.3.7 INFERENTIAL STATISTICS 110
3.4 INTEGRATION OF THE THREE PHASES OF RESEARCH 111
3.5 SUMMARY OF RESEARCH DESIGN 111
CHAPTER 4 PHASE 1 RESEARCH: DECONSTRUCTION OF LITERATURE – INTEGRATED LOGISTICS SUPPORT 112
4.1 INTRODUCTION 112
4.2 DECONSTRUCTION DEFINED AND USED 112
4.3 DECONSTRUCTION OF LITERATURE 113
4.3.1 MAINTENANCE SUPPORT 114
4.3.2 SUPPORT AND TEST EQUIPMENT 119
4.3.3 SUPPLY SUPPORT 122
4.3.4 PACKAGING, HANDLING, STORAGE AND TRANSPORTATION 126
4.3.5 TECHNICAL DATA AND DOCUMENTATION 131
4.3.6 FACILITIES 134
4.3.7 MANPOWER AND PERSONNEL 136
4.3.8 TRAINING AND TRAINING DEVICES 139
4.3.9 COMPUTER RESOURCES 142
4.3.10 RELIABILITY, AVAILABILITY, AND MAINTAINABILITY (RAM), DEPENDABILITY 144
4.3.11 CONFIGURATION MANAGEMENT 146
4.3.12 OBSOLESCENCE 149
4.3.13 DISPOSAL 153
4.4 SUMMARY OF DECONSTRUCTED LITERATURE 154

CHAPTER 5 PHASE 2 RESEARCH: DECONSTRUCTION OF CASE STUDIES 166
5.1 INTRODUCTION 166
5.2 BACKGROUND GENERAL AND TECHNICAL INFORMATION OF SYSTEMS USED IN CASE STUDIES 167
5.2.1 RADAR – BACKGROUND GENERAL AND TECHNICAL INFORMATION 168
5.2.2 RADIO NAVIGATION SYSTEMS – BACKGROUND GENERAL AND TECHNICAL INFORMATION 169
5.2.3 SATELLITE EARTH STATION – BACKGROUND GENERAL AND TECHNICAL INFORMATION 173
5.2.4 MODULAR NUCLEAR REACTOR – BACKGROUND GENERAL AND TECHNICAL INFORMATION 175
5.3 DECONSTRUCTED CASE STUDIES 181
5.3.1 SYSTEM ALPHA 181
5.3.2 SYSTEM BRAVO (SOUTH AMERICAN) 184
5.3.3 SYSTEM CHARLIE 186
5.3.4 SYSTEM DELTA 187
5.3.5 SYSTEM ECHO 190
5.3.6 SYSTEM FOXTROT 192
5.4 SUMMARY OF DECONSTRUCTED CASE STUDIES 194
5.4.1 MAINTENANCE 194
5.4.2 SUPPORT AND TEST EQUIPMENT 194
5.4.3 SUPPLY SUPPORT 195
5.4.4 PACKAGING, HANDLING, STORAGE AND TRANSPORTATION 196
5.4.5 TECHNICAL DATA AND DOCUMENTATION 196
5.4.6 FACILITIES 197
5.4.7 MANPOWER AND PERSONNEL 197
5.4.8 TRAINING AND TRAINING DEVICES 198
5.4.9 COMPUTER RESOURCES 198
5.4.10 RELIABILITY, AVAILABILITY AND MAINTAINABILITY 199
5.4.11 CONFIGURATION MANAGEMENT 199
5.4.12 OBSOLESCENCE 199
5.4.13 DISPOSAL 200
5.5 ASPECTS REQUIRING FURTHER RESEARCH 200
CHAPTER 6 PHASE 3 RESEARCH – QUANTITATIVE 209
6.1 INTRODUCTION 209

6.2 QUESTIONNAIRE FOCUS 209
6.3 PILOT STUDY QUESTIONNAIRE 210
6.4 STRUCTURED QUESTIONNAIRE 210
6.5 HIGH TECHNOLOGY SYSTEMS 213
6.6 QUESTIONNAIRE RESPONSE 214
6.7 DESCRIPTIVE STATISTICS – RESULTS 214
6.8 INFERENTIAL STATISTICAL ANALYSIS 228
6.8.1 CROSS TABULATION ANALYSIS 230
6.9 COLLATION OF PHASE 3 OF RESEARCH 252
CHAPTER 7 COLLATION OF THREE PHASES OF RESEARCH 260
7.1 INTRODUCTION 260
7.2 GROUNDED ELEMENTS OF THE FRAMEWORK 260
7.2.1 MAINTENANCE – THREE PHASES COLLATED 261
7.2.2 SUPPORT AND TEST EQUIPMENT – THREE PHASES COLLATED 263
7.2.3 SUPPLY SUPPORT – THREE PHASES COLLATED 264
7.2.4 PACKAGING, HANDLING, STORAGE, AND TRANSPORTATION – THREE PHASES COLLATED 266
7.2.5 TECHNICAL DATA AND DOCUMENTATION – THREE PHASES COLLATED 269
7.2.6 FACILITIES – THREE PHASES COLLATED 271
7.2.7 MANPOWER AND PERSONNEL – THREE PHASES COLLATED 273
7.2.8 TRAINING AND TRAINING DEVICES – THREE PHASES COLLATED 275
7.2.9 COMPUTER RESOURCES – THREE PHASES COLLATED 277
7.2.10 RELIABILITY, AVAILABILITY, AND MAINTAINABILITY – THREE PHASES COLLATED 279
7.2.11 CONFIGURATION MANAGEMENT – THREE PHASES COLLATED 282
7.2.12 OBSOLESCENCE – THREE PHASES COLLATED 283
7.2.13 DISPOSAL – THREE PHASES COLLATED 285
7.3 FRAMEWORK 288
7.4 GROUNDED TECHNOLOGICAL RULES SUMMARY 290
CHAPTER 8 CONCLUSION AND RECOMMENDATIONS 293
8.1 INTRODUCTION 293
8.1.1 BUSINESS PROBLEM 293
8.1.2 RESEARCH PROBLEM 294

8.2 INTEGRATED LOGISTICS SUPPORT SYSTEM FRAMEWORK (ILSS)..............295
8.3 RECOMMENDATIONS - GROUNDED TECHNOLOGICAL RULES SUMMARY....................297
8.4 CONTRIBUTION 300
8.5 CONCLUSION....................302
8.6 FUTURE RESEARCH....................306
8.7 SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS....................307
CHAPTER 9 REFERENCES 308
LIST OF APPENDICES XIII
LIST OF TABLES....................XIV
LIST OF FIGURES....................XVI

LIST OF APPENDICES

APPENDIX A: RELEVANT WORLD INDICES A-1
APPENDIX B: DEFINITION OF TERMS B-1
APPENDIX C: INTEGRATED LOGISTICS SUPPORT ELEMENT AND PLAN DEFINITIONS C-1
APPENDIX D: LIST OF TECHNICAL ABBREVIATIONS AND ACRONYMS D-1
APPENDIX E: ILS PILOT STUDY QUESTIONNAIRE E-1
APPENDIX F: ILS FINAL STUDY QUESTIONNAIRE – SAAF F-1
APPENDIX G: ILS FINAL STUDY QUESTIONNAIRE – INDUSTRIAL ORGANISATIONS – E-MAILED G-1
APPENDIX H: DESCRIPTIVE STATISTICS OF THE FINAL QUESTIONNAIRE DATA H-1
APPENDIX I: COMBINATION OF DECONSTRUCTION OF INTEGRATED LOGISTICS SUPPORT LITERATURE AND DECONSTRUCTION OF CASE STUDIES I-1
APPENDIX J: ADDITIONAL ACKNOWLEDGEMENTS J-1

LIST OF TABLES

TABLE 2–1: DRIVERS IN SUPPLY CHAIN 23
TABLE 2–2: SELECTED LITERATURE OF LOGISTICS AND SUPPLY CHAIN MANAGEMENT AND THE EXTENT TO WHICH THEY ARE LINKED TO THE STUDY 26
TABLE 2–3: ACCESS TO INFORMATION AND TECHNOLOGY 46
TABLE 2–4: TECHNOLOGY: DIFFUSION AND CREATION, AND GDP AND R&D 47
TABLE 2–5: MANUFACTURED AND HIGH TECHNOLOGY EXPORTS, AND PRIORITIES IN PUBLIC SPENDING 48
TABLE 2–6: ARMAMENTS 48
TABLE 2–7: GOVERNANCE INDICES 50
TABLE 2–8: NET PRIMARY AND NET SECONDARY ENROLMENT RATE 52
TABLE 2–9: HDI, ADULT LITERACY RATE, COMBINED GROSS ENROLMENT RATIO AND EDUCATION INDEX 53
TABLE 2–10: MILITARY EXPENDITURE ($) COMPARED TO GDP 87
TABLE 2–11: GLOBAL DEFENCE EXPENDITURE AGAINST % OF GDP 87
TABLE 3–1: DIFFERENCES BETWEEN MODE 1 AND MODE 2 92
TABLE 4–1: SUMMARY OF LITERATURE REVIEW 113
TABLE 4–2: DECONSTRUCTED LITERATURE REVIEW 155
TABLE 5–1: HULL-LOSS ACCIDENTS – FATAL AIRLINER, VARIOUS FLIGHT PHASES AND TRAINING 172
TABLE 5–2: FATAL CIVIL AIRLINER ACCIDENTS PER CONTINENT FROM 1945 TO 2007 172
TABLE 5–3: FATAL CIVIL AIRLINER ACCIDENTS PER GEOGRAPHICAL REGION FROM 1945 TO 2007. 172
TABLE 6–1: QUESTIONS ASKED RELATING TO INTEGRATED LOGISTIC SUPPORT THEMES FOR MILITARY AND INDUSTRIAL ORGANISATIONS 211
TABLE 6–2: INTEGRATED LOGISTICS SUPPORT CONCERNS BETWEEN REVIEWED LITERATURE AND CASE STUDIES, AND ADDITIONAL FURTHER STUDY REQUIRED 211
TABLE 6–3: CONTINGENCY TABLE STATISTICAL ANALYSIS CLASSIFIED BY QUESTIONS 4, 8 AND 11 229
TABLE 6–4: CHI-SQUARE AND CRAMER'S V STATISTICS OF CROSS TABULATION OF SPECIFIC QUESTIONS 230
TABLE 6–5: COLLATION OF PHASE 3 OF RESEARCH 253
TABLE 7–1: GROUNDED TECHNOLOGICAL RULES OF ILS RESEARCH 290

TABLE 8–1: GROUNDED TECHNOLOGICAL RULES OF ILS RESEARCH – (A REPEAT OF TABLE 7-1) 297
TABLE A–1: MILITARY EXPENDITURE ($) COMPARED TO GDP A-1
TABLE A–2: COMMITMENT TO EDUCATION: PUBLIC SPENDING A-1
TABLE A–3: TOTAL POPULATION, COMMITMENT TO HEALTH, HIV, AND LIFE EXPECTANCY AT BIRTH A-2

LIST OF FIGURES

FIGURE 1–1: RESEARCH OVERVIEW 11
FIGURE 1–2: THESIS DOCUMENT CHAPTER OUTLINE 16
FIGURE 2–1: DOMAIN IN WHICH INTEGRATED LOGISTICS SYSTEMS EXIST (ACRONYMS AVAILABLE IN THE LIST OF BUSINESS AND TECHNICAL ABBREVIATIONS AND ACRONYMS) 28
FIGURE 2–2: EVOLUTION OF THE INTEGRATED LOGISTICS CONCEPT 41
FIGURE 2–3: CRITICAL FAIURE PATTERNS 62
FIGURE 2–4: TYPICAL TRANSFER FROM MILITARY TO INDUSTRIAL APPLICATIONS 85
FIGURE 3–1: APPROACH TO RESEARCH (RESEARCH OVERVIEW) 95
FIGURE 5–2: THE WORLD AT NIGHT 177
FIGURE 5–3: PEBBLE BED REACTOR CERAMIC-ENCAPSULATED URANIUM FUEL AND FUEL SPHERES 180
FIGURE 6–1: RESPONDENTS' GENERAL DEMOGRAPHICS (GENDER, RACE, AND HOME LANGUAGE) 216
FIGURE 6–2: QUESTION 8 – JOB ORIENTATION 217
FIGURE 6–3: QUESTION 11 – KNOWLEDGE AND EXPERIENCE 218
FIGURE 6–4: QUESTION 12 – WRITING OPERATOR AND MAINTENANCE DOCUMENTATION IN SUCH A MANNER THAT OPERATING AND MAINTENANCE PERSONNEL ARE CAPABLE OF UNDERSTANDING THE CONTENTS THEREOF 219
FIGURE 6–5: QUESTION 18 – SUPPORT AND TEST EQUIPMENT FACTORS USED ON YOUR SYSTEM THAT REQUIRE IMPROVEMENT 220
FIGURE 6–6: QUESTION 20 – RELIABILITY, AVAILABILITY AND MAINTAINABILITY (RAM) - (DEPENDABILITY) ISSUES 221
FIGURE 6–7: QUESTION 24 – DETERMINANTS OF OBSOLESCENCE 223
FIGURE 6–8: QUESTION 25 – ECONOMICAL DECISIONS AS THEY RELATE TO SUPPLY SUPPORT 224
FIGURE 6–9: QUESTION 26 – USING THE FOLLOWING PLANS TO IMPROVE YOUR SYSTEM'S PERFORMANCE 225
FIGURE 6–10: QUESTION 27 – TYPICAL DISPOSAL COSTS 226
FIGURE 6–11: QUESTION 32 – POSSIBLE CAUSES OF MAINTENANCE PERSONNEL ERROR 227
FIGURE 6–12: QUESTION 34 – TYPES OF FAILURES/DEFECTS 228
FIGURE 6–13: CROSS TABULATION OF QUESTION 8 (JOB ORIENTATION) BY QUESTION 4 (BASIC TRAINING) 233

FIGURE 6–14: CROSS TABULATION OF QUESTION 8 (JOB ORIENTATION) BY QUESTION 9A (BEST PRACTICES) 233
FIGURE 6–15: CROSS TABULATION OF QUESTION 8 (JOB ORIENTATION) BY QUESTION 10A(ACCESSIBILITY) 234
FIGURE 6–16: CROSS TABULATION OF QUESTION 8 (JOB ORIENTATION) BY QUESTION 11 (EXPERIENCE AND KNOWLEDGE) 235
FIGURE 6–17: CROSS TABULATION OF QUESTION 8 (JOB ORIENTATION) BY QUESTION 12 (UNDERSTANDING OPERATOR AND MAINTENANCE MANUALS) 236
FIGURE 6–18: CROSS TABULATION OF QUESTION 8 (JOB ORIENTATION) BY QUESTION 18A (AVAILABILITY OF S&TE, AND PERSONNEL) 236
FIGURE 6–19: CROSS TABULATION OF QUESTION 8 (JOB ORIENTATION) BY QUESTION 18C (S&TE SUPPORT/MAINTENANCE) 237
FIGURE 6–20: CROSS TABULATION OF QUESTION 8 (JOB ORIENTATION) BY QUESTION 20A (CONDUCTING RAM ANALYSES) 238
FIGURE 6–21: CROSS TABULATION OF QUESTION 8 (JOB ORIENTATION) BY QUESTION 20C (IDENTIFYING PARTS WITH EXCESSIVE FAILURE RATES) 239
FIGURE 6–22: CROSS TABULATION OF QUESTION 8 (JOB ORIENTATION) BY QUESTION 24A (COST TO SUPPORT) 240
FIGURE 6–23: CROSS TABULATION OF QUESTION 8 (JOB ORIENTATION) BY QUESTION 25E (LEAD-TIME TO REPAIR) 240
FIGURE 6–24: CROSS TABULATION OF QUESTION 8 (JOB ORIENTATION) BY QUESTION 27C (REDESIGN FOR ALTERNATIVE USE (E.G. DEMILITARISATION)) 241
FIGURE 6–25: CROSS TABULATION OF QUESTION 8 (JOB ORIENTATION) BY QUESTION 34A (MAINTENANCE INDUCED FAILURES) 242
FIGURE 6–26: CROSS TABULATION OF QUESTION 8 (JOB ORIENTATION) BY QUESTION 34B (OPERATOR-INDUCED FAILURES) 243
FIGURE 6–27: CROSS TABULATION OF QUESTION 11 (EXPERIENCE AND KNOWLEDGE BASE) BY QUESTION 4 (BASIC TRAINING) 244
FIGURE 6–28: CROSS TABULATION OF QUESTION 11 (EXPERIENCE AND KNOWLEDGE BASE) BY QUESTION 8 (JOB ORIENTATION) 245
FIGURE 6–29: CROSS TABULATION OF QUESTION 11 (EXPERIENCE AND KNOWLEDGE BASE) BY QUESTION 18A (AVAILABILITY OF S&TE, AND PERSONNEL) 246

FIGURE 6–30: CROSS TABULATION OF QUESTION 11 (EXPERIENCE AND KNOWLEDGE BASE) BY QUESTION 18C (S&TE SUPPORT/MAINTENANCE) ... 247
FIGURE 6–31: CROSS TABULATION OF QUESTION 11 (EXPERIENCE AND KNOWLEDGE BASE) BY QUESTION 25B (COST TO REPAIR) ... 248
FIGURE 6–32: CROSS TABULATION OF QUESTION 11 (EXPERIENCE AND KNOWLEDGE BASE) BY QUESTION 25D (FAILURE PROBABILITY) ... 249
FIGURE 6–33: CROSS TABULATION OF QUESTION 11 (EXPERIENCE AND KNOWLEDGE BASE) BY QUESTION 25E (LEAD-TIME TO REPAIR) ... 250
FIGURE 6–34: CROSS TABULATION OF QUESTION 11 (EXPERIENCE AND KNOWLEDGE BASE) BY QUESTION 25G (RELIABILITY OF REPAIRED SYSTEM) ... 251
FIGURE 6–35: CROSS TABULATION OF QUESTION 11 (EXPERIENCE AND KNOWLEDGE BASE) BY QUESTION 32B (POOR SUPERVISION) ... 252
FIGURE 7–1: INTEGRATED LOGISTICS SUPPORT SYSTEM (ILSS) FRAMEWORK ... 288
FIGURE 8–1: INTEGRATED LOGISTICS SUPPORT SYSTEM (ILSS) FRAMEWORK – (A REPEAT OF FIGURE 7-1) ... 297
FIGURE H–1: RESPONDENT BREAKDOWN PER ORGANISATION ... H-11
FIGURE H–2: QUESTION 5 – RESPONDENT AGE ... H-12
FIGURE H–3: QUESTION 4 – IN WHICH DIRECTION IS YOUR BASIC TRAINING? ... H-12
FIGURE H–4: QUESTION 9 – FACTORS WHICH COULD IMPROVE YOUR ORGANISATION EFFICIENCY ... H-13
FIGURE H–5: QUESTION 10 – QUALITIES THAT MAKE INFORMATION VALUABLE TO AN ORGANISATION ... H-13
FIGURE H–6: QUESTION 13 – DEFINING THE MAINTENANCE AND OPERATIONAL PERSONNEL REQUIREMENTS ... H-14
FIGURE H–7: QUESTION 14 – CONDUCT PERIODIC AUDITS ... H-15
FIGURE H–8: QUESTION 15 – APPLYING CONFIGURATION MANAGEMENT ... H-15
FIGURE H–9: QUESTION 16 – APPLYING CONFIGURATION MANAGEMENT PRINCIPLES WITH RESPECT TO DOCUMENTATION ... H-16
FIGURE H–10: QUESTION 17 – ATTRACTING AND RETAINING APPLICABLY SKILLED PERSONNEL TO MAINTAIN AND OPERATE THE SYSTEM ... H-16
FIGURE H–11: QUESTION 19 – MAINTENANCE ISSUES ... H-17
FIGURE H–12: QUESTION 21 – COMMON MAINTENANCE PROBLEMS ... H-17
FIGURE H–13: QUESTION 22 – MATERIAL HANDLING PRINCIPLES ... H-18
FIGURE H–14: QUESTION 23 – SYSTEM OPERATIONAL REQUIREMENTS (BEYOND LIFE CYCLES) ... H-18
FIGURE H–15: QUESTION 28 – STORAGE FACILITY REQUIREMENTS ... H-19

FIGURE H–16: QUESTION 29 – PACKAGING REQUIREMENTS H-19
FIGURE H–17: QUESTION 30 – TRAINING FACTORS H-20
FIGURE H–18: QUESTION 31 – EFFECTIVELY MANAGE OBSOLESCENCE H-20
FIGURE H–19: QUESTION 33 – POSSIBLE CAUSES OF LOGISTICS DELAY TIME H-21

'Authors who use abbreviations extravagantly need to be restrained.'

– Maeve O'Connor.

LIST OF BUSINESS ABBREVIATIONS AND ACRONYMS

Arabsat	Arab Satellite Communication Organisation
Armscor	Armaments Corporation (of South Africa)
CPI	Corruption Perception Index.
DMSMS	Diminishing Manufacturing Sources and Material Shortages
DOD	Department Of Defence
EIA	Electronics Industry Association
EIR	Executive Intelligence Review
ESA	European Space Agency.
Eskom	Electricity Supply Commission
Eutelsat	European Telecommunications Satellite Organisation
GDP	Gross Domestic Product
HDI	Human Development Index
ICAO	International Civil Aviation Organisation.
IISS	International Institute for Strategic Studies
ILS	Integrated Logistics Support
ILSS	Integrated Logistics Support System
Inmarsat	International Maritime Satellite Organisation
Intelsat	International Telecommunications Satellite Organisation
Intersputnik	International Space Telecommunication Organisation
IP	Internet Protocol.
ISCED	International Standard Classification of Education.
ISO	International Organisation for Standardization
MIL-STD	Military Standard
OEM	Original Equipment Manufacturer
OJT	On the Job Training
OSSA	Office of Space Science and Applications
PBMR	Pebble Bed Modular Reactor
QA	Quality Assurance
SAAF	South African Air Force
SAN	South African Navy
SANDF	South African National Defence Force.
SIPRI	Stockholm International Peace Research Institute.
TAI	Technology Achievement Index.
UN	United Nations
UNAIDS	Joint United Nations Programme on HIV/AIDS
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific, and Cultural Organisation
UNICEF	United Nations Children's Fund
WHO	World Health Organisation

Additional abbreviations and acronyms are available in Appendix D.

'It should be borne in mind that there is nothing more difficult to manage, or more doubtful of success, or more dangerous to handle than to take the lead in introducing a new order of things. For the innovator has enemies in all those who are doing well under the old order, and he has only lukewarm defenders in all those who would do well under the new order. This lukewarmness arises partly from fear of their adversaries who have the laws on their side, and partly from the incredulity of men who do not truly believe in new things until they have had a solid experience of them.'

– The Prince, Niccolò Machiavelli (cited in Rebhorn, 2003:xx).

'The ultimate measure of a man is not where he stands in moments of comfort and convenience, but where he stands at times of challenge and controversy.'

– Martin Luther King.

'A journey of a thousand miles begins with a single step.'

– Confucius.

'Well begun is half done.'

– Aristotle.

CHAPTER 1 THE PROBLEM AND ITS SETTING

1.1 Introduction

Competitive and high-risk environments require complex high technology systems, which need to be supported and maintained throughout their life cycles. Effective support and ongoing maintenance require complex management systems.

There are significant management and leadership challenges in South Africa, Africa and the rest of the developing world. The business environment is constantly changing, necessitating the implementation of new and diverse methodologies to provide an organisation with competitive advantages. Traditional engineering approaches can be used to solve some of these challenges, if designed to address the constraints and risks relevant in a developing world. Integrated logistic support (ILS) is one such system that can assist in gaining a competitive advantage over competitors by effectively and efficiently supporting the high technology assets owned and utilised by the company. Integration of supply chain management activities requires adequate strategy, planning and implementation.

An integrated logistics support system (ILSS) attains a competitive advantage for an organisation in terms of the management and support of a high technology complex system throughout its life cycle, from concept phase to disposal or retirement phase. Traditionally, integrated logistics support is used within the military environment, but over the years the concept has been introduced into industry. An ILSS consists of various elements, namely: maintenance, training and training devices, manpower and personnel, support and test equipment, facilities, packaging; handling; storage; and transportation, obsolescence, disposal, supply support, technical data and documentation, configuration management, reliability and availability, and computer resources.

The complex systems utilised in delivering products and services are designed, developed, and manufactured to have relatively long life cycles (typically in the range of between 20 and 40 years). This is evident with the B-52 [United States Air Force's long range strategic bomber], where development started in 1946, and is expected to be operational past the year 2040, (Livingston, 2000:2). Some of these complex systems are used beyond their expected life cycles and/or suffer from component obsolescence, and are then upgraded and/or refurbished to extend their system life cycle. This is especially true in the context of environments where access to capital is limited, as is often the case in the developing world. The logistic system is upgraded and elements are often neglected, leading to reductions in cost effectiveness and performance.

Complex systems progress through a product life cycle where there are specific costs associated. These associated costs are called life cycle cost (LCC) and includes all costs associated with the system from concept to disposal. Blanchard (2004:81) defines LCC as including *'… all system costs and may be broken down into various categories to include design and development cost, construction and/or production cost, system operation and maintenance cost, and system retirement and material recycling or disposal cost …'*

A term related to life cycle costing is total cost of ownership, that is, costs associated with the procurement and use of equipment; it is defined by Monczka, Trent and Handfield (2002:438-439) as *'the sum of all expenses and costs associated with the purchase and use of equipment, materials, and services'.*

A system can be regarded of as a group of different types of components formed to provide a function. INCOSE (2006:appendix-8) defines a system as *'a combination of interacting elements organized to achieve one or more stated purposes'*. A complex system, on the other hand can be regarded as an integrated system, as it combines numerous different components, parts, line replaceable units (LRUs) and so forth to form an integrated whole or system, used to perform a specific function. Furthermore, a complex system can fail due to a vast number of reasons. Nowlan and Heap (1978:37) define a complex item as having '… many different failure modes'. The term "integrated" can be viewed as a group of components assembled to form a system, and used to perform a specific function. One definition of 'integrated': *'A collection of distinct elements or components that have been built into one unit.'* (PC Magazine, 2008).

A combination of complex sub-assemblies forming a system complicates the functionality of the system. The system becomes even more complicated once the human element is added. Once the system (including the human element) becomes operational, the support for the system becomes even more complex, adding more risk and uncertainty to the system functionality. Kasser and Palmer (2005:3) support this postulation arguing that system boundaries are changed in order to add external elements, and the system becomes more complex as more external elements are added.

Supply chain, supply network, and supply chain management strive to meet customer requirements throughout the life cycle of a product, asset or service. The rationale for this study is to create knowledge that is valid, reliable, applicable and relevant. The study will contribute significantly to the integrated logistic support (ILS), supply chain, supply network, and supply chain management body of knowledge, where the solutions developed using the wider operations management body of management knowledge will be applicable and relevant in complex technological systems in a developing world situation.

Within Chapter 1 the problem statement is discussed, the scope of the study is delineated, the research problem and research question are discussed and presented. The propositions, assumptions, and delimitations as they relate to the study are explained. The research overview is described by means of Figure 1–1. The importance of the study is described in detail. In conclusion to this chapter the chapter outline is detailed by means of Figure 1–2.

1.2 Statement of the problem

This section discusses the problem statement where the business environment is constantly changing and new and diverse methodologies are needed to provide an organisation with a competitive advantage. Integration of supply chain management activities requires adequate strategy, planning and implementation. Leveraging supply chain integrating activities provides opportunities in competitive environments. A fully implemented ILS system can be a mechanism to gain competitive advantage by effectively and efficiently supporting the high technology assets owned and utilised by the organisation, delivering products quickly and efficiently and supporting long term customer requirements. From an integrated logistics support perspective, certain aspects influence drivers in the supply chain in many ways; these include, but are not limited to location, facilities, responsiveness, obsolescence, maintenance, transportation and storage.

Managing the organisation’s asset base satisfactorily, requires adequate ILS principles. This is especially true in some developing countries where resources are scarce: these are essential to successfully operate high technology complex systems. The scarcity is evident in skills shortages, where knowledge and experience is lacking, as well as in support systems.

There is a lack within the current body of knowledge of supply chain, supply chain management, and operations management literature, which forms the basis of ILS in terms of its formulation and usage The lack of knowledge concerns the support of high technology complex systems where assets are frequently utilised beyond their intended life cycle.

Life cycle support of high technology systems is lacking, due to continuous improvement of technological processes and components becoming obsolete. Furthermore, diminishing manufacturing sources and material shortages (DMSMS) are evident where suppliers are improving their ‘time to market’ philosophies in order to remain competitive in a turbulent environment.

Many organisations are not willing to divulge their intellectual property, product information, and support philosophies and strategies as this will reduce their competitive advantage, market share, and profitability. Furthermore, the increase of industrial espionage is a major contributing risk factor resulting in organisations protecting their information and knowledge base.

In this section the statement of the problem was discussed. In the next section the scope of the study is discussed.

1.3 Scope of study

The scope of the study is discussed in this section. Environments requiring complex technology systems (typically high investment) with high consequence of failure and with the need to be supported and maintained over their designed or extended life cycles, require complex support infrastructures in order for the systems to attain their operational objectives. These systems require complex management systems during planning, implementation and operation to ensure an integrated supply network. Some of these systems are used beyond their expected life cycles and/or suffer from component obsolescence, and are then upgraded and/or refurbished to extend their system life cycle.

The most complex context for which to develop such an ILSS, is in high technology complex systems, where the benefits can be utilised both in other developing countries and in developed countries.

Research will focus on overcoming obstacles within the supply chain integration process through the use of an ILSS. The ILSS will be able to provide adequate strategies to ensure the sufficient support of high technology systems throughout its intended and often extended life cycle.

Case studies of certain high technology electronic (military and industrial) and mechanical (power generation) systems were used for the study. The writer focused on case studies of systems of which he has knowledge and experience, for which information was available and security clearance for usage had been obtained. Case studies of other systems can be added to these case studies in the study in further investigations. The study is relevant to the high technology industry, although the results may be used as a model within other industries, especially as solutions in those industries may be less complex.

The study was conducted within South Africa, and a case study from a South American country. However, the results can be applied to other developing countries where high technology systems are subjected to beyond designed life operation and where they suffer from obsolescence and DMSMS. The results can also be applied to developed (first world) countries utilising complex systems.

The scope of the study was discussed in this section, and specifically the complexities of supporting a high technology complex system in a developing country. In the next section the research problem is discussed.

1.4 Research problem

This section concerns the research problem. High technology systems are complex and consist of many individual complicated sub-systems; these need to be supported to deliver functions for which they were designed. As a consequence of the development and introduction of new technologies over the last few decades, systems have become more complex. It takes a considerable amount of time to develop and procure new systems/products, many of which fail to meet the consumers' expectations in terms of quality, cost-effectiveness and performance (Blanchard, 1991:23).

There are many constraints in implementing an integrated logistics support system for high technology complex systems, especially in developing countries. The most complex of the potential systems that require ILS can be found in:

1) High Technology industries;
2) Systems with significant consequence of failure;
3) Developing countries; and
4) Systems currently in use and adapted from original design, and especially beyond designed life.

The research problem is therefore that there is no framework available for the development of an ILSS for a complex system that does not assume that the ILS is *developed simultaneously with the design of the system. ILS is required in high technology complex systems currently in use, which are situated in developing countries and which have a high consequence of failure.*

The research problem was discussed in this section, namely, that no ILSS framework exists for complex systems, assuming the ILS is not developed simultaneously with the system. In the next section the research question and requirements to answer are discussed.

1.5 Research question and requirements to answer

This section deals with the research question and the requirements to answer the research question. The research question, which flows from the research problem asks whether an ILS framework and system can be developed for a high technology industry within a developing country.

The research question can be formulated as:

Can a framework and system be developed:

1) *to design an ILS system considering proven concepts, theory and principles,*
2) *in the highest complex reality, that is:*
    i) *a high technology industry; and*
    ii) *in a developing country?*

In order to satisfy the requirements for implementation and usefulness, this framework not only needs to be academically satisfied with regards to:

1) validity and reliability,

but also;

2) relevance and applicability, for example, Design Science Research and Mode 2 Research (van Aken, 2004).

Design science implies the need of *'prescription driven'* research (van Aken 2004:236). The aim is to design solutions to solve problems. The product of research (heuristic, solution focused or technological rule) may be developed around a local problem, but its applicability will not be within the local domain in which it was developed (van Aken, 2004).

The research question can also be described as Mode 2 Research or Mode 2 Knowledge production. Mode 2 is a multidisciplinary and problem focused approach to research, (Gibbons; Limoges; Nowotny; Schwartzman; Scott; and Trow; {1994}, and Nowotny; Scott; and Gibbons; {2001}, in van Aken, 2005:20). It can be argued that Mode 2 Research is not new, but is the original form of research, prior to the 19th century where research was isolated (in some cases) into academic institutions (Etzkowitz and Leydesdorff, 2000). Mode 2 is therefore interested in the requirements of society, business and industry. Design Science Research (DSR) and/or Mode 2 Research is therefore very well suited to research aimed at a professional doctorate such as a Doctor of Business Leadership (DBL).

In order to ensure that a solution developed for a localised problem can be used in a general context, it should continue until theoretical saturation is reached for validity and reliability (van Aken, 2004).

This section dealt with the research question and requirements to answer. The research question was postulated, and the requirements to satisfy the question were provided, focusing on the need for the framework to be valid, reliable, relevant and applicable. In the next section the propositions for the study are discussed.

1.6 Propositions

This section concerns the propositions as they relate to the study. These propositions include:

1) The ILS framework developed in this work should be applicable to the most challenging environments of a developing country and complex system contexts where a robust solution is required.
2) Concerns regarding training, skill level and experience as related to ILS.
3) An organisation gaining a competitive advantage by applying this proposed ILS framework, and the associated proposed ILS grounded technological rules. The outcome will be an increased market share and customer support base, which will ultimately result in an improved bottom line, reduced life cycle costs and the associated total cost of ownership.
4) Gaining a competitive advantage by utilising an integrated logistics support system (ILSS) to effectively and efficiently support all the high technology assets owned and utilised by a firm. A well-implemented ILSS can improve management of the organisation's asset base. This is particularly true in developing countries where scarce resources are required to

successfully operate high technology complex systems. These scarce resources include the lack of appropriate skills, where experience and knowledge is limited.

5) Effective and efficient management of the asset base, where the risk associated with obsolescence and diminishing manufacturing sources and material shortages (DMSMS) can be reduced, thereby mitigating the effects of long lead times, and long repair times. Systems used beyond their designed life cycles suffer from high levels of obsolescence, as well as DMSMS, and require critical maintenance tasks. Adequate planning for refurbishment, modifications, upgrades, cannibalisation, mothballing, phase-out, disposal, and waste can reduce the risks associated with these aspects of ILS.

6) The attraction and retention of the appropriately skilled personnel can assist to support a high technology complex system adequately. This means that improving and retaining the skill sets within the firm can provide potential benefits in supporting a system. The lack of proper training further induces maintenance and operational errors. It is also proposed that the human element and its effects are under emphasised in the available body of knowledge.

7) Documentation and configuration management is critical and essential within the ILS domain. Successful management of any language-based deficiency in interfaces between personnel and documentation (including labels, marking, and so forth) can reduce maintenance time on tasks, and reduce operator- and maintenance-induced errors.

In the section that follows, the assumptions related to the study are discussed.

1.7 Assumptions

Some assumptions had to be made in order to conduct this study. These assumptions include the fact that academic literature on this study is not readily available and that military documentation may not be fully regarded as equivalent to academic literature. Furthermore, certain confidential company information on how to develop an ILSS is utilised as a competitive edge by supporting houses or organisations, and will not be kindly divulged in the body of knowledge.

Due to the nature of the subject topic area of integrated logistics support originating from the military, certain military standards were also used as part of the literature review. These military standards are not necessarily academically peer reviewed, but they are peer reviewed by the military and industry, and many industrial organisations actually use military standards as a guideline to industrial ILS processes and procedures.

This section concerned the assumptions as they relate to the study. In the next section the research overview is discussed.

1.8 Delimitations

The study was conducted within the high technology industry in a developing country – the delimitations, therefore, are as follows:

1) The qualification of the thesis title is based on the highest level of complexity, where case analyses and special area analyses in high technology industries were conducted (for example military radar, modular nuclear power station, military and industrial navigational aids, and industrial satellite earth station). Furthermore, the deconstruction of literature surveyed contains elements of developing country scenario. The literature deconstruction for deployment (if not long term support) in a developing country was analysed, case analysis in the deconstructed model were obtained within developing countries, written and analysed, and the area of concern, that is, the management problem, was identified;
2) As far as reasonably possible, the demographics of the available respondents were a representative sample of the population within the organisation and industry;
3) The quantitative analysis was restricted to companies that were willing to participate in the study, and the completion of the questionnaire. One organisation was willing to subject all their relevant (engineering and management level) personnel to the completion of the study. Another was willing to distribute the questionnaire to their staff and postgraduate students. However, some organisations were only willing to offer a limited number of respondents;
4) Additional time was permitted to complete the pilot study questionnaire and final study questionnaire in order to improve the response rate and improve the reliability and validity of the data;
5) The military questionnaire was subjected to a security clearance process. The military questionnaire consisted of 25 questions only, compared to the industrial questionnaire, which posed an additional nine questions;
6) Accessibility of the companies (military and industry);
7) Willingness of the companies to participate;
8) Access to company information. Some of the information has been in the public domain and available on websites, while other information has been more difficult to access, as it is deemed sensitive;
9) Number of questionnaires received back from the companies;
10) Errors in responses; and
11) Preconceived notions or exclusions addressed through workshops and detailed interviews with people in the area of radar, navigational aids and satellite.

It is clear that the field of ILS can be very wide; therefore the following will be excluded from the study:

1) Military expenditure. The systems used in the study are military and industrial systems, and these systems are already operational, except for one of the case studies which is under development, but similar data is available on similar operational systems;
2) Armed forces deployment. The systems used in the study are military and industrial systems, and these systems are already operational, except for one of the case studies which is under development, but similar data is available on similar operational systems;
3) Acquisition process. The systems to be used in the study have already been acquired and are in operation at various stages of their life cycle.
4) Logistic support analysis (LSA)/logistic support analysis record (LSAR), (it is assumed that this has been completed on the system, or may need to be done in order to develop the ILS). LSA is normally conducted during the design of the system. It would be possible to attempt to conduct an LSA but this may take years of work to complete.
5) Integrated distribution of material. Various aspects of ILS exist including material, packaging, training, facilities; as such the concept (per se) of integrated distribution of material is excluded, although some principles may be found in ILS.
6) Failure modes, effects, and criticality analysis (FMECA), (it is assumed that this has been completed on the system, or may need to be done in order to develop the ILS). FMECA like LSA/LSAR is normally conducted during the design of the system. It would be possible to attempt to conduct an FMECA but this may take years of work to complete.
7) Life cycle costing (LCC). It is unknown what costs are involved in the research and development or what the investment costs of the systems are. The operations and maintenance costs may be difficult to attain, due to the sensitive nature of the equipment.
8) Reliability, availability and maintainability (RAM) analysis. It will be assumed that certain figures are available and it will not be necessary to conduct analyses or calculations.

1.9 Research overview

In this section the study research overview is discussed. The research overview used for this study is depicted in Figure 1–1. The research is split into three stages, namely, research proposal, phase 1 to phase 3 research, and finally the findings, recommendations and contribution. The second stage (phase 1 to phase 3 research) is further split into three sub-stages, namely, phase 1 research (qualitative), phase 2 research (qualitative), and phase 3 research (quantitative).

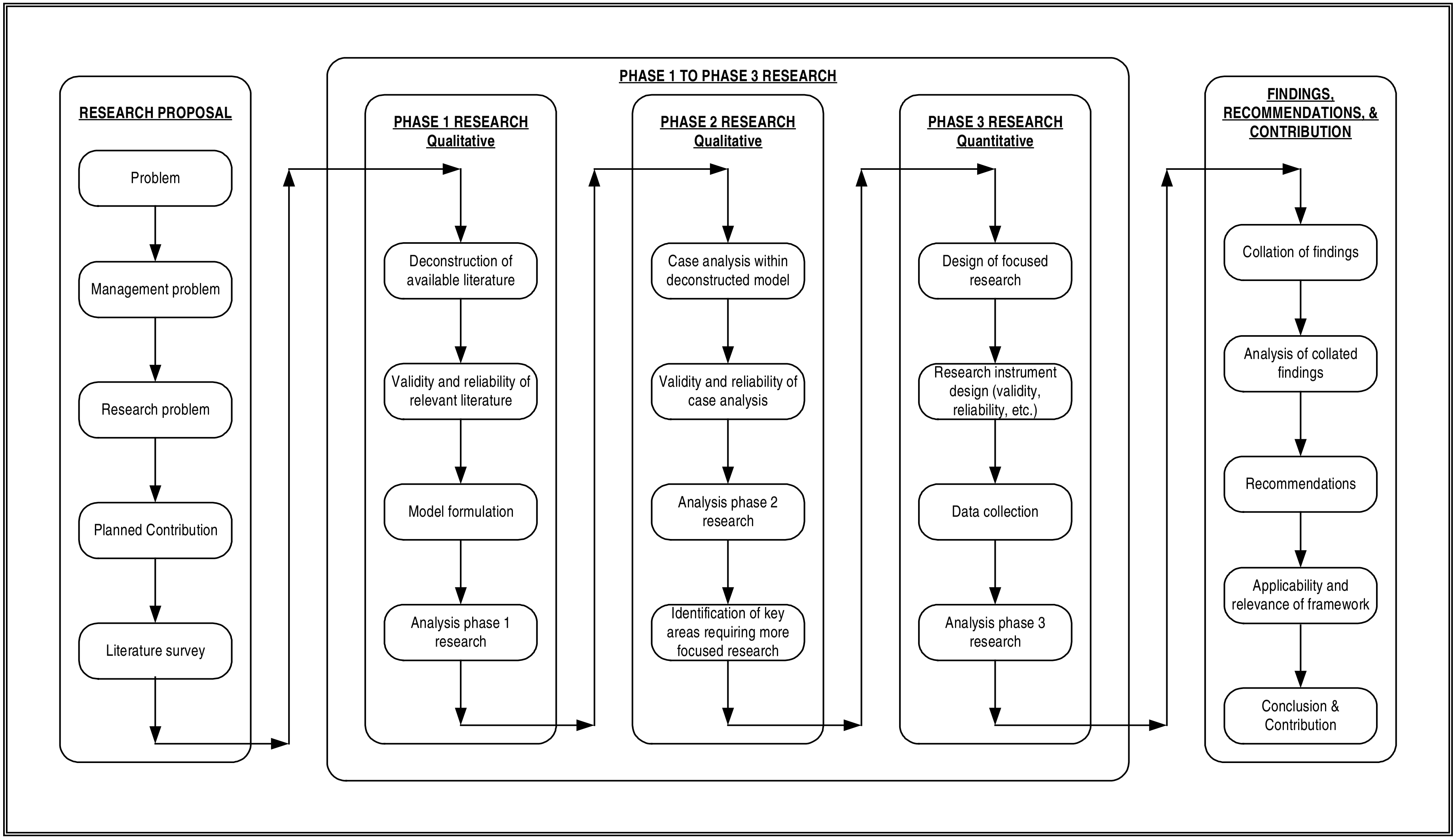


Figure 1–1: Research overview

During the first stage the research proposal is explored, the problem, management problem, research problem, planned contribution, and literature survey is examined.

During the second stage of the study, the three phases of research is performed. Phase 1 of the research entails the deconstruction of the available literature. The relevant literature's validity and reliability is corroborated, the proposed model is formulated, and the phase 1 research is analysed. Phase 2 of the second stage entails the deconstruction of the case studies, the validity and reliability of the case studies is substantiated, the phase 2 research is analysed, and key areas are identified that require more focused research. During phase 3 of the second stage of the research, the focused research is designed, the research instrument is designed, including the validity and reliability thereof, the research instrument data are collected, and the third phase of the research is analysed.

In the final stage of the research the findings of the research are collated and analysed, recommendations are proposed, the framework applicability and relevance is discussed, as well as the contribution to the body of knowledge of the wide field of operations management.

In this section, the research overview was illustrated by Figure 1–1. In the next section the delimitations of the study are discussed.

1.10 Importance of the Study

For an organisation to deliver products and services effectively and efficiently, it requires strategic leadership and a strategic advantage. This advantage may be founded in an asset base to deliver products and services.

Challenges exist where assets contain high technology complex systems used in challenging environments, such as presented in developing countries. The benefits of an effective and sustainable ILS system are in an effective operational system, improved functional strategic planning, and reduced operating costs.

Leveraging an ILSS framework can result in shared knowledge throughout the supply network that can be made readily available to industry to improve the support of their asset base. Integrated logistics support systems are considered as complementary and analogous to integrated supply chain management; therefore, ILSS can be regarded as subject matter and a discipline of supply chain, supply chain management and operations management.

Complex, high technology and expensive equipment is required to deliver their required functionality. The asset base in developing countries is rather complex, hence the need for support throughout their life cycle. An organisation needs to offer an operational system to meet operational objectives and gain a competitive advantage over its competitors by properly maintaining the asset during its intended and/or extended life cycle.

Specific challenges exist where high technology complex systems are the assets used in challenging environments, such as presented in developing countries. To manage technology, an organisation needs to implement the management functions of planning, organising, leadership and control. This implementation is achieved by applying ILS as an interface between the high technology system and the management functions.

An ILS system should be systematically developed in order to support these assets. This concept has been developed and proven for single acquisition events within the developed world context and in specific controlled environments (military). The ILS system consists of plans, which include maintenance, manpower and personnel, training and training devices, packaging; handling; storage and transportation, packing and marking, facilities, supply support (spare and repair parts), data and documentation, computer resources, configuration management, and reliability; availability and maintainability.

The above mentioned ILS elements also require organizing and this is achieved by assigning resources to the system as prescribed in the necessary plans, for example assigning personnel, providing training, and supplying the necessary facilities. When management provides effective leadership, personnel are motivated to carry out the ILS plans of the organisation and system. Control is essential and involves regular measuring by comparing the outcome to the proposed plan. Any deviation from the plan is evaluated and some form of corrective action implemented.
High technology systems can be considered as systems containing various complex sub-systems and assemblies. In the process of technology advancing at a rapid rate and creating even more complex systems as they are upgraded and modified, disadvantaged countries are left behind. The systems used in the study can be considered high technology systems as they consist of many complex systems, sub-systems and assemblies, and have a high consequence of failure.

Normal supporting functions are inefficient to manage and maintain these high technology systems during their expected life cycle, especially where extended life situations and varying generations of technology exist and where ILS is applicable. An ILS system can solve this dilemma by reducing life cycle costs, reducing total cost of ownership and extending the life cycle of the complex high technology assets. This also improves the value of the assets, and ensures cost effective and efficient asset management.

The benefits of an effective and sustainable ILS system include a competitive advantage over competitors, while improved functional strategic planning and operating costs are reduced significantly. It enables efficient management of inventory and making better use of facilities. Furthermore, resources are used more effectively and better training is provided for personnel. Lastly, system assemblies are handled properly when moved or transported, and assemblies are packed and stored, ensuring they are not damaged.

There is no current framework available in the body of knowledge that allows for the systematic development of an ILS in situations that are not a single event or highly structured development, or that address some of the realities that are faced in the operation of complex systems in the developing world

ILS framework and methodology can be used in other developing countries, especially where resources and funds are very scarce commodities and the systems are used beyond their expected life cycle. This is especially relevant to high technology systems containing numerous complex subsystems. In order to manage technology, an organisation needs to effectively and efficiently implement the management functions of planning, organising, leadership and control. This is achieved by using ILS as an interface between the management functions and the high technology system.

This ILS interface includes maintenance and support planning in order to support the high technology system. Organising involves assigning resources to fulfill these plans. Effective leadership from management motivates personnel to carry out the ILS plans of the organisation and system. Control is essential and involves regular measuring by comparing the outcome to the proposed plan.

An ILS system framework will contribute significantly towards improved management of supply systems by increasing customer satisfaction with systems that meet intended quality parameters at an acceptable cost. This will lead to efficient maintenance planning and management. It will also lead to an optimisation of life cycle costs of company assets and decreased total cost of ownership. Personnel will become more knowledgeable with improved training and skills. The organisation will achieve a competitive advantage over other contenders by effectively and efficiently supporting the high technology assets. By implementing an ILS system an asset will be able to perform its operational objectives. An ILS system exists as a concept and a formalised process in the complexity of the real world.

In this section the importance of the study, as it relates to a high technology system and industry utilised in a developing country, was discussed. In the next section, the chapter outline of the thesis is covered.

1.11 Chapter outline

This thesis document chapter outline is depicted in Figure 1–2. The thesis document starts with Chapter 1 (this chapter), explaining the research problem and it's setting including the scope of the study. The literature review (Chapter 2) follows Chapter 1, Chapter 2 concerns the seminal literature as it relates to operations management - the definitions of logistics and ILS are explained and a brief history of logistics is provided. In Chapter 3, the research design is discussed, including the approach to research and an explanation of the three phases of research. In Figure 1–2, a solid line links chapters 1, 2, and 3; these chapters follow a chronological order, flowing from Chapter 1 to Chapter 2 to Chapter 3. The dashed lines indicate conceptual flow.

Phase 1 research: deconstruction of reviewed literature – integrated logistics support (Chapter 4) follows directly (solid line linkage) from Chapter 3. In Chapter 4 the ILS literature is deconstructed.

Chapter 4 flows directly into Chapter 5 (phase 2 research: case studies (deconstruction)). In Chapter 5 the numerous case studies are discussed and deconstructed. Chapter 3 (research design) also indirectly influences Chapter 5 (phase 2 research: case studies (deconstruction)), hence the dashed line linking the two chapters.

Chapter 5 flows directly into Chapter 6 (phase 3 research – quantitative), hence the solid line. Chapter 3 (research design) also indirectly influences Chapter 6 (phase 3 research – quantitative), hence the dashed line linking the two chapters. In Chapter 6 the third phase of research is discussed, which includes the research instrument.

Collation of three phases of research (Chapter 7) follows directly (solid line linkage) from Chapter 6. In Chapter 7 the three phases of research are collated. Chapter 7 is also indirectly influenced by Chapter 4 and Chapter 5, hence the dashed lines in Figure 1–2.

Chapter 7 flows directly into Chapter 8 (conclusions and recommendations), where the conclusion to the study is discussed, recommendations are proposed; and future research topics are offered.

In this section, the chapter outline was explained with the aid of Figure 1–2. A synopsis of this chapter is provided in the next section.

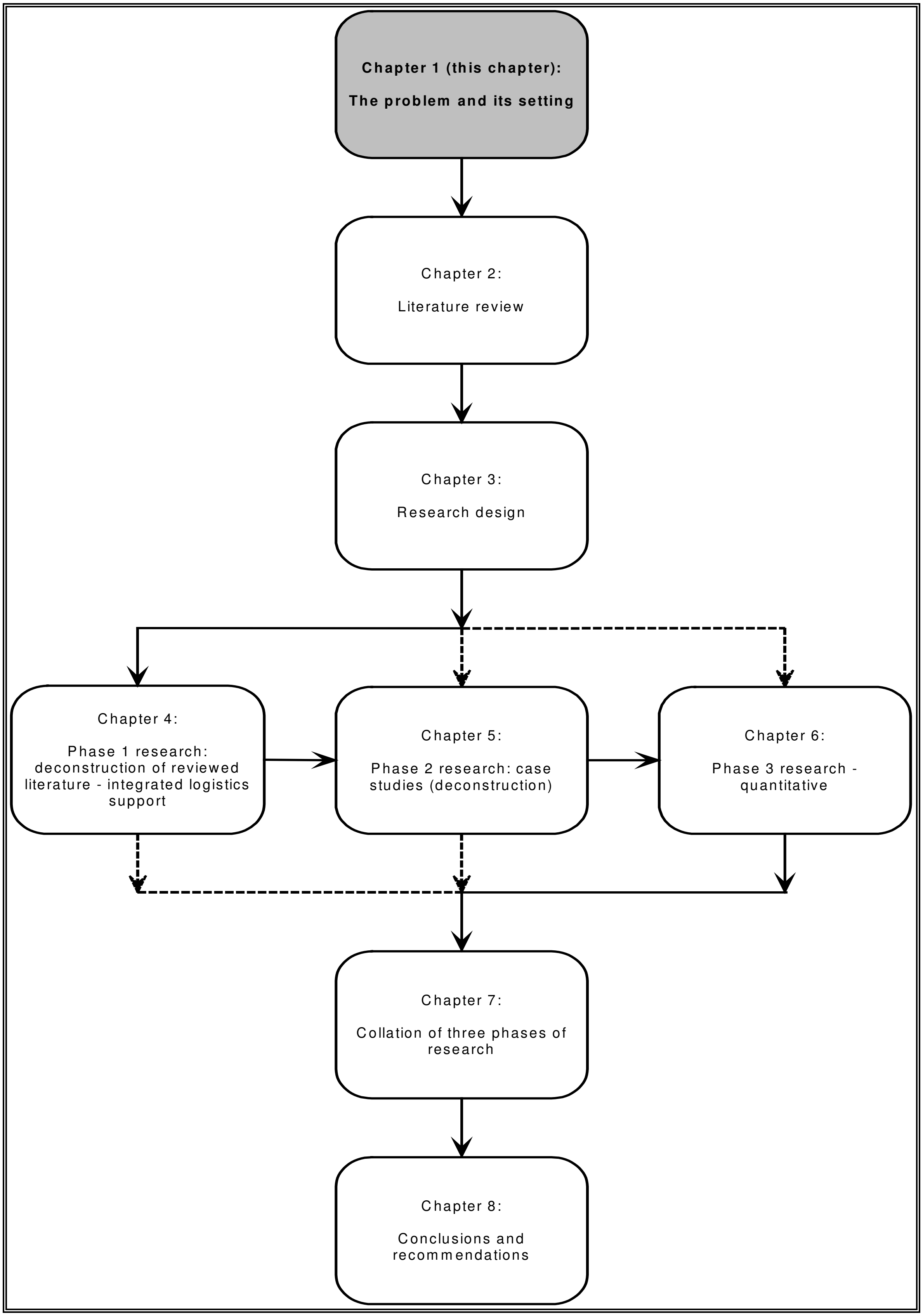


Figure 1–2: Thesis document chapter outline

1.12 Synopsis of the problem and its setting

Chapter 1 focused on the business problem and the research problem, and included a discussion of the study's importance. Furthermore, the life cycle concept was discussed wherein high technology systems are used beyond their intended designed operational life.

There is no current framework available in the body of knowledge that allows for the systematic development of an ILS in situations that are not a single event or highly structured development, or that address some of the realities that are faced in the operation of complex systems in the developing world

Some assumptions were necessary in order to conduct the study and certain delimitations were also necessary in order to complete the study; these assumptions and delimitations were also described within this chapter.

The concept of Mode 2 was discussed, and in particular how it will be used to support the research conducted in this study. This discussion follows in the research design (Chapter 3).

In Chapter 2, the available literature with regards to ILS is reviewed; the history of logistics, and definitions of logistics and ILS are explored.

'Logisticians deal with unknowns. They attempt to eliminate unknowns, one by one, until they are confident that they have done away with the possibility of paralyzing surprises. This is what we did in the Gulf.'

– Pagonis, (1992:2).

'All men by nature desire to know.'

– Aristotle.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

In this chapter a review of the applicable literature is presented. An extensive review was conducted to determine the orientation of prior research and to understand the body of knowledge and direction that integrated logistics support (ILS) has followed. It also focuses on the other relevant areas that constitute the appropriate body of knowledge. A brief history of logistics and ILS is provided. Definitions of logistics and ILS are explored with respect to commonalties and dissimilarities. The domain explored for the study is described and the ILS elements are discussed.

2.2 Seminal literature – operations management

Numerous seminal literature sources on the subject of operations management were reviewed: some of these are discussed in the paragraphs that follow.

2.2.1 *Taylor – scientific management*

Frederick Taylor's (1911) scientific management (or task management) is concerned with performing a task in a scientific manner in one specific way. Taylor (1967:9-10) proposes that management's primary objective is to obtain maximum success for the employer and employee: he uses the words *'maximum prosperity'*. Scientific management aims not only to provide maximum prosperity for the employer, but also argues that it cannot exist without providing maximum prosperity for the employee, and vice versa (Taylor; 1967, and Taylor in Pugh and Hickson, 2007). Taylor stressed the importance of ensuring internal operations are as rational, predictable and efficient as possible (Cardullo, 1996:222). Scientific management proposes *'one* *best way'* of performing a task (Robbins, 1998:A-3). The *'task idea'* is the most important element in scientific management (Handel, 2003:27). Task management is relevant in ILS in that maintenance actions are task orientated, whereby specific tasks are allocated specific resources.

2.2.2 *Fayol – principles of management*

Henri Fayol (1949) pioneered the principles of the management of planning, organising, commanding, coordinating, and control. He also proposed 14 principles to undergird his system of management thinking (Fayol, 1949, and Fayol, 1988; revised by Gray, 1988). Fayol used the term *'departmentation'*, which categorises organisational resources based on processes, purpose, geographic area, customers, and etcetera (Cardullo, 1996:222). Fayol (in Handel, 2003:11) describes a bureaucratic organisation, where specialisation in function and division of labour allows people to master proficiency and knowledge in their respective tasks. For Fayol (in Pugh and Hickson, 2007:145) managing denotes looking to the future, implying that planning and forecasting are central to business. Fayol's (1949) principles are pertinent to ILS where maintenance actions are planned in detail (in some environments even to the minute and second), these planned actions are organised per a time schedule (i.e. monthly inspections, yearly preventive maintenance), and resources are allocated to these tasks, be it personnel, equipment, spares, etcetera. These resources are managed in order to control the time, cost and effort that these resources expend.

2.2.3 *Drucker - management by objectives*

Drucker (1954) introduced the concept of management by objectives (MBO), whereby objectives are set and the personnel of the organisation are measured according to these objectives. Peter Drucker (in Pugh and Hickson, 2007:161-162) emphasises the necessity of *'management by objectives'* if high performance is to be achieved. Objectives should be in place *'… where performance affects the health of an enterprise.'* (Smit and de J. Cronjé, 1992:74) MBO makes use of goals in order to motivate employees instead of controlling them (Drucker, 1954, in Robbins 1998:204). MBO has altered since Drucker introduced the concept: these changes include motivating employees by using performance appraisals; furthermore MBO has also been used as a strategic planning tool (Smit and Cronjé, 1992:74). Drucker (1970:21) mentions that the assumptions made regarding the practice and theory of management of fifty years ago [50 years before 1970], had become inappropriate, invalid and obsolete; furthermore, managers are becoming conscious of new ways of thinking and of new management tools, for example the *'information revolution'*. Drucker's (1954) MBO is applicable to the field of ILS where certain maintenance objectives are set, and these set objectives need to be managed efficiently and effectively.

2.2.4 ***<u>Woodward – production management</u>***

Woodward's (1958) contribution to operations management was in the form of organisational structures for different production categories. Such structures concentrated on lines of command and levels within the organisational hierarchy. Production processes included unit production, mass production and process production, each of these production processes further consisting of sub-categories. Woodward's research involved a survey of manufacturing companies between 1953 and 1957 (Woodward, 1958 and 1965). Woodward's contribution is evident in engineering firms and organisations conducting maintenance where short hierarchies exist.

According to Woodward (in Pugh, and Hickson, 2007:20), technology is the major determinant of the structure of manufacturing firms. Woodward's findings concluded that organisation structure differed between *'unit and small batch'*, *'large batch and mass production'* and *'process production'* (Pugh and Hickson; 2007:21, and Handel; 2003:58). Lines of command were longer and hierarchies taller in process technology production (Hickson and Pugh; 2007:21). Woodward's (1958) organisational structures are applicable to ILS, where organisations involved in developing high technology complex systems possess certain organisational structures, depending on the product they design and manufacture.

2.2.5 ***<u>Schein – organisational culture</u>***

Schein's (1980, cited in Pugh and Hickson; 2000:239-240) research concerns the motivation of people by their managers. He proposes four assumptions regarding the motivation of employees: the *'rational-economic model'*, the *'social model'*, the *'self-actualizing model'* and the *'complex model'*. Managers need to be flexible regarding their behaviour and variations thereof (Pugh and Hickson, 2007:230-231). Schein's (1980) research is evident in the difference of culture between military and industrial organisations as this manifests itself in the third phase of research, where the questionnaire response rate and responses differed between industrial and military respondents.

2.2.6 ***<u>Senge – learning organisation</u>***

Senge's (1990) interest lies in the organisation that must learn continuously in accordance with the rapid change surrounding it. Senge (in Pugh and Hickson, 2007:270) is concerned to establish the characteristics of a *'learning organization'*, that is, one that is able to learn continuously. Senge (1990:14) defines a learning organisation as *'… an organization that is continually expanding its capacity to create its future. For such an organization, it is not enough merely to survive.'* Senge

(1990:14) also postulates that the majority of problems faced by humans stem from our *'… inability to grasp and manage the increasingly complex systems of our world'.* Senge's (1990) learning organisation is relevant to ILS, where training, and manpower and personnel are specific ILS elements requiring development in order to support a high technology complex system.

2.2.7 *Allison – 'Essence of Decision: Explaining the Cuban Missile Crisis'*

Allison and Zelikow (1999:1-2) go into great depth explaining the events of October 1962 with regards to the Cuban missile crisis. They take a case study approach when explaining the occurrence of events. They pose central questions /statements that they explore, these being the placement of missiles in Cuba by the Soviet Union, the naval quarantine imposed by the United States on Soviet Union shipments to Cuba, the reasoning behind the withdrawal of the missiles, and finally the lessons learned from the Cuban missile crisis. Three methodologies of explaining the Cuban missile crises are proposed by Allison and Zelikow (1999) and Allison (1969, in Handel; 2003:187-196): *'Model I: Rational policy'*, *'Model II: Organizational Process'*, and *'Model III: Bureaucratic Politics'*.

2.2.8 *Relevance to integrated logistics support systems*

Within section 2.2 some of the relevant seminal literature regarding operations management was discussed. These literature sources are relevant to the current study in that according to Taylor's (1911) scientific management, specific maintenance tasks on high technology complex systems are repetitive, and performed in a specific manner. In terms of Fayol's (1949) principles of management, all ILS related functions require some form of planning, organising, commanding, coordinating and control. Drucker's (1954) MBO indicates that all the staff members of an organisation need motivation. Woodward's (1958) organisational structures are relevant to all organisations involved with design and support of high technology complex systems. Schein's (1980) organisational culture is evident in organisational culture differences between the military and industrial organisations. With respect to Senge's (1990) *'learning organization'*, all employees are encouraged to learn, and gain knowledge, in order to improve the support of high technology systems. Lastly Allison and Zelikow (1999) provide a case study approach to *'… Explaining the Cuban Missile Crisis'*, which assists in explaining the support of the high technology systems used in the study. In the next section the supply chain, supply network, and supply chain management are discussed.

2.3 Supply chain, supply network and supply chain management

Within this section the relevant topics of the supply chain, supply network, and supply chain management as they are associated with operations management and integrated logistics support are discussed. The literature discussed ranges from 1986 to 2008. The definitions from some of the relevant available literature regarding supply chain and supply chain management are examined. Furthermore, the concepts of logistics and supply chain management and the extent to which they are linked to the study are also discussed.

The activity of leveraging supply chain integrating activities provides opportunities in competitive environments. A fully implemented integrated logistic support system can offer a mechanism to gain competitive advantage by effectively and efficiently supporting the high technology assets owned and utilised by the organisation, delivering products quickly and efficiently and supporting long term customer requirements.

Integrated logistics support (ILS) and integrated logistics support system (ILSS) can be associated with supply chain management and operations management. This is since ILS and ILSS can be considered as supporting the assets of an organisation, furthermore, supply chain management is sometimes referred to as integrated logistics, while supply chain management is viewed as designing processes to meet customer requirements. Not only is supply chain management viewed as a design process, but it also includes asset management, fund management, and improving the bottom line.

It is obvious that researchers contribute to the body of knowledge. According to the Project Management Institute (PMI) (2000:3) the body of knowledge *'… rests with the practitioners and academics that apply and advance it'.*

Mode 2 can be considered as generating knowledge within a specific context and functions from a practical point of view in that the theory generated can be applied in practice (Burgoyne and James, 2006:304). Kelemen and Bansal (2002:105) mention that Mode 1 is based in academia, while Mode 2 is based on *'networks of academics and practitioners'*.

Numerous drivers affecting the supply chain network exist, from facilities to transportation to suppliers of materials and services. Table 2–1 below denotes the numerous drivers in the supply chain.

2.3.1 *Definitions of supply chain, supply network and supply chain management*

In this section definitions of supply chain, supply network and supply chain management are provided and discussed. Slack, Chambers and Johnston (2007) view the supply chain as an operational function providing services and goods to an end user. They define supply chain as a:

> *'… linkage or strand of operations that provides goods and services through to end customers; within a supply network several supply chains will cross through an individual operation.'* (Slack, Chambers and Johnston, 2007:706)

Table 2–1: Drivers in supply chain

NO.	DRIVERS IN SUPPLY CHAIN	INFLUENCE
1	Suppliers of material	Location, price, discounts, responsiveness, reliable, efficient, commercially-off-the-shelf, available, and etcetera.
2	Suppliers of service	Training, language, accessibility of information, skill sets, knowledge, experience, and etcetera.
3	Sourcing	Reliable, efficient, responsive, make-or-buy, import constraints, warranty, spare parts policy, obsolescence, and etcetera.
4	Pricing	Buyer behaviour, supply chain performance, economies of scale, buy or buy and support, accessibility of specialist support, and etcetera.
5	Transportation	Mode, route, cost, urgency, packaging, fragility, delays, labelling, and etcetera.
6	Inventory	Type, quantity, cost, lead-time, responsiveness, original equipment manufacturer requirements, critical spares, and etcetera.
7	Facilities	Site selection, storage space, environmental conditions, location, infrastructure, and etcetera.
8	Process	Integration, operational requirements and limitations, and etcetera.
9	Information and information technology	Data analysis, management decisions - requirement, configuration management, compatibility, forecasting, and etcetera.
10	Customer	Identifying key customers & quality requirements, and etcetera.
11	Service	After sales service, maintenance (service) contract, communication, quality of service, information, and etcetera.
12	Forecasting	Future support needed, preventive maintenance and predictive maintenance requirements, demand & demand pattern forecasting, and etcetera.

Source: Adapted from: Chopra and Meindl (2007:44-45) and Wisner, Leong and Tan (2005)

The most complete and updated definitions of the supply chain and supply chain management are defined by Chopra and Meindl (2007). They view such a chain as involving all alliances in order to meet a client's requirements and define it as follows:

> *'… consists of all parties involved, directly or indirectly, in fulfilling a customer request.'* (Chopra and Meindl, 2007:3).

The supply network can be viewed as the combination of end user and supplier interrelationships; Slack, Chambers and Johnston offer the following definition:

> *'the network of supplier and customer operations that have relationships with an operation.'* (Slack, Chambers and Johnston, 2007:706).

Fawcett, Ellram and Ogden (2007) define supply chain management from a design point of view as existing between organisations, meeting the end user needs. Their definition is as follows:

> *'… the design and management of seamless, value-added processes across organisational boundaries to meet the real needs of the end customer'.* (Fawcett, Ellram and Ogden; 2007:8)

One team of authors (Chopra and Meindl, 2007) view supply chain management as maximising the profitability of the supply chain, defining it as follows:

> *'… involves the management of supply chain assets and product, information, and fund flows to maximize total supply chain profitability'.* (Chopra and Meindl, 2007:6)

Supply chain management is accorded many meanings, connotations and implementation processes, depending on the application. Wisner, Loeng and Tan (2005:12) mention that supply chain management is also referred to by means of other terms, these being integrated logistics, quick response, or service response logistics. Hence integrated logistics and ILS can be viewed as aspects of supply chain management.

Comparing the definitions of supply chain and supply chain management above, Chopra and Meindl (2007) are the only authors who mention funds and profit, which means managing funds, reducing risk and improving the bottom line as functions of supply chain management, operations management, integrated logistics and integrated logistics support.

In summary, the supply chain, supply network and supply chain management strive to meet customer requirements throughout the life cycle of a product, asset or service. These aspects are associated with ILS in the sense that they represent the schools of thought as concerns operations management. The supply chain is regarded as an operational function (Slack, Chambers, and Johnston, 2007), and as meeting customer requirements (Chopra and Meindl, 2007). Supply networks are regarded as interrelationships between an end user of operational equipment and the supplier of such equipment (Slack, Chambers, and Johnston, 2007). Furthermore, Wisner, Leong and Tan (2005:12) argue that supply chain management is often referred to as 'integrated logistics'.

Definitions of supply chain, supply network and supply chain management were consequently furnished and discussed in this section. The literature relevant to logistics and supply chain management is discussed in the next section.

2.3.2 *Logistics and supply chain management*

In this section the relevant literature, and the extent that it is linked to the study, is indicated. Table 2–2 below lists the newest literature regarding logistics and supply chain management and the extent to which they are linked to the study. Within the table mention is made of maintenance (and corrective maintenance), repair, transportation, sourcing, site selection (facilities or location), leadership and logistics, and performance measurement, and other traditional elements of ILS. In the next section integrated logistics systems are discussed.

2.4 Introduction to integrated logistics systems

The body of knowledge regarding ILS directly poses certain problems in that the literature sources are not always readily available, various authors hold different views on logistics and ILS and there are major discrepancies in the definitions used. The primary sources of information consulted within the discipline of ILS included academic articles, master's dissertations, doctoral theses, military standards; specifications and handbooks (the military standards are not necessarily deemed academic literature, but are extensively peer reviewed); books, and non-academic publications of specific industries.

Table 2–2: Selected literature of logistics and supply chain management and the extent to which they are linked to the study

AUTHOR, YEAR, TITLE	EXTENT LINKED TO STUDY
Wisner and Stanley (2008). 'Process Management: Creating Value along the Supply Chain'	Supply chain, includes maintenance, repair, operating supplies, and sourcing
Chopra and Meindl (2007). 'Supply Chain Management: Strategy, Planning, & Operation'	Supply chain drivers and metrics, transportation, supply chain, and sourcing
Fawcett, Ellram, and Ogden (2007). 'Supply Chain Management: From Vision to Implementation'	Supply chain, sourcing, process thinking, supply chain mapping, and performance measurement
Langford (2007). 'Logistics: Principles and Applications'	Logistics and integrated logistics support, quality assurance for operations management, logistics statistics, reliability; availability and maintainability, and corrective maintenance frequency
Metters, King-Metters, Pullman and Walton (2006). 'Successful Service Operations Management'	Service operations management, site selection, sourcing, customer expectations, designing and improving the delivery system
Wisner, Leong, and Tan (2005). 'Principles of Supply Chain Management'	Supply chain, transportation, service response logistics, logistics, purchasing management, and performance measurement
Monczka, Trent and Handfield (2004). 'Purchasing and Supply Chain Management'	Supply chain, purchasing, insourcing/outsourcing, purchasing and transportation services
Lambert and Stock (2001). 'Strategic Logistics Management'	Logistics, physical distribution of goods, logistics strategy, logistics information and technology
Juga (1996). 'Changing Logistics Organisation'	Logistics, semi-integrated supply chains, and overcoming logistics fragmentation
Robeson, Copacino, and Howe (1994). 'The Logistics Handbook'	Logistics, evolution of integrated logistics concept, logistics strategy, and logistics network modelling
Pagonis (1992). 'Moving Mountains: Lessons in Leadership and Logistics from the Gulf War'	Case study - modern logistics, ILS, leadership and logistics, appropriate behaviour for leaders, and brainstorming
Bowersox, Closs, and Helferich (1986). 'Logistical Management. A Systems Integration of Physical Distribution, Manufacturing Support, and Materials Procurement'	Logistics, sourcing, physical distribution, materials procurement, and manufacturing support

Source: As listed in Table 2–2.

The lack of compilations for the purposes of industrial applications is evident from the literature. Military documentation is not always available, and most books are also not readily obtainable, being either out of print, or with only a very small number in print. The United States Department of Defense Directive was found in a NASA publication (Carpenter, 1967) dated in 1967, before the first lunar landing in 1969. The United States MIL-STD-1369-A (1988) stems from the late 1980's, and the United States Army Regulation 700-127 (1999) is from the late 1990's. Other NASA publications deal with the space shuttle programme and a logistics management plan (NASA, 1974), while Palguta, Bradley and Stockton (1987) consider an ILS system for OSSA (Office of Space Science and Applications) payloads.

Books surveyed include volumes from the late 1980's, the early 1990's, 2004 and 2006 publications such as engineering logistics (Blanchard, 1992 and 2004), or design engineering (Finkelstein and Guertin, 1988); industrial integrated logistics by Jones (1995; 1998; and 2006) and studies by Hutchinson (1987) and Langford (1995). The majority of academic literature in the form of books is prior to 1999; the available books consist only of those authored by Blanchard (2004) and Jones (2006). The literature surveyed deals mostly with developed countries (United States and United Kingdom sources) with newly designed systems, not necessarily with systems already in use and used beyond their intended design operational life.

As mentioned earlier, the literature shows discrepancies between the various authors' definitions of logistics and integrated logistics support, both between different purposes (military versus industrial), and within specific usage domains. The comparison between theories from various sources, including NASA, military standards, and academic literature, evidences various schools of thought concerning integrated logistics support. Military standards are linked to proven principles and various ad-hoc implementations. The military standards are not necessarily academic per se, but, as previously indicated are peer reviewed, and are more stringent with regards to design specifications and guidelines for newly developed systems.

Various areas within ILS will be focused on; these are depicted in Figure 2–1. The main focus areas include maintenance (support), packaging; handling; storage and transportation (PHS&T), support and test equipment, supply support, facilities, technical data and documentation, configuration management, and obsolescence.

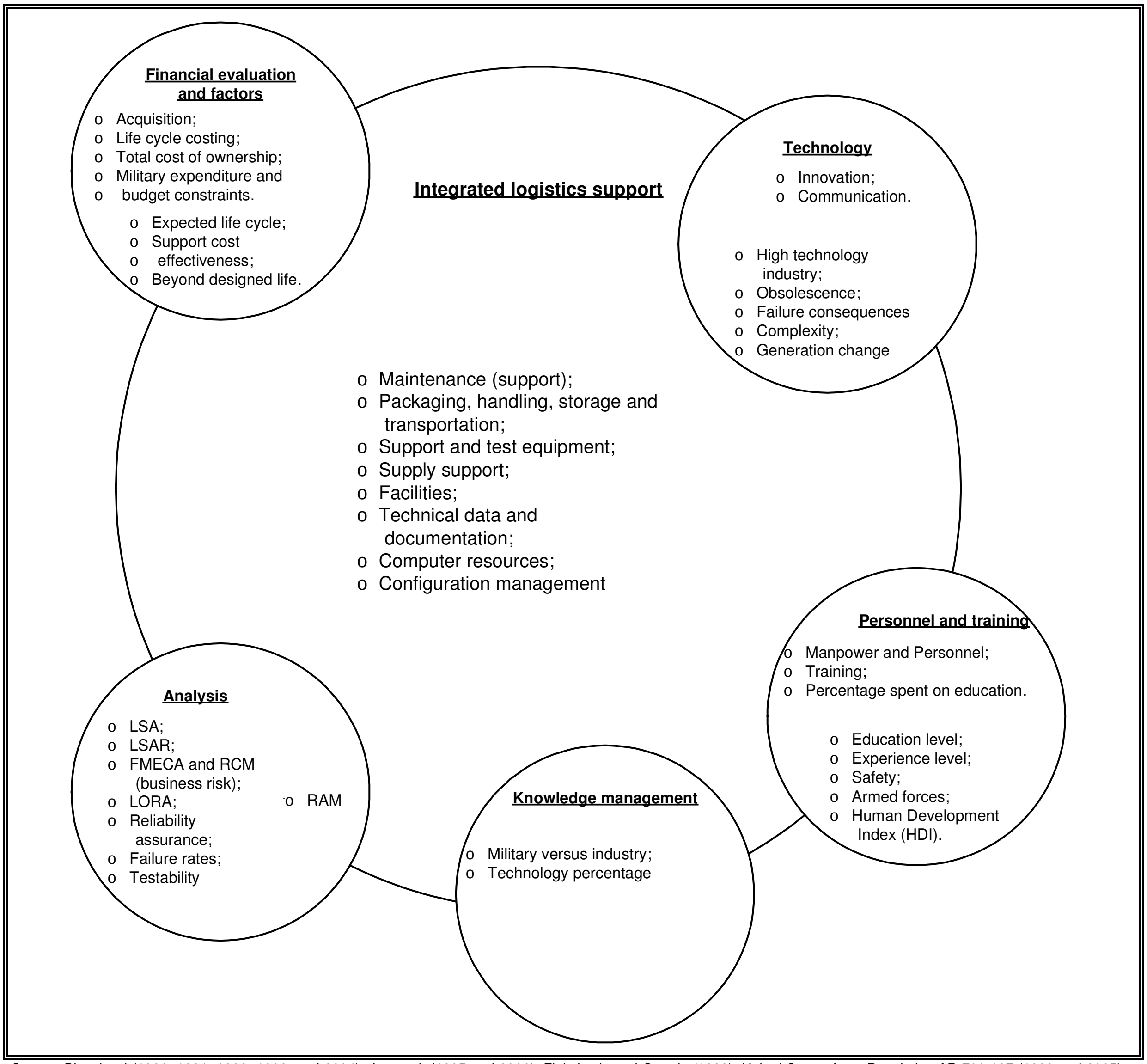
This section introduced integrated logistics systems, including the problems associated with the literature sources, and different views regarding the definitions of logistics and ILS. In the next section a brief history of logistics is discussed.

2.5 Brief history of logistics

This section offers a brief history of logistics, beginning with the early wars and moving to the Industrial Revolution of the 19th century and the efficient use of electronic communication in the 20th century.

During the early documented wars (490 & 481 BC) the armies lived off the land or their supplies were shipped in, in order to survive (*The New Encyclopaedia Britannica*, 1974:78). The size of armies increased in the early 17th century, where they kept on the move in order to survive. In the 18th century, warfare was about sieges and not battles (*Encyclopaedia Britannica*, 2004, 10-11).

Historically armies did not possess self-propelled transportation, and supplies took a while to reach armies cut off from the supply chain. The advent of motorised transportation decreased the necessity of armies needing to be close to supply depots, as supplies could be transported to them more easily and quickly than previously. Enemies would typically try and cut the armies off from their supplies by damaging their supply chain.



Source: Blanchard (1986; 1991; 1992; 1998; and 2004), Jones, J. (1995 and 2006), Finkelstein and Guertin (1988), United States Army Regulation AR-700-127 (1999 and 2005), Carpenter (1967), European Cooperation for Space Standardization (1996), Galloway (1996), Biedenbender; Vryn and Eisaman (1993), Levitt (2003), Moubray (1991 and 1997), Nowlan and Heap (1978), Palguta; Bradley and Stockton (1987), Hutchinson (1987), Quayle (1993), Smith and Hinchcliffe (2004), United Kingdom Ministry of Defence (2004), United States (U.S.) Department of Defence (DoD) MIL-STD-1629 (1980), and U.S. DoD MIL-STD-1369-A (1988).

Figure 2–1: Domain in which integrated logistics systems exist (Acronyms available in the list of business and technical abbreviations and acronyms)

Steam-driven machinery during the Industrial Revolution of the 19th century changed the nature of war (*The New Encyclopaedia Britannica*: 1974, Volume 11, 78). During the latter part of the 19th century the telegraph, the steamship and the railroad had a serious effect on logistics, especially on transport and information. The 20th century saw more efficient methods of electronic communication, viz. the radio, television, telephone, radar, and the high-speed computer (*Encyclopaedia Britannica*: 2004:12-13).

One of the 20th century developments was the invention of the powered vehicle (*Encyclopaedia Britannica*: 2004:13). Logistic systems and techniques altered after World War II, where consequences of failure beyond design limits and dependency on logistics became more important. New weapons of destruction followed, including intercontinental ballistic missiles and missile launching submarines (*Encyclopaedia Britannica*: 2004:17).

According to Pagonis (1992:1-2) (a Lieutenant General responsible for logistics in the Gulf War) during the year between August 1990 and August 1991, more than 122 million meals were planned, moved, and served, 1.3 billion gallons of fuel were pumped and 52 million miles were driven. Armies' needs are always complex, numerous, and contradictory. Pagonis (1992:1-2) further mentions that *'Armies need well-trained, mobile, flexible fighting forces'* which need support services including: ammunition, social counsellors, planes, carpenters, bakers, morticians, cashiers, and tanks. The logistics of the Gulf War were complicated and required immense strategic planning. Containers in the Gulf War were lacking suitable and adequate lifting equipment, which made lifting the containers very difficult (White, 1995: 120-121). Spares in the Gulf were initially sufficient, however, certain supply support items required additional lead times (White, 1995:123).

Logistics of complex developments and designs include NASA, military radar systems, industrial satellite earth stations, industrial and military navigational and instrument landing systems, industrial automated weather observation systems, industrial very small aperture terminal (VSAT) systems, military aircraft and weapon systems, and nuclear power plants. In the next section we deal with the definitions of logistics.

2.6 Definitions of logistics

This section deals with the various definitions that exist for logistics, ranging from general references in operations management literature and the *Encyclopaedia Britannica*, to definitions proposed by the Council of Supply Chain Management Professionals, the Society of Logistics Engineers, NATO, military sources, and academic sources, such as Jones (1998 and 2006).

Before ILS can be considered, the word *'logistics'* needs to be defined. Again, discrepancies exist between the various descriptions and interpretations. Dictionaries and the encyclopaedia provide a definition of the word *'logistics',* viewing it from a military perspective. Some of the key definitions are listed below:

1) Academic literature.

Operations management literature views logistics as a supply chain function whereby goods are moved from one location to another.

From a European perspective Slack, Chamber and Johnston (2007) largely view logistics from the point of view of physical distribution although they define logistics in more than one manner. Firstly Slack, et al (2007:404) define logistics as *'… an extension of physical distribution management [which] usually refers to the management of materials and information flow from a business, down through a distribution channel, to the retail store or direct to consumers ….'* Within the same book Slack, et al (2007:413 and 702) later define logistics from a supply chain management perspective which is *'… broadly analogous to physical distribution management.'* In one definition Slack et al view logistics as physical distribution management but according to another definition they view logistics as an extension of such management.

American authors Jacobs and Chase (2008:198) view logistics as a support function of material flow, defining logistics as:

> *'Management functions that support the complete cycle of material flow: from the purchase and internal control of production materials; to the planning and control of work-in-process; to the purchasing, shipping, and distribution of the finished product.'*

Jacobs and Chase (2008:218) further define logistics from an industrial and military context. Within the industrial context Jacobs and Chase (2008:218) view logistics as *'… the art and science of obtaining, producing, and distributing material and product in the proper place and in the proper quantities.'* From a military perspective Jacobs and Chase (2008:218) include personnel movements.

The Association for Operations Management (cited in Jacobs and Chase, 2008:204) defines logistics as:

> *'the art and science of obtaining, producing, and distributing material and product in the proper place and in proper quantities.'*

Another set of authors from a supply chain background provides more definition of logistics, somewhat different in terms of wording and vocabulary used but almost similar in meaning. Fawcett, Ellram, and Ogden (2007:152) define logistics as:

> *'… the art and science of moving things from one point to another and storing them along the way.'*

Fawcett, et al (2007:152), Jacobs and Chase (2008:218), and The Association for Operations Management (cited in Jacobs and Chase, 2008:204) all view logistics as an *'art and science'*.

From yet another supply chain point of view, but more specifically from a process management perspective, Winser and Stanley (2008:400) use the definition (found below under the Council and Society definitions of this text) of the Council of Supply Chain Management Professionals (previously Council of Logistics Management) as their reference point for defining logistics.

Another set of American authors, Melnyk and Denzler (1996:31), view logistics management as *'… the movement and storage activities within the supply chain, beginning with the supplier and ending with the consumer.'*

South African authors Adendorff and de Wit (1997:210) define logistics management as an activity that *'… coordinates all material flow activities such as purchasing, inventory holding, material handling, production, packaging and transport.'*

A further European definition is to be found in an excerpt from a book by military writer and philosopher General Antoine Henri Jomini, the title of which is '*Précis de l'art de la guerre*' ('The Art of War'). Jomini perceives logistics as making certain that troops reach a specific area, as this extract indicates:

> *'Logistics comprises the means and arrangements which work out the plans of strategy and tactics. Strategy decides where to act; logistics brings the troops to this point.'* (Jomini; 1838, cited in Logisticsworld; 2005).

There are numerous definitions of logistics available, the most relevant of which are explained below:

i) Doctrine for United States Logistics Support of Joint Operations (1992). This doctrine explains that not all logistics principles (or elements) are equally relevant and important at any given moment in time; it is the identification of those specific principles for a given situation that will enhance effective support. (The full definition is provided in Appendix B.)

ii) *Encyclopaedia Britannica* (2004). This also views logistics as a military function including all activities of the armed forces, and defines logistics in military science. (The full definition is provided in Appendix B.)

Numerous authors are quoted in the *Encyclopaedia Britannica* (1974 and 2004), including Jomini, Mahan, Thorpe, and Eccles. Their viewpoints are discussed below.

The term logistics is based on a Greek word *'logistikos'*, meaning *'the science of computation, or calculating.'* Jomini's book '*Précis de l'art de la guerre* (1836), defined logistics as *'the practical art of moving armi*es' that includes engineer, staff work and reconnaissance (*The New Encyclopaedia Britannica*: 1974:77). United States Captain Alfred Thayer Mahan (a naval historian), defined logistics as *'the support of armed forces by the economic and industrial mobilization of a nation'* (*The New Encyclopaedia Britannica*: 1974:77).

Lieutenant Colonel Cyrus Thorpe (an officer in the United States Marines, published 'Pure Logistics' in 1917), arguing *'that the logical function of logistics, as the third member of the strategy–tactics–logistics trinity, was to provide all the means, human and material, for the conduct of war, including not merely the traditional functions of supply and transportation but also war finance, ship construction, munitions manufacture, and other aspects of war economics.'* (*Encyclopaedia Britannica*, 2004).

Henry E. Eccles (a retired United States Navy Real Admiral), in 1959 published *'Logistics in the National Defense'* in which he expanded Thorpe's theory to include *'strategy, tactics, logistics, intelligence, communications.'* Eccles *'envisaged logistics as the military element in the nation's economy and the economic element in its military operations ...'* (*Encyclopaedia Britannica*, 2004).

2) Council and Society definitions:

The Council of Supply Chain Management Professionals and the Society of Logistics Engineers (SOLE) each furnish a definition of logistics. Although these definitions do not necessarily conflict with each other, they could be open to different interpretations.

i) The definition by the Council views logistics management as a supply chain management function fulfilling customers' requirements by planning, implementing and controlling all activities regarding the supply of services and products during the entire life-cycle of these services and products. (The full definition is to be found in Appendix B.)

ii) The Society (1974) views logistics as a science of management, technical activities and engineering, in order to support operations by means of maintaining resources. (The full definition is available in Appendix B.)

3) The North Atlantic Treaty Organisation (NATO) (2002) views logistics as a military operation, including transportation of personnel, medical services, acquisition and distribution of materiel, acquisition and construction of facilities, and provision of services. According to NATO logistics means 'different things in different contexts.' In addition there seem to be differences in the terminology used by NATO members as well as by military operation support categories. (Appendix B contains the full definition.)

4) The U.S. Military (Air Force Report) and Department of Defense (DoD) Directive. The United States Military views logistics as the movement of forces, while the Department of Defense Directive views logistics as distribution and system support; these definitions are explained below. (The full definition is furnished in Appendix B.)

i) U.S. Air Force technical report (1981). This definition of logistics includes the maintenance and movement of forces, and is somewhat similar to NATO's definition of logistics. It also views logistics as a military operation, including the movement and hospitalisation of personnel, movement of material, acquisition of facilities, and acquisition of services. (See Appendix B for the full definition.)

The primary difference between the U.S. Air Force technical report (1981) and the NATO (2002) definition is that the former report (1981) mentions the 'movement' of 'material' whereas NATO (2002) mentions the 'transport' of 'materiel'. In addition, the U.S. Air Force technical report mentions that logistics deals with the 'movement, evacuation, and hospitalization of personnel', while NATO (2002) only refers to the 'transport of personnel'. NATO (2002) mentions the '… provision of services', but the U.S. Air Force technical report refers to the '… furnishing of services'. NATO (2002) also views logistics as 'medical and health service support'; although the U.S. Air Force report does not mention this, it does refer to the '… hospitalization of personnel', which can be viewed in terms of all the contexts where NATO is currently involved in peacekeeping in Africa, and wherever medical and health services are needed, whereas the U.S. Air Force technical report (1981) is interested in the evacuation and hospitalization of their armed forces.

ii) The Department of Defense Directive (DoDD) 5000.39 (1983). This definition of logistics views logistics as a military function and includes distribution and system support elements. The elements include computer resources support, personnel, training, technical data, support equipment, packaging; handling; storage; and transportation, facilities, supply support, and maintenance planning.

5) James V. Jones (*'Integrated Logistics Support Handbook'*):

Jones (1998 and 2006) is one of the most prominent academic authors on the subject of ILS. He views logistics as an applied science using resources, although not necessarily from a military point of view. Jones defines logistics as follows in two editions of his book:

> *'… the applied science of defining supportable systems and of planning and implementing the acquisition and use of resources.'* (Jones, 1998:1.1); and
>
> *'… the applied science of planning and implementing the acquisition and use of resources.'* (Jones, 2006:1-1)

The only difference between the two definitions above is that Jones (1998) mentions that supportable systems must be defined, whereas in the 2006 definition there is no mention of specific defined systems.

This section dealt with the various definitions that exist for logistics and points out that each definition deems different aspects as important. Only the definition of logistics in the US Air Force Technical Report and NATO's definition are similar. Most of the definitions, except for those by Jones, have a military connotation. The next section deals with definitions of integrated logistic support.

2.7 Definitions of Integrated Logistics Support

In this section the various definitions of integrated logistics support (ILS) are discussed, starting with the military, progressing to engineering and being further broadened to industry.

1) Military definitions of ILS:

Various military sources were consulted for the definition of ILS: U.S. MIL-STD-1369-A (1988), U.S. Army Regulation 700-127 (1999 and 2005), U.S. Department of the Army Pamphlet 700-127 (1989), U.S. Department of Defense Directive (DoDD) 5000.39 (1980 and 1983), U.S. DoDD 4100.35 (G) (1967 and 1968) and DoD Pamphlet TM38-710; APF800-7; and NAVMAT P-4000 (1972), and the United Kingdom Ministry of Defence [s.a.]. The first three definitions are somewhat similar. However, the U.S. DoDD 4100.35 and the U.S. DoDD 5000.39 differ. The DoD Pamphlet TM38-710, APF 800-7, and NAVMAT P-4000 are somewhat similar to the definitions of U.S. DoDD 4100.35 (G). All are explained below.

i) The Department of Defense Directive 5000.39 (1983, cited in Blanchard, 1992:13) defines integrated logistics support as a management and technical approach used to influence the support of a designed system in order that the system can be supported at a minimum cost during the utilisation phase of the systems life cycle. (The full definition is contained in Appendix B.)

   This definition is exactly the same as the definition given by the Defense Systems Management College (DSMC) (1994), as found in Blanchard (2004:7-8). This definition evolved from an earlier version, from 1980, as found in Rossi (1990:25) as defined in paragraph vi) of this section. This definition is also similar to the definition provided by DSMC (1986 and 1994) as found in Blanchard (1991:23 and 2004:7-8), except that the definition excludes the word '*and'* between the words '*unified'* and '*iterative'*.

ii) MIL-STD-1369-A (1988:7) defines integrated logistics support as the management and technical approach used to influence the support of a designed system in order for the system to be supported at a minimum cost during the utilisation phase of the system's life cycle. (See Appendix B for the full definition.)

iii) U.S. Army Regulation 700-127 (1999, and 2005). There are four different definitions of integrated logistics support (ILS) in the two editions of this source: two from the

1999 edition and two from the 2005 edition. These are explained below, while the full definitions are provided in Appendix B:

a) U.S. Army Regulation 700-127 (1999:5-6, first citation), views ILS as a management and technical approach used to influence materiel and operational requirements and system specifications in order that a system can be supported at the best possible value to the end user, and in order to seek improvements in the life cycle cost (LCC) of the system and system support.

b) U.S. Army Regulation 700-127 (1999:53-54, second citation) describes ILS as a management and technical approach used to influence materiel and operational requirements and design specifications in order that a system can be supported at the lowest cost to the end user, to seek improvements in the LCC of the system and system support, and to continuously re-evaluate the utilisation support requirements.

c) U.S. Army Regulation 700-127 (2005:1-2, first citation) views ILS as a management and technical approach used to influence materiel and operational requirements, system specifications and integrated maintenance in order that a system can be supported at the best value to the end user, to implement 'performance based logistics', to seek improvements in the LCC of the system and system support, and to determine the system support requirements.

d) U.S. Army Regulation 700-127 (2005:35, second citation) views ILS as a management and technical approach used to influence materiel and operational requirements and design specifications in order that a system can be supported at the lowest cost to the end user, to seek improvements in the LCC of the system and system support, and to examine the system support requirements during the utilisation phase of the system.

All the four definitions above view ILS as a management and technical approach used to influence materiel and operational requirements, and to improve the LCC of the system and system support. They all mention influencing either the system or the design specifications and all refer to a cost factor; however, there is a difference between 'best possible value' and 'lowest cost'. Each of the four definitions differs regarding the examining of support requirements: the first citation in the 1999 edition does not mention the examination of support requirements, whereas the second citation in the 1999 edition does. The first citation in the 2005 edition mentions defining the support requirements but not examining them, while the second citation from the 2005 edition does mention such an examination.

The definitions proposed by Defense Directive 5000.39 (1983), MIL-STD-1369-A (1988), and U.S. Army Regulation (1999) are the same in some aspects, with a few exceptions:

a) MIL-STD-1369-A (1988:7) starts the definition with '*The'* – something that is specific, whereas the department of Defense Directive 5000.39 (1983) and U.S. Army Regulation 700-127 (1999:5-6) starts their definition with '*A'* – something which is not specific.

b) U.S. Army Regulation 700-127 (1999:5-6 and 2005) does not include the concept of '*disciplined'*, whereas DoD Directive 5000.39 (1983) and MIL-STD-1368A (1988:7) do so.

c) MIL-STD-1369-A (1988:7) calls for '*acquired support*' whereas DoD Directive 5000.39 (1983) refers to *'required'* support. U.S. Army Regulation 700-127 (1999:5-6) also calls for the development of the required support.

d) Army Regulation 700-127 (1999 and 2005) is dated some 11 to 16 years later than the other two, with significant activities listed.

iv) Department of the Army Pamphlet 700-55 (1989:17), as per the previously mentioned military definitions, also views ILS as a management and technical approach used to influence materiel and operational requirements and design specifications in order that a system can be supported at the lowest cost to the end user, to seek improvements in the LCC of the system and system support, and to continuously re-evaluate the utilisation support requirements. This definition is exactly the same as AR700-127 (1999:53-54, second citation). (The full definition is contained in Appendix B.)

v) Department of Defense Directive 4100.35 (G). Two references were found containing the DoDD 4100.35 definition of ILS. The two definitions of DoDD 4100.35 (1967 and 1968) view ILS as system support at all maintenance levels. The ILS definition (1967) cited in Blanchard (2004:7) views ILS as a combination of the factors supporting a system during utilisation, and considers ILS as part of system procurement and operation. The ILS definition (1968) cited in Rossi (1990:24) perceives ILS as a combination of elements to support a system during utilisation, and includes the synthesis of the elements. (The full definition is to be found in Appendix B.)

The two definitions are similar except for the following:

a) DoDD 4100.35G (1967) mentions *'a composite of all support considerations necessary …'* whereas DoDD 4100.35 (1968) mentions *'… a composite of the elements necessary …'*.

b) The last sentence of each definition also differs considerably. DoDD 4100.35G (1967) maintains that ILS *'is an integral part of all other aspects of system acquisition and operation.'* whereas DoDD 4100.35 (1968) considers '*It is characterized by the harmony and coherence obtained between each of its elements …'.*

vi) DoD directive 5000.39 (1980) defines ILS as a technical and management activity used to develop support requirements and influence the design of the system in order that the system is supportable, and to support the system during the utilisation phase of the life cycle at minimum cost. (The full definition is furnished in Appendix B.)

vii) DoD pamphlet TM38-710, APF 800-7, NAVMAT P-4000 (1972), as cited in Rossi (1990:25), defines ILS as all support elements and requirements combined, ensuring an economical support system throughout the life-cycle of the system. All these elements are integrated to form the support system. (See Appendix B for the full definition.)

viii) The Department of the Army Pamphlet 700-127 (1989:1) views ILS as the integration of all required elements to support a system economically throughout the entire life-cycle of the system. (The full definition is to be found in Appendix B.)

ix) AMS (Acquisition Management System) UK (United Kingdom) MOD (Ministry of Defence) Through Life Support Directorate (TLSD), ([s.a.]:1), views ILS as providing cost and supportability factors during the design phase, hence influencing the design, thereby reducing the cost implications. (The full definition is contained in Appendix B.)

x) DEF-STAN 00-60 (Part 0), (2004:A-7) views ILS as a management function, optimising system LCC. This includes influencing the design & the support system. (The full definition is furnished in Appendix B.)

2) Engineering definition of ILS. One definition was used concerning integrated logistics support and engineering. Blanchard (1992:13) views the integrated logistics support of a system from an engineering and management perspective, which encompasses costs; planning; and controlling the design of a system, thereby ensuring that the end user receives a system that can be supported throughout its life cycle at the minimum cost. (The full definition is to be found in Appendix B.)

3) Industry definitions of ILS. Various industrial definitions of integrated logistics support include those of Hutchinson (1987), Quayle (1993), Jones (1998 and 2006), Lambert & Stock (1996), and Adler (1967). These definitions are explained further below.

i) Hutchinson (1987) views ILS as identifying and resolving logistics problems, before they occur. This includes operational, systems, and subsistence logistics. (See Appendix B for the full definition.)

ii) Quayle (1993) perceives ILS from an aircraft industry viewpoint, including the provision of a technical support system at minimum cost. (The full definition is provided in Appendix B.)

iii) Jones (1998) defines ILS as a technical discipline for military forces, and also mentions support of industrial systems such as shipping, rail systems, petroleum industry, and commercial aviation. He views ILS in a non-military environment as comprising customer services or product support. Jones (1998) regards ILS as a management activity, where technical disciplines develop support systems. Jones (2006) also views ILS as a management activity of all disciplines (not just technical) in order to develop a support system at a minimum cost within predefined objectives. (The full definitions are available in Appendix B.)

iv) Lambert and Stock (1993) view integrated logistics management as an integrated system of administrative functions. ILS and integrated logistics management can be viewed as one and the same. (The full definition is to be found in Appendix B.)

v) Adler (1967) describes ILS as the analysis of total cost, from a systems viewpoint, for the purpose of resolving management concerns. (The full definition is provided in Appendix B.)

4) Definition of ILS utilised in the study:

Based on the above definitions, a more refined one will be used for the present study:

> *'A management responsibility which ensures that the most appropriate and reliable product/s and/or technical service/s supplied are of the highest quality and are both efficient and effective, are in the correct quantity, at the correct location, at the correct time to support a system throughout its intended or extended life cycle at the minimum cost.'*

After reading the various definitions of ILS it is quite discouraging to realize that each author holds a different perspective on ILS, from military points of view to engineering to industry. Their viewpoints are also based on different functional areas within an organisation, while the sources range between 1967 and 2006, during which major technological advancements arose. The next section deals with the evolution of the integrated logistics concept.

2.8 Evolution of the integrated logistics concept

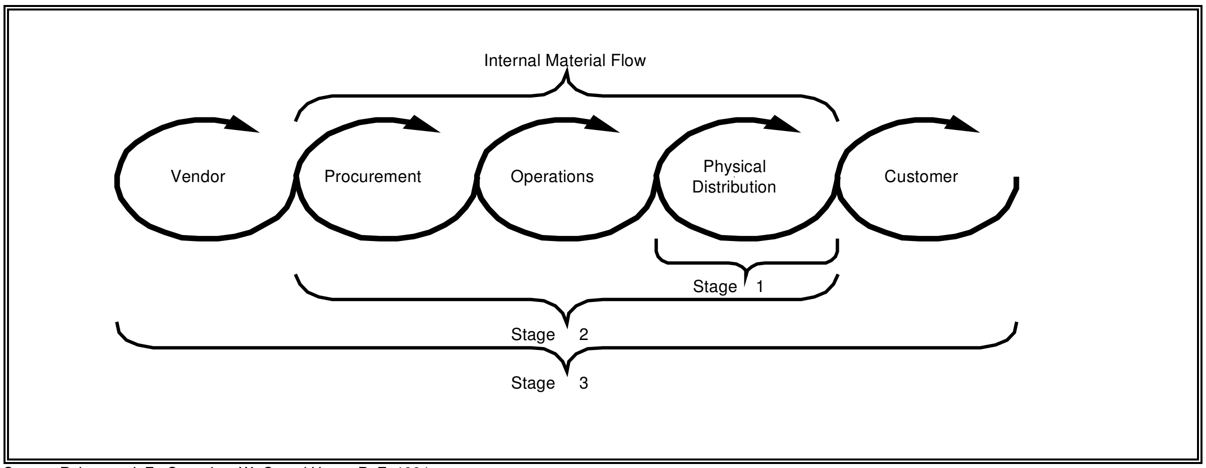
In this section the development of integrated distribution and the evolution of integrated logistics management are discussed. Just as logistics systems have evolved from the military to engineering to industry over the years, integrated distribution and integrated logistics management have developed.

2.8.1 *Development of integrated distribution*

Integrated distribution has made rapid progress over the last few decades after the advent of World War II, together with improved scientific management and processing technology. Advancements in computer technology made an automated inventory a reality for many, while customer focus was the central management idea of the 1950's and 1960's, and profit leverage was seen to be attainable by reducing logistics costs (La Londe, Grabner and Robeson {1970} in Robeson, Copacino and Howe, 1994:6-8).

2.8.2 *Evolution of integrated logistics management*

The integrated logistics concept has evolved over time, and consists of three stages as shown in Figure 2–2. Stage 1 deals with physical distribution, stage 2 with procurement, operations and physical distribution, while stage 3 concerns the processes of stage 2 as well as the vendor and the customer.



Source: Robeson, J. F., Copacino, W. C. and Howe, R. E. 1994.

<u>Figure 2–2: Evolution of the integrated logistics concept</u>

1) *'Stage 1: Physical Distribution. To manage finished goods distribution in a way that met customer expectations at the lowest possible cost.'*

2) *'Stage 2: Internal Linkages. Logistics did not necessarily reflect an organizational change within the firm, but rather a change in the way the firm thought about value linkages across the three internal material flow loops.'*

3) *'Stage 3: External Linkages. Stage three of the evolution, shifted the logistics concept to include externally focused change. Firms began to think "*out of the box" *and searched for efficiencies in relationships with vendors, customers, and third parties.' (Robeson, et al., 1994:9-10).*

The evolution of the integrated logistics concept was briefly discussed above. The concepts reviewed included scientific management, customer focus, data processing technology, and profit leverage. Physical distribution, internal and external linkages were also briefly discussed. The following section deals with the available models of integrated logistic support - military.

2.9 Available models of integrated logistics support – Military

Boeing is one of the few system developers that is sharing its life cycle support system, devised for the UK Royal Air Force helicopter arm, with other users, including The Netherlands and Italy, and is entering discussions with the Israeli Air Force logistics associates (Kemp, 2006).

According to Gething (2001) the development and upgrade of the H-1 Bell helicopter for the United States Marine Corps was expected to reduce logistics support costs by 'billions of dollars', in terms of ground handling, support & test equipment costs, supply support requirements, training, and overall manpower requirements, amongst other factors.

Obsolescence in systems (as in all complex systems) is an issue since suppliers do not necessarily keep a stock of components. Since technology has changed significantly compared to 30 years ago (Jane's, 2000), the life cycle for commercially off the shelf (COTS) components obtained from suppliers is between two and three years, whereas the life cycle for defence contractors is required to be between seven and 15 years, while government and sustainable life cycles are between 25 to 40 years (Jane's, 2000).

The use of one, or a few, supply bases or logistics bases offers many advantages including cost reductions, reduction in manpower and process, and reduced lead times. According to Ripley (2003), the UK expected to use Basra International Airport as a helicopter and logistics base, and the US expected to save money by reducing the number of its bases within the Middle East/Gulf region.

Logistics support services vary per contract. The end user may require a full integrated logistics support programme, or may only request the training and supply support component. These services offered come at a price and a premium for the intellectual property being offered. According to the European Defence Agency (EDA), The European Aeronautic Defence and Space Company (EADS) was awarded a contract in 2006 worth €75,000 for logistic support services to evaluate the current status of a specific system (EDA, 2007). Furthermore, a Market Research website also mentions that the logistics support of military systems is reliant on industrial contractors (MarketResearch.com, 2006).

The Defence Materiel Organisation (DMO) manages the logistics for the Australian Defence Force (ADF); they are responsible for the maintenance of the ADF equipment and its acquisition for the ADF (DMO, 2008). Other international defence forces also use contractors to provide ILS. According to *Turkish Defence News* (2007), Turkish Aerospace Industries, Inc. (TAI) is responsible for the ILS, system integration, engineering, contract management, programme management, final design and production of the T-129 Attack Helicopter. According to Russell (2006) logistics does not involve those personnel in charge of production [and maintenance], but is the responsibility of everyone involved in the product's design.

The serious consequence of the failure of systems means that they need to be reliable in order to provide the service for which they were acquired. Should these systems be unreliable the total cost of ownership increases and the bottom line decreases; in fact, lives may be lost if the systems do not properly function. According to *Jane's Defence Weekly* (2007) contractors must possess the appropriate skills and resources to support a system; should these not be in place, the lives of servicewomen and –men are at risk.

In the Iraqi war there are *'… two coalition armies …'*, one being the military fighting the war, the other being the private contractors who support the systems (Knickerbocker, 2007). The technology used within military systems is so complex and requires such specialised support that only the original equipment manufacturer (OEM) can supply the latter (Thompson, in Knickerbocker, 2007).

Logistics means many things to different people based on their background, knowledge and experience. In the military sense it generally denotes supporting a system. According to Russell (2005), in this context it includes design, transportation, storage, material acquisition, specialised storage facilities, special tools and equipment, personnel and maintenance, while the staff may be required to travel the globe to obtain training and to maintain their respective systems.

Inadequate training of maintenance personnel, or a lack of training, may cause serious problems. A case in point, according to McDermott (2004), is the crash of the Russian bomber [on 09 July 2004] which killed its crew, and which can be attributed to *'poor training':* Russia's defence force needs improvement in its training hierarchy, especially as it supports a *'system designed for the Cold War'* (McDermott, 2004).

The Russian Federation Armed Forces therefore uses training and support to ensure military security, including the education of their servicemen (and women); furthermore they employ the procedures and standards prescribed by the CIS, United Nations and OSCE when providing technical and logistics support (Federation of American Scientists, 1999).

Available models of ILS – military were discussed in this section. Aspects covered included some military systems, their end-users and original equipment manufacturers (OEM). Military expenditure is considered in the section that follows.

2.10 Military expenditure

It is clear that logistic support represents a major element of the total cost of ownership (TCO) of the operations of complex military systems. Governments and the military departments of the major countries of the world spend millions of their respective currencies on military expenditure, for offensive and/or defensive purposes.

Although worldwide military expenditure decreased from 1985 (5.1% of gross domestic product {GDP}) to 1990 (3.4% of GDP) (Gupta, de Mello and Sharan, 2001), competition amongst arms producers has increased due to the decrease in military spending worldwide since the mid 1980's (International Monetary Fund {IMF}; 2000 cited in Gupta; et al. 2001, and Gupta; Schiff & Clements; 1996). The IMF's database (World Economic Outlook) mentions that the percentage share of GDP occupied by military expenditure was 2.1% in 1999, compared to 3.4% in 1990 and 5.1% in 1985, where military outlays (the total spending share) fell 4.2% from 14.2% between 1990 and 1999, (IMF, cited in Gupta; et al. 2001).

There is no predicted direction of correlation between economic growth and military expenditures (Dakurah; Davies and Sampath, 2001:652). In 2003 world military expenditure reached $956 billion (current dollars), an increase by 18% (in real terms) over two years, that is 11% in 2003 and 6.5% in 2002, in addition, 16% of the world's population live in high-income countries, which in turn account for approximately 75% of the world's military expenditure (Sköns, Perdomo, Perlo-Freeman and Stålenheim, 2004a).

South Africa disbursed $2,653.4 million on military expenditure in 2003, which was 1.70% of gross domestic product (GDP), whereas the United States of America (USA) spent $370,700 million in this regard: 3.30% of their GDP (CIA World Factbook, 2004), Table A–1 in Appendix A provides further information.

Sub-Saharan Africa spent US$8,147 million on defence in 2002, while the USA spent $329,616 million: this is quite a large difference as the numbers of personnel in the armed forces is almost identical. Sub-Saharan Africa deployed 1,393,700 armed personnel and the USA 1,414,000; hence the USA spent in excess of 40 times more on military expenditure than Sub-Saharan Africa did in the same period (IISS, 2003·2004:335-340).

Payments for high technology complex systems are evident in public expenditure where specific elements need consideration. The management of public expenditure requires five complementary aspects ensuring a national level of efficiency: divisional strategic planning; a performance review of the previous year; establishing priorities and affordability; sector resource allocation; and effective and efficient resource use in accordance with agreed priorities (Le Roux, 2004:3).

Military and public expenditure were considered in this section, where South Africa as a developing country, as well as Sub-Saharan Africa, were compared to world indices. In the next section the developing world context is discussed.

2.11 Developing world context

Operating high technology complex systems in countries situated within the developing world offers numerous challenges when one compares these to developed countries. These challenges include, but are not limited to, access to information, for example internet usage, research and development costs, political freedom, education and armament budgets, and 'adult literacy rates'. These challenges are discussed below.

The quality-of-life index (*The Economist* 2005) for South Africa is 5.245 (ranked 92nd), compared to the USA (7.615, ranked 13th). Incidentally, Ireland ranks first with a score of 8.333, and Zimbabwe 111th with a score of 3.892. This index consists of nine indicators, that is health, 'political stability and security', material wellbeing, community life, family life, 'climate and geography', gender equality, political freedom, and job security. (Full definitions are contained in Appendix B.)

Differences concerning access to information and technology between South Africa, Sub-Saharan Africa, Ecuador, South America, the United States of America (USA), and North America are shown below (EarthTrends, 2003). The data in Table 2–3 below (except for the 'Number of Internet hosts' and 'Status of Freedom of Information legislation') are per 1,000 of the population. Ecuador and South America have been used as examples and for purposes of comparison to South Africa and Sub-Saharan Africa respectively.

The Technology Achievement Index (TAI) *'… aims to capture how well a country is creating and diffusing technology and building a human skill base–reflecting capacity to participate in the technological innovations of the network age.'* (UN Human Development Report: 2001) The TAI consists of four dimensions, viz. (CountryWatch 2002):

1) Creation of technology. *'… as measured by the number of patents granted to residents per capita and by receipts of royalties and license fees from abroad per capita.'*

2) Diffusion of new innovations. *'… as measured by the number of Internet hosts per capita and the share of high-and medium- technology exports in total goods exports.'*

3) Diffusion of old innovations. *'… as measured by telephones (mainline and cellular) per capita and electricity consumption per capita.'*

4) Human skill. *'… as measured by mean years of school in the population age 15 and above and the gross tertiary science enrolment ratio.'*

Table 2–3: Access to information and technology

COUNTRY / THEME	SOUTH AFRICA	SUB-SAHARAN AFRICA	ECUADOR	SOUTH AMERICA	USA	NORTH AMERICA
NUMBER OF INTERNET HOSTS (2000)	187,649	211,036	228	1,352,369	80,556,944	82,936,837
INTERNET USERS (2001) {a}	70	6	25	60	500	493
PHONE LINES (2001) {a}	113	14	104	184	665	664
MOBILE PHONE SUBSCRIPTIONS (2001) {a}	210	23	67	158	444	432
RADIO RECEIVERS (1997-2000) {b}	338	198	418	460	2,118	2,012
TELEVISION SETS (2000)	128	58	218	290	830	830
STATUS OF FREEDOM OF INFORMATION (FOIA) LEGISLATION (2002) {c}	In effect	No data	X	No data	In effect	No data

Source: Extracted from EarthTrends (2003).
a. Some regional data for Sub- Saharan Africa is for the year 2000, not 2001.
b. Data are for the most recent year available in the range of years listed.
c. An 'X' indicates either that data is not available or that no Freedom of Information Legislation exists for this country.

The TAI ranks South Africa in the 'Dynamic adopters' group in 39th position at 0.340, while Ecuador is also in the same group ranked at 53rd position at 0.253, whereas the USA is ranked 2nd at 0.733, Finland tops the ranking at 0.744, and both are in the 'Leaders' group (UN Human Development Report 2001).

Table 2–4 below lists: technology – diffusion and creation (telephone mainlines, cellular subscribers, internet users, patents granted), research and development (R&D), and researchers (per million people) in R&D and Gross Domestic Product (GDP) for Norway, USA, Ecuador, Latin America and The Caribbean, South Africa, Sub-Saharan Africa and the World (United Nations Development Programme {UNDP}: 2004).

Table 2–4: Technology: diffusion and creation, and GDP and R&D

COUNTRY / THEME/YEAR	NORWAY	USA	ECUADOR	LATIN AMERICA AND THE CARIBBEAN	SOUTH AFRICA	SUB-SAHARAN AFRICA	GLOBAL WORLD
TELEPHONE MAINLINES {a, e} (PER 1,000 PEOPLE)							
1990	502	547	48	89	93	5	81
2002	734	646	110	166	107	15	175
CELLULAR SUBSCRIBERS {a, e} (PER 1,000 PEOPLE)							
1990	46	21	0	No data	No data	No data	2
2002	844	488	121	191	304	39	184
INTERNET USERS {e} (PER 1,000 PEOPLE)							
1990	7.1	8.0	0.0	0.0	0.0	0.0	0.5
2002	502.6	551.4	41.6	81.2	68.2	9.6	99.4
PATENTS GRANTED TO RESIDENTS (PER MILLION PEOPLE) 2000 {f}	88	298	0	1	0	No data	48
GDP							
US$ BILLIONS 2002 {i}	190.5	10,383.1	24.3	1,676.1	10.2	303.5	31,927.2
PPP US$ BILLIONS 2002 {i}	166.1	10,308.0 {h}	45.9	3,796.1	456.8	1,157.4	48,151.1
RESEARCH AND DEVELOPMENT (R&D) EXPENDITURES (% OF GDP) 1996-2002 {b, g}	1.6	2.8	0.1	0.5 {c}	No data	No data	2.5
RESEARCHERS IN R&D (PER MILLION PEOPLE) 1990-2001 {b,g}	4,377	4,099	83	285 {d}	992	No data	1,096 {d}

Source: United Nations Development Programme (UNDP): (2004), unless otherwise stated.
a. Telephone mainlines and cellular subscribers combined form an indicator for Millennium Development Goal 8. (UNDP: 2004).
b. Data refer to the most recent year available during the period specified.
c. Data refer to 1999.
d. Data refer to 1996.
e. Source: ITU 2004
f. Source: UNDP (2004), calculated on the basis of data on patents granted to residents from WIPO 2004 and data on population from UN 2003.
g. Source: World Bank 2004, based on data from UNESCO; aggregates calculated for the Human Development Report Office by the World Bank.
h. In theory, for the United States the value of GDP in PPP US dollars should be the same as that in US dollars, but practical issues arising in the calculation of the PPP US dollar GDP prevent this.
i. Source: World Bank 2004, aggregates calculated for the Human Development Report Office by the World Bank

In Table 2–5 below, manufactured and high technology exports, and priorities in public spending on education, health and military for various countries and regions, are listed while Table 2–6 below lists armaments imports and exports, and total armed forces (UNDP, 2004).

South Africa's military consists of the South African National Defence Force (SANDF), which comprises: the South African Navy (SAN), the South African Air Force (SAAF), the South African Army, the Military Health Service, Military Intelligence, the Joint Support Command and the Joint Operations Command (CIA, 2007).

Table 2–5: Manufactured and high technology exports, and priorities in public spending

COUNTRY / THEME/YEAR	NORWAY	USA	ECUADOR	LATIN AMERICA AND THE CARIBBEAN	SOUTH AFRICA	SUB-SAHARAN AFRICA	GLOBAL WORLD
MANUFACTURED EXPORTS (% OF MERCHANDISE EXPORTS) {a}							
1990	33	74	2	34	No data	No data	74
2002	22	81	10	48 {b}	63	35 {c}	78
HIGH-TECHNOLOGY EXPORTS (% OF MANUFACTURED EXPORTS) {a}							
1990	12	33	No data	7	No data	No data	18
2002	22	32	7	16	5	4 {c}	21
PUBLIC EXPENDITURE ON EDUCATION {d} (% of GDP)							
1990 {g, j}	7.1	5.2	2.8	No data	6.2	No data	No data
1999-2001 {h, k}	6.8	5.6	1.0 {i}	No data	5.7	No data	No data
PUBLIC EXPENDITURE ON HEALTH {e} (% OF GDP)							
1990 {l}	6.4	4.7	1.5	No data	3.1	No data	No data
2001 {l}	6.8	6.2	2.3	No data	3.6	No data	No data
MILITARY EXPENDITURE {f} (% OF GDP)							
1990 {m}	2.9	5.3	1.9	No data	3.8	No data	No data
2002 {m}	2.1	3.4	2.8	No data	1.6	No data	No data

Source: Extracted from UNDP (2004), unless otherwise stated.
a. Source: World Bank 2004, based on data from United Nations Conference on Trade and Development and the International Monetary Fund; aggregates calculated for the Human Development Report Office by the World Bank;
b .Data refer to 2001.
c. Data refer to 2000.
d. Data refer to total public expenditure on education, including current and capital expenditures.
e. Source: World Health Organization (WHO): 2004a.
f. As a result of a number of limitations in the data, comparisons of military expenditure data over time and across countries should be made with caution. For detailed notes on the data see SIPRI 2003. (sipri - Stockholm International Peace Research Institute).
g. Data may not be comparable between countries as a result of differences in methods of data collection.
h. Data refer to the most recent year available during the period specified.
i. Data refer to UNESCO Institute for Statistics estimate when national estimate is not available.
j. Source: Calculated on the basis of GDP and public expenditure data from UNESCO Institute for Statistics 2003c.
k. Source: UNESCO Institute for Statistics 2004b.
l. Source: World Bank 2004.
m. Source: SIPRI 2004a

Table 2–6: Armaments

THEME / COUNTRY	CONVENTIONAL ARMS TRANSFERS {a, b} (1990 PRICES) IMPORTS (US$ MILLIONS) 1994	IMPORTS (US$ MILLIONS) 2003	EXPORTS (US$ MILLIONS) 2003	TOTAL ARMED FORCES (THOUSANDS) 2002 {c}
NORWAY	99	No data	150	27
USA	725	515	4,385	1,414
ECUADOR	No data	No data	No data	60
LATIN AMERICA AND THE CARRIBEAN	No data	No data	No data	1,268
SOUTH AFRICA	19	13	23	60
SUB-SAHARAN AFRICA	No data	No data	No data	1,283
WORLD	19,253 {d}	18,679 {d}	18,680 {d}	19,045

Source: Extracted from UNDP (2004), unless otherwise stated.
a. Data are as of 25 February 2004.Figures are trend indicator values, which are an indicator only of the volume of international arms transfers, not of the actual financial value of such transfers. Published reports of arms transfers provide partial information, as not all transfers are fully reported. The estimates presented are conservative and may understate actual transfers of conventional weapons.
b. SIPRI 2004b.
c. IISS 2003
d. Data refer to the world aggregate from SIPRI 2004b. This includes all countries and non-state actors with transfers of major conventional weapons as defined in SIPRI 2004b.

This section discussed various technology and human development index differences related to South Africa as well as some other countries of the world, which lead to specific challenges in operating complex systems. The next section details some environmental factors that need to be taken into consideration.

2.11.1 ***Environmental factors***

Environmental factors can exert a significant effect on the support of high technology complex systems, in that numerous factors need to be considered when deploying a complex system. Such factors include ambient temperature, humidity, precipitation, elevation, overall weather conditions, terrain to and surrounding the site, natural hazards and global warming.

Various environmental factors need to be taken into consideration when deploying a high technology complex system in South Africa, and these are listed below:

1) Elevation extremes. The lowest point is at the Atlantic Ocean at zero meters, the highest point is at Njesuthi [a mountain range in KwaZulu-Natal] at 3,408 meters (Central Intelligence Agency {CIA}, 2007).

2) Subtropical, semi-arid South African climate conditions. South Africa's climate is defined by the CIA's World Factbook (CIA, 2007) as:

   'mostly semiarid; subtropical along east coast; sunny days, cool nights'.

3) The terrain of South Africa as defined by the CIA's World Factbook (CIA, 2007) is a:

   'vast interior plateau rimmed by rugged hills and narrow coastal plain'.

4) Natural hazards include '*prolonged droughts*' (CIA, 2007).

5) Current environmental issues include '*lack of important arterial rivers or lakes [which] requires extensive water conservation and control measures; growth in water usage outpacing supply; pollution of rivers from agricultural runoff and urban discharge; air pollution resulting in acid rain; soil erosion; desertification'* (CIA, 2007).

This section highlighted various environmental factors; the following section deals with the political environment in South Africa.

2.11.2 ***Political environment***

This section considers the importance of the political environment in a country, especially the political (in)stability index and the political stability of a country as defined by various authors. The governance index and quality-of-life indexes are also discussed.

Two papers by various authors define political stability: one author (Annett, 2001a) defines the political (in)stability index, while Kaufmann, Kraay and Mastruzzi (2003) define political stability:

1) According to Annett (2001b) the Political Stability Index (2000/01) of South Africa is 0.07 compared to Ecuador (-0.80) and the USA (1.18). A definition of the political (in)stability index can be found in Appendix B.

2) Kaufmann, Kraay and Mastruzzi (2003) indicate that the Political Stability (2002) of South Africa is -0.09, compared to Ecuador (-0.70) and the USA (0.34). A definition of this term is available in Appendix B.

The statistics in Table 2–7 record the differences in Governance Indices between South Africa and the USA; Ecuador is included as a South American developing country (EarthTrends, 2003).

Table 2–7: Governance indices

COUNTRY THEME	SOUTH AFRICA	ECUADOR	USA
FREEDOM HOUSE INDICES {a} (2001)			
LEVEL OF FREEDOM (FREE, PARTLY FREE, NOT FREE)	Free	partly free	Free
POLITICAL RIGHTS (1=MOST FREE, 7=LEAST FREE)	1	3	1
CIVIL LIBERTIES (1=MOST FREE, 7=LEAST FREE)	2	3	1
PRESS FREEDOM (1-30=FREE, 31-60=PARTLY FREE, 61-100=NOT FREE)	23	40	16
POLITY IV INDICES (2000)			
LEVEL OF DEMOCRACY/ AUTOCRACY (-10 IS STRONGLY AUTOCRATIC, +10 IS FULLY DEMOCRATIC)	9	6	10
LEVEL OF POLITICAL COMPETITION {b}	4 transitional	3 factional	5 competitive
TRANSPARENCY INTERNATIONAL INDICES			
CORRUPTION PERCEPTIONS INDEX (2001) (10=LEAST CORRUPT, 0=MOST CORRUPT)	5	2	8

Source: Extracted from EarthTrends (2003).
a. "Freedom House is a US-based, non- profit organization that advocates for American- style leadership in international affairs; the organization conducts extensive research about the level and nature of freedom and civil liberties around the world."
b. "Index values range from 0 to 5, as follows: (0) Not Applicable, (1) Repressed, (2) Suppressed, (3) Factional, (4) Transitional, and (5) Competitive."

This section dealt with the political environment in a developing country. In the next section language proficiency and the human development index are dealt with.

2.11.3 ***Language proficiency and the human development index***

In this section various factors of a developing country in relation to a developed country are provided. Language proficiency as it concerns a South American country with regards to English language documentation is dealt with. Net primary and net secondary education enrolment rates are also provided. In addition the adult literacy rate, combined gross enrolment ratio for primary, secondary and tertiary schools, and the education index for various countries and regions is provided.

There are 11 official languages of South Africa: Afrikaans, English, isiNdebele, isiXhosa, isiZulu Sepedi, siSwati, Setswana, Sesotho, Tshivenda, and Xitsonga (South African Government, Constitution of South Africa, 1996).

South Africa possesses 24 distinct living languages and three second languages (definitions of the terms 'second language' and 'extinct language' are provided in Appendix B). These consist of Afrikaans (5,811,547), Birwa, Camtho, English (3,457,467), Fanagalo (several hundred thousand), Gail, Hindi (890,292), Kxoe (1,100), Nama (56,000), Ndebele (586,961), N|u (10), Oorlams, Ronga (86,618), Northern Sotho (3,695,846), Southern Sotho (3,104,197), South African Sign Language (12,100), Swahili (1,000), Swati (1,013,193), Tsonga (1,756,105), Tsotsitaal, Tswa, Tswana (3,301,774), Urdu (170,000), Venda (876,409), Xhosa (7,196,118), Xiri (87) and Zulu (9,200,144), while the four extinct languages are Korana, Seroa, |Xam and ||Xegwi (Gordon, 2005).

In comparison, Ecuador has 23 living languages and 1 extinct language: the official or national languages are Spanish, Quichua and Cofan (Gordon, 2005).

The 23 living languages of Ecuador are Achuar-Shiwiar (2,000), Awa-Cuaguer (1,000), Chachi (3,450), Cofan (800), Colorado (2,300), Ecuadorian Sign Language (188,000), Epena (50), Media Lengua (1,000), Quichua Calderon Highland (25,000), Quichua Canar Highland (100,000), Quichua Chimorazo Highland (1,000,000), Quichua Imbabura Highland (300,000), Quichua Loja Highland (30,524), Quichua Napo Lowland (4,000), Quichua Northern Pastaza (4,000), Quichua Salasaca Highland (14,331), Quichua Tena Lowland (5,000), Secoya (290), Shuar (46,669), Siona (250), Spanish (9,500,000), Waorani (1,650), and Zaparo (1), while the extinct language is Tetete, (Gordon, 2005).

Table 2–8 records the net primary and net secondary education enrolment rates, as well as the percentage of tertiary students in science, mathematics and engineering for various countries

(UNDP: 2004). Ecuador reports a higher net primary enrolment rate than South Africa, while South Africa exhibits a higher net secondary enrolment rate.

Table 2–8: Net primary and net secondary enrolment rate

COUNTRY / THEME	NORWAY	USA	ECUADOR	SOUTH AFRICA
NET PRIMARY ENROLMENT RATE {a} %				
1990/91 {g}	100	97	98	88
2001/02 {b, g}	101 {e}	93 {f}	102	90
NET SECONDARY ENROLMENT RATE {a, c}				
1990/91 {g}	88	85	No data	No data
2001/02 {b, g}	95 {e}	85 {f}	50	62 {e}
TERTIARY STUDENTS IN SCIENCE, MATH AND ENGINEERING (% OF ALL TERTIARY STUDENTS) 1994-97 {d, g}	18	No data	No data	18

Source: Extracted from (UNDP: 2004), unless otherwise stated.
a. The net enrolment ratio is the ratio of enrolled children of the official age for the education level indicated to the total population of that age. Net enrolment ratios exceeding 100% reflect discrepancies between these two data sets.
b. Data on net enrolment ratios refer to the 2001/02 school year, and data on children reaching grade 5 to the 2000/01 school year, unless otherwise specified. Data for some countries may refer to national or UNESCO Institute for Statistics estimates. For details, see http://www.uis.unesco.org/.Because data are from different sources, comparisons across countries should be made with caution.
c. Enrolment ratios are based on the new International Standard Classification of Education, adopted in 1997 (UNESCO 1997), and so may not be strictly comparable with those for earlier years.
d. Data refer to the most recent year available during the period specified. Calculated on the basis of data on tertiary students from UNESCO 1999.
e. Data refer to the 2000/01 school year.
f. Preliminary UNESCO Institute for Statistics estimate, subject to further revision.
g. Source: UNESCO Institute for Statistics 2004c

Table 2–9 records the human development index (HDI), adult literacy rate, combined gross enrolment ratio for primary, secondary and tertiary schools, and the education index for various countries and regions (UNDP 2004). Norway is ranked number one while the USA is ranked at number eight: they are both in the *'High human development'* group. Ecuador is ranked at 100, above South Africa, which is ranked at 119; both of them are in the *'Medium human development'* group.

Table A–2 in Appendix A lists the commitment to education (public spending) for Norway, USA, Ecuador, and South Africa (UNDP 2004). South Africa (UNDP 2004) for the year 1990, spent 6.2% of its GDP on public expenditure on education, compared to 2.8% by Ecuador and 7.1% by Norway.

Table A–3 in Appendix A lists total population, commitment to health, HIV, and life expectancy at birth for various countries and regions (UNDP, 2004). South Africa (UNDP, 2004) reports an estimated life expectancy of 47.7 for the years 2000-05, compared to 70.8 for Ecuador and 78.9 for Norway.

Table 2–9: HDI, adult literacy rate, combined gross enrolment ratio and education index

COUNTRY / THEME	NORWAY	USA	ECUADOR	LATIN AMERICA AND THE CARIBBEAN	SOUTH AFRICA	SUB-SAHARAN AFRICA	WORLD
HDI RANK {a}	**1**	**8**	**100**	**No data**	**119**	**No data**	**No data**
HDI VALUE							
2002 {b}	0.956	0.939	0.735	0.777	0.666	0.465	0.729
2000 {b}	0.954	0.935	No data	No data	0.690	No data	No data
1995 {b}	0.935	0.926	0.719	No data	0.735	No data	No data
1990 {b}	0.911	0.914	0.710	No data	0.729	No data	No data
1985 {b}	0.897	0.899	0.696	No data	0.697	No data	No data
1980 {b}	0.886	0.886	0.674	No data	0.672	No data	No data
1975 {b}	0.866	0.866	0.630	No data	0.655	No data	No data
ADULT LITERACY RATE (% AGES 15 AND ABOVE) 2002 {c}	No data	No data	91.0 {e}	88.6	86.0	63.2	No data
COMBINED GROSS ENROLMENT RATIO FOR PRIMARY, SECONDARY AND TERTIARY SCHOOLS (%) 2001/02 {d}	98 {f}	92 {g}	72 {f, h}	81	77	44	64
EDUCATION INDEX	0.99	0.97	0.85	0.86	0.83	0.56	0.76

Source: Extracted from UNDP (2004)
a. The HDI rank is determined using HDI values to the fifth decimal point.
b. Calculated on the basis of life expectancy from United Nations (UN) 2003; data on adult literacy rates from the United Nations Educational, Scientific and Cultural Organization (UNESCO) Institute for Statistics 2003a; data on combined gross enrolment ratios from UNESCO 1999 and UNESCO Institute for Statistics 2004c; and data on Gross Domestic Product (GDP) per capita (1995 PPP US$) and GDP per capita (current PPP US$) from World Bank 2004.
c. Data refer to estimates produced by UNESCO Institute for Statistics in July 2002, unless otherwise specified. Due to differences in methodology and whether underlying data is recent or not, comparisons across countries and over time should be made with caution. UNESCO Institute for Statistics 2004a.
d. Data refer to the 2001/02 school year, unless otherwise specified. Data for some countries may refer to national or UNESCO Institute for Statistics estimates. For details, see http://www.uis.unesco.org/. Because data are from different sources, comparisons across countries should be made with caution. UNESCO Institute for Statistics 2004c.
e. Census data.
f. Data refer to a year other than that specified.
g. Preliminary UNESCO Institute for Statistics estimate, subject to further revision.
h. UNESCO Institute for Statistics 2003b.

This section discussed the diversity of South Africa; its population compared to that of another developing country, that is, Ecuador, and other selected countries in the world. High technology is dealt with in the next section.

2.12 High technology

This section investigates the advancement of technology, dealing with the concept of technology devised by R. J. Van Wyk (2005), and ending with laws governing the spread of technology developed by Moore, Gilder and Metcalfe. Technology continuously advances: compare the changes in cell phones that were bulky a few years ago to present day cell phones with Bluetooth and mobile-office capability, amongst many other features.

In high-technology systems the components used in the design phase of a project have either been improved, modified and/or retrofitted in size, specification, and/or capability or have become obsolete and need to be replaced, with a newly designed component stemming from current day technology.

The modules where these newly designed components are used also need to be upgraded/modified. The related cost is dependent on quantities ordered, and Rand exchange rates as regards foreign currency.

Various definitions of technology also exist: in a work by R. J. Van Wyk (2005) technology is defined thus:

> *'The concept of technology is used in three contexts:*
>
> *1) Technology is a combination of means, such as hardware, software and skill, associated with a specific field of technical competence.*
>
> *2) Technology is a totality of means created by people to enhance human capability.*
>
> *3) Technology is a field of study.*
>
> *Note the following concepts:*
>
> *1) Created - Technology is not a free gift of nature. To be available it first has to be brought into being.*
>
> *2) Means - Means are instrumentalities, not ends. In deciding whether one is dealing with ends or means, the function of the entity is the distinguishing feature.*
>
> *3) Entities - These are the depositories of capabilities. They may either be concrete or abstract in nature.*
>
> *4) Enhance - Mostly this means extending human capability. Sometimes it means replacing human capability'.* (Van Wyk, 2005)

Microsoft (1995, in Cardullo; 1996:1) views technology as automation assisting humans, offering the following definition of technology:

> *'Technology is a general term for the processes by which human beings fashion tools and machines to increase their control and understanding of the material environment.'* (Microsoft, 1995 in Cardullo, 1996:1)

More specifically,

> *'Technology consists of knowledge, actions, and accouterments'* (Cardullo, 1996:1). Consequently, *'Technology transfer is the process by which technology, knowledge, and information developed in one enterprise for a particular purpose is applied and utilized in another enterprise for another purpose. Technology transfer can range from disseminating information on basic science research to commercialization of a specific product. Knowledge varies, over time, from the initial concept of how a basic phenomenon can be applied to the solution of problems to knowledge applied to large complex systems.'* (Cardullo, 1996:231.)

In 1970, Toffler conceived the rate of change of society as exponential in nature. He argued that there is an inherent reproductive principle in technology which creates more technology (Pellissier, 2000:66).

Three laws that are generally accepted as governing the spread of technology are those of Moore, Gilder and Metcalfe (Pinto, 2004). According to Moore's law, the number of transistors that fit on a chip [semiconductor] doubles every two years (Intel, 2008).

Gilder's law states, *'bandwidth grows at least three times faster than computer power'.* As a result, *'(t)his means that if computer power doubles every eighteen months (per Moore's Law), then communications power doubles every six months.'* (Netlingo, 2004) Metcalfe's law states, *'the usefulness, or utility, of a network equals the square of the number of users'.* (Netlingo, 2004)

A great number of technological advances have occurred over the years, from electronic circuit boards consisting of separate components, to current day technology where a similar function can be performed by a much smaller printed circuit board or even an integrated circuit (IC). One may just apply Moore's law to current day compact cell phones as compared to the introductory bulky cell phones, with none of the previously mentioned features and an antenna to boot.

This section dealt with the advancement of technology, dealing with definitions of technology and finally describing laws that govern the spread of technology. Knowledge management is dealt with in the next section.

2.13 Knowledge management

Data, information and knowledge are accorded various different definitions and meanings, depending on the context within they are used. Data creates information and information creates knowledge. Awad and Ghaziri (2004:36-37) define these concepts as follows:

1) Data. *'… are unorganized and unprocessed facts. They are static; they just sit there'.* (Awad and Ghaziri, 2004:36-37)
2) Information. *'… is an aggregation of data that makes decision making easier. It is also facts and figures based on reformatted or processed data*'. (Awad and Ghaziri, 2004:36-37)
3) Knowledge is *'human understanding of a specialized field of interest that has been acquired through study and experience'.* (Awad and Ghaziri, 2004:36-37)

Malaga simply defines data and information in the following words (2005:8):

1) Data: Raw facts.
2) Information: *'… raw facts within a given context'.*

Turban & Aronson (1998: 111) offer different definitions of data, information, and knowledge, although closely related to Awad and Ghaziri.

1) Data: *'Data items about things, events, activities, and transactions are recorded, classified, and stored, but are not organized to convey any specific meaning. Data items can be numeric, alphanumeric, figures, sounds, or images.'*
2) Information: *'Information is data that has been organized so that it has meaning to the recipient.'*
3) Knowledge: *'Knowledge consists of data items that are organized and processed to convey understanding, experience, accumulated learning, and expertise as they apply to a current problem or activity.'* (Turban and Aronson, 1998:111)

Knowledge management (KM) focuses on improving employees' learning and familiarizing them with the newest knowledge in their disciplines. This is achieved in many ways, including internalization and externalization, communities of practice, and socialization (Becerra-Fernandez, et al, 2004:52). *'KM is not a technology.'* It's a technology enabled activity *'produced by people'.* (Awad and Ghaziri, 2004:93).

In this sense internalization is the conversion of *'explicit knowledge into tacit knowledge'* while externalization denotes the opposite process (Nonaka and Takeuchi, 1995 In Becerra-Fernandez, et al, 2004:52). Communities of practice are self-organized and comprise an organic group of individuals who are organizationally or geographically dispersed but who communicate on a regular basis to discuss issues of mutual interest. Socialization also assists individuals in acquiring knowledge, but normally by means of combined activities, such as informal conversations and meetings (Becerra-Fernandez, et al, 2004:53).

Churchman (1971) emphasises the viewpoint of the philosophers Kant and Leibniz *'that knowledge resides in the user and not in the collection of information.'* (Awad and Ghaziri, 2004:92). *'To conceive of knowledge as a collection of information seems to rob the concept of all of its life. Knowledge resides in the user and not in the collection. It is how the user reacts to a collection of information that matters'*. (Churchman, 1971, In Awad and Ghaziri, 2004:92)

Intellectual property (IP) can be defined as *'… any results of a human intellectual process that has inherent value to the individual or organization that sponsored the process.'* (Becerra-Fernandez, et al, 2004:350). IP includes designs, organizational structures, marketing plans, algorithms, music scores, works of art, literary works, computer programs, strategic plans, processes and inventions, amongst others (Becerra-Fernandez, et al, 2004:350-351). In many a case IP is an *'organization's most valuable asset'.* Loss of IP can harm a company exactly as much as real capital property loss (Becerra-Fernandez, et al, 2004:351).

In this section knowledge management was discussed, and definitions of data, information and knowledge were furnished. In the next section the specific literature as it relates to ILS is discussed.

2.14 Integrated logistics support elements (disciplines)

In this section the relevant literature regarding integrated logistics support is discussed. The ILS elements or disciplines (as some authors call them) will be briefly considered. A further literature review containing a deconstruction of these ILS elements is to be found in Chapter 4.

Firstly a discrepancy exists regarding the taxonomy and nomenclature of the ILS principles: some authors (Blanchard; 2004, U.S. MIL-STD-1369; 1988, U.S. AR 700-127; 2005, U.S. Army Pamphlet 700-127; 1989, ECSS-M-70A; 1996, U.S. Army Pamphlet 700-28; 1994, Biedenbender, et al. 1993, Palguta; 1987, Carpenter; 1967, Hutchinson; 1987, Finkelstein and Guertin; 1988, Blanchard and Fabrycky; 1998, and U.S. AFI10-602; 2005) use the term '*elements*'; other authors employ the term '*disciplines'*, while still others make use of '*element'* and '*discipline' (DSMC; 1989, and* UK DEF-STAN 00-60; 2004), and '*element'*, '*discipline'*, and '*activity'* (Jones, 2006) within the same source.

A '*discipline'* can be regarded as a specific field of study, where '*element'* can be regarded as basics, component, or first principles, and '*activity'* can be regarded as an '*action'*, or '*deed'*. This has caused many a debate amongst professionals practising ILS , regarding which nomenclature to use, but will not be delved into here, although all end-users and contractors need to be in agreement when discussing contractual issues and deliverables. The ILS elements discussed in this section are as follows:

1) Maintenance support (Nowlan and Heap, 1978; Moubray 1991 and 1997; Levitt, 2003; Palguta, Bradley and Stockton, 1987; and Smith and Hinchcliffe; 2004);
2) Support and test equipment (S&TE) (Jones, 1995; 1998 and 2006; Blanchard; 1992 and 2004; Carpenter, 1967; Biedenbender, Vryn and Eisaman, 1993; Langford, 1995; AR-700-127, 1999; Galloway, 1996; Hutchinson; 1987, and UK MOD; [s.a.]);
3) Supply support (Jones, 1995; Carpenter, 1967; Palguta, et al, 1987, Hutchinson, 1987; Finkelstein and Guertin, 1988; Biedenbender et al. 1993; and Blanchard, 1992 and 2004).
4) Packaging, handling, storage and transportation (PHS&T) (Jones, 1995; Biedenbender; et al 1993; Blanchard, 2004; Galloway, 1996; AR-700-127; 1999; and Finkelstein and Guertin, 1988);
5) Technical data and documentation (Jones, 1995; Galloway, 1996; Carpenter, 1967; Finkelstein and Guertin, 1988; AR 700-127, 1999; Biedenbender et al, 1993; Blanchard, 1992 and 2004; and Langford, 1995);
6) Facilities (Jones, 1995; Galloway, 1996; Carpenter, 1967; Finkelstein and Guertin, 1988; AR 700-127, 1999; Biedenbender et al 1993; and Blanchard, 1992 and 2004);
7) Manpower and personnel (Galloway, 1996; Carpenter, 1967; AR 700-127, 1999; Biedenbender et al 1993; and Blanchard, 1992 and 2004);
8) Training and training devices (Galloway, 1996; Finkelstein and Guertin, 1988; AR 700-127, 1999; Biedenbender et al. 1993; and Blanchard, 1992 and 2004);
9) Computer resources (Jones; 1995; Galloway, 1996; Carpenter, 1967; Finkelstein and Guertin, 1988; AR 700-127, 1999; Biedenbender et al 1993; Blanchard, 2004; and Langford, 1995);
10) Reliability, availability and maintainability (RAM - dependability), (Jones, 1995; Finkelstein and Guertin, 1988; Blanchard, 2004; Hutchinson, 1987; Awad and Ghaziri, 2004; Smith and Hinchcliffe, 2004; Moubray, 1991; and Langford, 1995);
11) Configuration management (Finkelstein and Guertin, 1988; Blanchard, 2004; and Langford, 1995);

12) System operational requirements (Blanchard, 2005; and Jones, 2006);
13) Equipment list (major assemblies) (Jones, 2006);
14) Obsolescence (Hutchinson, 1987; and Finkelstein and Guertin, 1988);
15) Disposal (Jones, 1995; and Blanchard, 2004); and
16) Risk management (Project Management Institute, 2000; and Blanchard, 2004).

All man-made products progress through a life cycle, beginning with a conceptual or starting phase and ending with a disposal (finishing) phase. Various authors, depending on their background, system purpose, and the industry in which they are involved, propose different life cycles, the authors are:

1) Project Management Institute (PMI), (2000:12-13);
2) United States Department of Defense Instruction (DODI) 5000.2, (2000, in PMI, {2000:14});
3) International Organisation for Standardization (ISO)/International Electrotechnical Commission (IEC) 15288 (International Council on Systems Engineering (INCOSE), 2006:3.3-3.4);
4) United States Department of Energy (Forsberg, in INCOSE, 2006:3.5);
5) Typical High-Tech Commercial Systems Integrator (Forsberg, in INCOSE, 2006:3.5);
6) Typical High-Tech Commercial Manufacturer (Forsberg, in INCOSE, 2006:3.5);
7) Blanchard (2004:15), and
8) American National Standards Institute (ANSI)/Electronics Industry Association (EIA)-724, Onkvisit and Shaw (1989), and Pecht and Das (2000), (cited in Livingston, 2000:1, and EIA, 2001:2-4).

In this section the discrepancy regarding the taxonomy and nomenclature of the ILS principles was provided. Maintenance support is described in the next section.

2.14.1 ***Maintenance support – failure and maintenance***

In this section maintenance is discussed, including the definition of maintenance, the definition of a failure and a functional failure, while types of failures are also considered. In addition maintenance concepts, repair policies, various levels of maintenance and maintenance plans are also discussed.

Maintenance is work undertaken to restore a failed item to its pre-failure condition. Basically although an item may be operational, it often eventually ceases functioning and needs to be restored to its working condition. A failure can be seen as an item of equipment or a system which is unserviceable. Various authors (Moubray, 1991 and 1997; and Nowlan and Heap, 1978) confirm this statement from various perspectives, listed below.

A failure can be defined as *'… the inability of any asset to do what its users want it to do'.* (Moubray, 1997:46). Moubray (1991:49) and Nowlan and Heap (1978:18) all identify a failure as *'… an unsatisfactory condition'.*

A functional failure could be described as the situation arising when an item has failed and become unserviceable, making it unable to meet a specific requirement. Various authors (Nowlan and Heap, 1978; Moubray, 1991 and 1997) define a functional failure in line with the above statement. Nowlan and Heap (1978:18) define such a failure as:

> *'… the inability of an item (or the equipment containing it) to meet a specified performance standard.'*

Moubray presents, in different editions of his book (1991 and 1997), two different definitions of a functional failure, although each basically means that an asset is not meeting a certain performance standard. These are listed below:

Moubray (1991:50) in his first edition defines a functional failure as follows:

> *'… the inability of any physical asset to meet a desired standard of performance.'*

Moubray (1997:47) in his second edition offers the following definition:

> *'… the inability of any asset to fulfil a function to a standard of performance which is acceptable to the user.'*

The 1991 version describes an asset as a *'physical'* asset. Both versions mention a *'standard of performance'* although the 1991 edition cites a *'desired performance standard'*. The 1997 edition reads, *'to fulfil a function'*, compared to the 1991 edition that uses the words *'to meet'*. In addition the 1997 edition cites a performance standard *'which is acceptable to the user'*, which could be linked to the 1991 edition's words *'desired'*.

The traditional bathtub failure rate is not applicable in complex systems, as shown by Nowlan and Heap (1978). Nowlan and Heap (1978:47-48) argue that a complex item shows infant mortality, and a constant or increasing failure probability, but no specific age can be identified where wear-out starts. In contrast simple items do have a wear-out age (Nowlan and Heap, 1978:48).

The literature is somewhat contradictory regarding the topic of “bathtub” curve and complex systems. Jardine (1973:22) argues that a complex system often takes the form of a bathtub curve. Lewis (1987:84) states that the “bathtub curve is an ubiquitous characteristic both of inanimate, complex engineering devices and of living creatures.”

Failure can occur over various time scales: one item may fail within a year and an identical item in another system might fail every six months. A similar (or different) item might fail every three months. Various statistical curves depict various failure patterns (Nowlan and Heap, 1978:46), while Levitt (2003:35) confirms this rationale with his methodology of failure patterns.

There are different ways in which an asset can fail, expressed as future probability against age. These curves are called *‘age-reliability patterns’* as defined by Nowlan and Heap (1978:46), and *‘critical wear curves’* as Levitt terms them (2003:35). Moubray (1997:12) uses the term *‘patterns of failure’*. The patterns or curves are displayed in Figure 2–3 overleaf.

Once a failure or a functional failure occurs, some action (maintenance) needs to be taken to restore the item to its pre-failure or fully serviceable condition. Various authors (Moubray, 1991 and 1997; and Palguta, Bradley and Stockton, 1987) hold different views regarding maintenance, which are described below.

Moubray (1991 and 1997) proposes two different definitions for maintenance in these two editions, the first being worded thus:

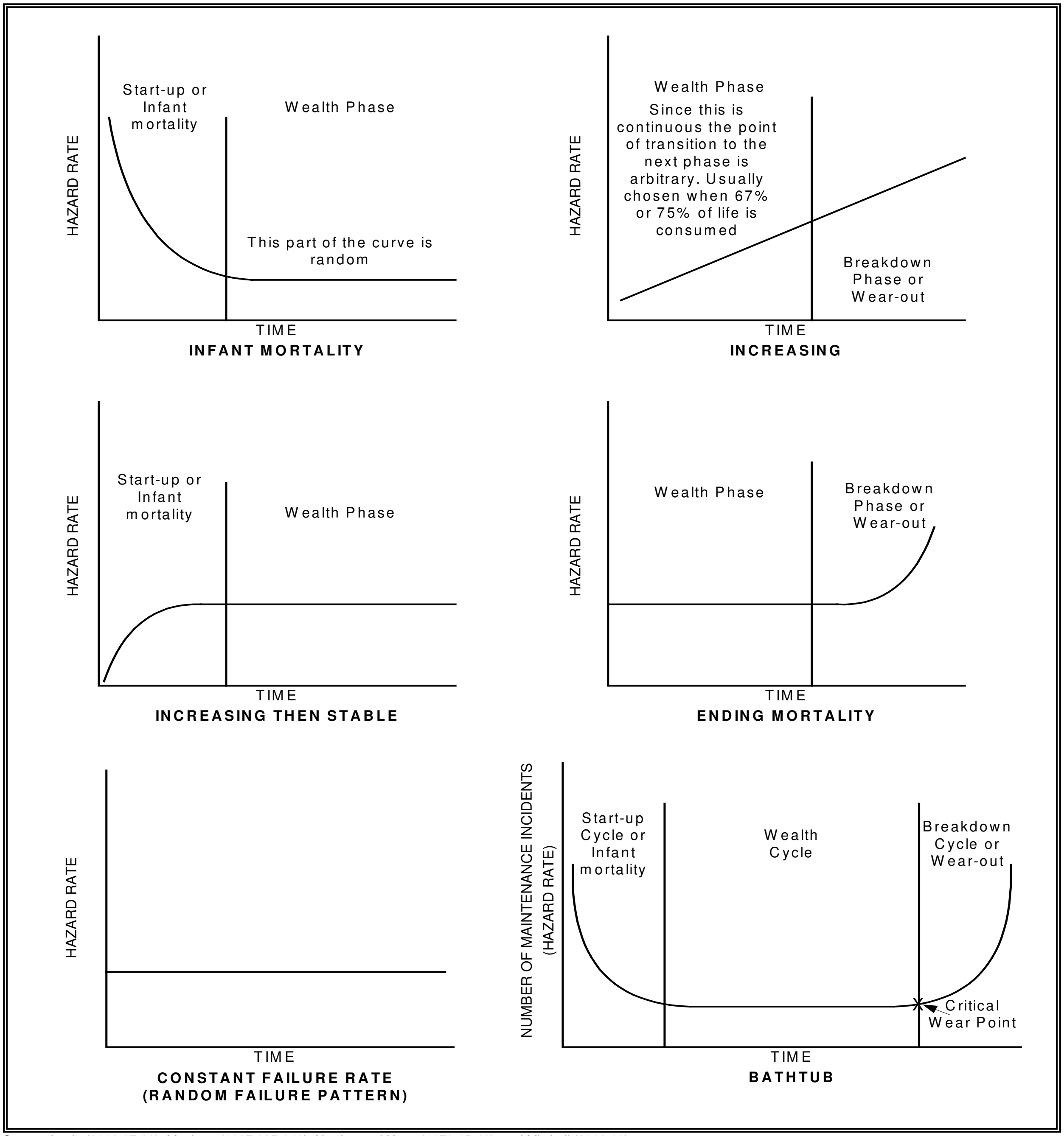
> *‘… ensuring that physical assets continue to fulfill their intended functions’.* (Moubray, 1991:6,).

Moubray (1997), in the second edition of his book, proposes a different definition:

> *‘… ensuring that physical assets continue to do what their users want them to do’.* (Moubray, 1997:6).

Palguta, Bradley and Stockton (1987:81) define maintenance as:

> *‘All action taken to retain materiel in or to restore it to a specified condition. It includes: inspection, testing, servicing, classification as to serviceability, repair, rebuilding, and reclamation.’* (Palguta, et al, 1987:81)



Source: Levitt (2003:37-38), Moubray (1997:235-249), Nowlan and Heap (1978:45-48), and Mitchell (2002:68).

Figure 2–3: Critical faiure patterns

In an incident on 12 October 2007 where a number of soldiers were killed in South Africa when a piece of ordnance malfunctioned, it was found that a failed pin had caused the malfunction (Semono, 2008). Furthermore a similar failure had occurred in another country but had not been communicated to the end-user organisation in South Africa; in addition the manufacturer had not provided pin maintenance information or information regarding corrective action in the event of a pin failure (Semono, 2008).

Common maintenance problems reported during the last 30 years of industry-wide historical data include but are not limited to human error in the form of incorrect maintenance, processes and procedures not being followed correctly, and inadequate planned maintenance (Electric Power Research Institute, cited in Smith and Hinchcliffe, 2004:3-7).

In Chapter 4 the concept of maintenance is discussed further in deconstructive fashion. In the next section support and test equipment is discussed.

2.14.2 *Support and Test Equipment*

This section discusses Support and Test Equipment (S&TE), beginning with general background information concerning S&TE, and furnishes a definition of support and test equipment.

When any system or item of equipment fails it will require some form of support and test equipment to be used in order to perform diagnostic testing and repairs.

The test equipment employed needs to be compatible with the system and just as reliable and maintainable, as this could affect the reliability and maintainability of the main system. It will need to support maintenance tasks at the various maintenance levels and to support scheduled as well as unscheduled maintenance. A trade-off analysis needs to be conducted to determine whether the specific item of test equipment will be purchased or rented or borrowed, to repair and/or calibrate a failed or no longer calibrated item of the main system.

Once again various terms fall under the scope of S&TE. These include test and support equipment; special to type test equipment; common test equipment; test, measurement and diagnostic equipment; test, measurement, handling and support equipment; special condition monitoring equipment; servicing and handling equipment. This nomenclature will be discussed in the present section.

S&TE includes all items necessary to support the equipment, be they tools, oscilloscopes, analysers, power supplies, automatic test equipment, built in test equipment (BITE), or indicators (meters, light emitting diode's {LED's}, etc.) on equipment. S&TE also needs to be supported and maintained, that is repairs, cleaning, calibration, etcetera. Certain items of test equipment that need to operate within certain parameters, for example, oscilloscopes, power supplies, torque wrenches and the like, must be calibrated on a regular basis.

Calibration is necessary since out of specification test equipment may have an adverse effect on the overall system, especially where it is used to set-up and/or calibrate the system for use.

Calibration certificates need to be kept for auditing purposes. Some form of sticker also needs to be fixed to the calibrated support and test equipment, giving an indication of when the item was last calibrated and when it is next due for calibration. The support and test equipment may also have a limited capability (i.e. cannot operate within the full parameters for which it was designed), and be thus labelled.

Support and test equipment could be mobile or permanently fitted to the main system and may be needed for on equipment or off equipment maintenance. Requirements also need to take into consideration the skill levels of the personnel that will be using the specific support and test equipment and should be standardized, because special support and test equipment requires additional expense and training and support requirements.

Various definitions and different nomenclature are once again evident in numerous authors (Jones, 1995; 1998 and 2006; Blanchard, 1992 and 2004; Carpenter, 1967; Biedenbender et al 1993; Langford, 1995; AR-700-127, 1999; Galloway, 1996; Hutchinson, 1987; and UK MOD TLSD [s.a.]).

Certain types of test equipment identify a fault whereas others repair it. Jones (1995) confirms this in remarking that support equipment is classified as supporting the maintenance or operation of a system. Test equipment used for one specific use is called *'special to type'* test equipment, while such equipment with several uses is normally termed *'common'* test equipment. *'Test, measurement, and diagnostic equipment (TMDE)'* usually performs tests which identify a fault in an item, whereas support equipment usually repairs the fault. (Jones, 1995, 2nd reprint:8.1).

Blanchard's 4th edition (1992:12) definition of *'test and support equipment'* included, *'special condition monitoring equipment'*; *'servicing and handling equipment'*, but does not mention *'to support operational and maintenance functions'*. However it does refer to *'… scheduled and unscheduled maintenance actions associated with the system or product.'* The 5th edition of Blanchard (1998:9), does not mention *'operational and maintenance functions'* but is similar to the definition in the 4th edition of Blanchard (1992:12), while the 5th edition of Blanchard (1998:9) remarks *on '… all scheduled and unscheduled maintenance actions associated with the system'.* Blanchard (1992:12) writes of *'test and support equipment'* whereas Blanchard's 1998 (1998:9) and 2004 (2004:14) editions refer to *'test, measurement, handling, and support equipment'*. Various tools, diagnostic tools, condition monitoring equipment (predictive maintenance), calibration equipment, maintenance stands, etcetera for the purposes of supporting a system, can all be viewed as S&TE.

Blanchard's (2004:14) definition of test, measurement, handling, and support equipment includes:

> *'… all tools, condition monitoring equipment, diagnostic and checkout equipment, special test equipment, metrology and calibration equipment, maintenance fixtures and stands, and special handling equipment required to support operational and maintenance functions …'*

Further definitions and a deconstruction of the relevant literature are provided in Chapter 4. The next section deals with supply support.

2.14.3 ***Supply support***

Supply support is discussed in this section, beginning with background information and providing a definition. Supply support involves all the items necessary to support a system throughout its intended and/or extended life cycle. These items are not limited to spares but also include procurement processes, distribution and warehousing.

The supply support requirements need to be determined for the purposes of carrying out scheduled and unscheduled maintenance, bearing in mind that spare and repair parts may not be readily available in the country where the system is based and that the part may only be available from an international supplier. To source or manufacture the part could also include predetermined or variable lead times. The difficulties in procuring it from an international supplier include foreign exchange rates and negotiating customs procedures.

There are also trade-offs in supply support: does one make or buy, and does one keep sufficient stock in inventory, or purchase as the need arises for the part? Provisioning requirements and procedures should be set in place.

But what exactly is supply support? Repair and spare parts, supply support, provisioning, inventories are all different names for this concept. Different definitions of the term *'supply support'*, *'provisioning'* and *'spares'* are found in various authors (Jones, 1995; Carpenter, 1967; Palguta et al, 1987; Hutchinson, 1987; Finkelstein and Guertin, 1988; Biedenbender et al 1993; and Blanchard, 1992 & 2004). These definitions include, but are not limited to, the identification of materials and the acquisition thereof to support a system, for instance as components needed to repair an item of equipment. Supply support can be viewed as a management activity necessary to acquire, store, receive, issue, dispose of, and replenish items. The identification of spares, documentation of repair and spare parts, replacements for items that have failed during the operation of a system, consumables, repair and spare parts, software and computers are all perceived as supply support items. Such support further includes S&TE, handling and transportation equipment, facilities, training equipment, and the personnel required to perform the supply support functions. The different definitions will first be discussed.

Jones (1995) views supply support from a military viewpoint, including the procurement of materials to support the operation of the system as well as the maintenance thereof, and defines supply support thus: *'Operation and maintenance actions require material in the form of spare and repair parts. Identification and acquisition of the materials necessary to support the operation and maintenance of military systems is another key responsibility of the ILS organisation. The disciplines of provisioning and supply support fulfill this requirement.'*

Further definitions and a deconstruction of the said literature are provided in Chapter 4. The next section deals with packaging, handling, storage, and transportation.

2.14.4 ***Packaging, handling, storage, and transportation***

Packaging, handling, storage, and transportation (PHS&T) are discussed in this section beginning with general comments, followed by one author's definition of PHS&T. The storage requirements for spare and repair parts, sub-assemblies, mothballed systems, and cannibalised systems need to be determined as facilities, security, environmental and geographical considerations need to be assessed.

Special handling requirements may be called for. These could include antistatic precautions for static sensitive devices, more than one person being needed to handle heavy items, or special hoisting devices being necessary to move items to and from confined areas,

Numerous modes of transport could be used to transport a system: air, rail, road, and/or water. A pipeline could even be used to transport fluids, while a conveyor belt could be used to transport crops, etcetera. Policies and procedures defining all PHS&T requirements need to be documented.

The design of the packaging and packaging material needs serious thought as it needs to be able to withstand environmental extremes, protect equipment, transportation constraints, etcetera. The labelling and identification should also be considered in the packaging design phase. Language limitations often hamper PHS&T efficiency, in that transporting a component from one country to another creates challenges where the languages differ.

Various definitions and different nomenclature are applied, such as *'physical distribution and transportation'* or *'Packing, handling, storage, and transportation'* as defined by various authors (Jones, 1995; 1998; MIL-STD-1367 [1989]; Biedenbender et al, 1993; Blanchard, 2004; Galloway, 1996; AR-700-127, 1999, and Finkelstein and Guertin, 1988). Jones (2006) uses the term *'packaging, handling, storage, and transportability'*.

The four components of PHS&T) each can be defined as follows (MIL-STD-1367 [1989], cited in Jones, 2006:22.1. Jones {2006:22.1} only cited MIL-STD-1367; no year is provided; the 1989 edition of MIL-STD-1367 supersedes the 1972 edition):

1) Packaging. *'Includes all the operations and devices required to prepare items for distribution, such as preservation-packaging, packing, marking for shipment, unitizing, and palletizing. It does not, however, include loading of the mode of transportation, e.g. truck, train, aircraft, or ship.'* (MIL-STD-1367 [1989], cited in Jones, 2006:22.1). MIL-STD-1367 ([1989]) views packaging as preparation for distribution, excluding loading.

2) Handling. *'Moving items from one place to another within a limited range. Handling is normally limited to a single area, such as between warehouses, storage areas, or operational locations, or movement from storage to the mode of transportation.'* (MIL-STD-1367 [1989], cited in Jones, 2006:22.1). MIL-STD-1367 ([1989]) describes handling as movement of items limited to a certain area.

3) Storage. *'The short- or long-term storing of items. Storage can be accomplished in either temporary or permanent facilities.'* (MIL-STD-1367 [1989], cited in Jones, 2006:22.1). MIL-STD-1367 ([1989]) views storage as keeping items in a facility.

4) Transportability. *'The inherent capability of an item to be moved by towing, self-propulsion, or common carrier via highway, railway, waterway, airway, or sea.'* (MIL-STD-1367 [1989]; cited in Jones; 2006:22.1). MIL-STD-1367 ([1989]) views transportation as moving an item a further distance than simply handling.

(MIL-STD-1367 [1989], cited in Jones; 2006:22.1) further defines *'Shipment'* and *'Modes of transportation'* as follows:

1) Shipment. *'Transfer of an item for an appreciable distance (several miles or more) using commonly available equipment such as rail cars, trucks, ships, or aircraft.'* (Jones, 1995:13.1). MIL-STD-1367 ([1989]) perceives shipment as the movement of an item using commonly available equipment.

2) Modes of transportation. *'The various ways in which items are physically shipped, i.e., truck, aircraft, rail, or ship.'* (Jones, 1995:13.1). MIL-STD-1367 ([1989]) defines transportation modes in terms of the method of movement, be it road, air, etcetera.

Further definitions and a deconstruction of the relevant literature are to be found in Chapter 4. The next section deals with technical data and documentation.

2.14.5 ***Technical data and documentation***

First, some general background information is provided. Technical data and documentation includes all information concerning a specific system as well as all support information (facilities, support and test equipment, training documentation, technical manuals, etc.) The data could include, but are not limited to, all software, firmware and various media items, whereas documentation could include, but is not limited to, all technical manuals, specifications, standards, drawings, design documentation and bills of material.

When developing maintenance and operating documentation, the author needs to bear in mind the skill levels of the personnel who will be using it. These documents need to be written in such a manner that the maintenance and operating personnel are able to understand their contents. This includes clarity of language and clearly understandable drawings.

The term *'technical data and documentation'* is defined differently by various authors (Jones, 1995; and 1998, and Galloway, 1996 – *'technical documentation'*, Carpenter, 1967 – *'technical logistic data and information'*, Finkelstein and Guertin, 1988; AR 700-127, 1999; Biedenbender et al 1993 – *'technical data'*; Blanchard, 1992 & 2004 – *'technical data, reports, and documentation'*, and Langford, 1995 – *'logistics technical documentation'*). Technical documentation will first be discussed.

Jones (1995) views technical data and documentation as system operating and maintenance instructions and defines the latter (1995:1.5) as follows, *'The equipment user needs instructions on how to operate and maintain the system. Technical documentation is prepared by the technical publications discipline that accompanies the system. This documentation describes all the actions required for system operation and maintenance.'*

Further definitions and a deconstruction of the literature in this respect are provided in Chapter 4. The next section deals with facilities.

2.14.6 ***Facilities***

Facilities include all land, structures, buildings, roads, equipment plants, workshops, warehouses, training rooms, storage facilities, utilities built in or on land, that are necessary for operational use, and maintenance support, at all the levels of maintenance throughout a system's life cycle. These facilities can be mobile or fixed and must also be reliable in order to meet operational requirements.

The size and location of the above mentioned facilities are critical, as too small a location cannot be used efficiently, whereas too large a facility wastes unused space. Various definitions of the term *'facilities'* will first be discussed.

Jones (2006:21.1) views facilities as encompassing real property including installed equipment that provides a specific function, and defines facilities as *'… any real property which provides a specific capability. A facility is normally made up of a building plus the equipment which is installed within the building that enables the user to perform certain desired functions. This includes parcels of land and buildings, structures, or utilities built on or in the land'.*

According to Carpenter (1967:24) facilities include real estate (buildings including equipment) required for maintenance; he defines facilities as *'Physical plants such as real estate and improvements thereto, including buildings and associated equipment which are required for or contribute to system or equipment maintenance activities.'*

Biedenbender, et al (1993:282), from a logistic support analysis (LSA) point of view, define facilities as encompassing all facilities (modified or new), required for support; that is, *'… real property assets required for the support of the end item, including both new and modified facilities'.*

From a military (Unites States Army) perspective, U.S. AR 700-127 (1999:53) specifies facilities as encompassing all real estate, be it semi-permanent or permanent, required for system support including storage, training, housing, and maintenance: *'The permanent or semi-permanent real property assets specifically required to support the system, including facilities for training, equipment storage, maintenance, contractor, ammunition storage, mobile shop storage, classified storage, troop housing, fuels and lubricant storage, and special facility requirements.'*

Finkelstein and Guertin (1988:148), distinguish between commercial and military facilities, defining commercial facilities as *'… the areas in which equipment is distributed and is properly housed, the materials support is made available, the inventory and distribution systems are in place, the* *warehouses are properly supported and additional space has been provided to meet the needs of any future device'.* Military facilities (Finkelstein and Guertin, 1988:148) on the other hand *'… encompass the real property assets required to support the product and the studies that define types of facilities or facility improvements, location, space needed, etc'.*

Blanchard (2004:13-14) defines facilities as *'maintenance and support facilities and utilities'*, and includes warehouses, buildings, plant, vehicles, housing, workshops, that is, *'… all special facilities that are unique and are required to support logistics activities, to include storage buildings and warehouses and maintenance facilities at all levels … Physical plant, portable buildings, mobile vans, personnel housing structures, intermediate-level maintenance shops, calibration laboratories, and special repair shops (depot, overhaul, material suppliers) must be considered. Capital equipment and utilities (heat, power, energy requirements, environmental controls, communications, safety and security provisions, etc.) are generally included as part of facilities'.*

Blanchard (1992:12) in an earlier edition of his book also describes *'real estate'* as a facility, and adds that facilities are needed for *'… system operation and the performance of maintenance functions at each level'.*

Further descriptions and a deconstruction of the literature are provided in Chapter 4. The next section deals with manpower and personnel.

2.14.7 *Manpower and personnel*

Manpower and personnel as it pertains to supporting a high technology system are discussed in this section, encompassing all the human factors that need consideration in the support of a system throughout its life cycle. This includes the amount of personnel needed per specific discipline (technical and administrative), as well as the prerequisite skills, education, competencies and experience.

Some authors have combined the concepts of manpower and personnel and training; where possible these two aspects will be kept separate in separate paragraphs (2.14.7 and 2.14.8), but where the authors have combined the two aspects they will be discussed under one of the two paragraphs.

The term *'manpower and personnel'* is variously defined; according to Biedenbender, et al (1993:279), manpower and personnel can be defined as identifying and planning '… *for the availability of the military and civilian personnel with the appropriate skills required to support the end item'.*

Galloway (1996:26-27) only defines manpower and does not include personnel, but does mention *'manpower and personnel integration'* in his article, and regards manpower as *'… necessary to identify, justify and make provision to acquire and train the optimum number of personnel, from within the parent organisation and contracted out, with the skills and grades needed to operate and support the system throughout its projected life'.*

Carpenter (1967:23) combines manpower, personnel and training into one discipline, defining manpower and personnel as *'logistic support personnel'* and regarding training as pertaining to skill assessment, training, requirements for human factor engineering, the safety and protection of personnel. Carpenter (1967:23) defines this discipline as *'Qualitative and quantitative skill, performance requirements, and standards; training requirements, standards, curricula and devices; human factors engineering requirements; personnel protection, including safety, survival, clothing, escape and rescue and stress pertaining to the system or equipment under development.'*

Blanchard (2004:12) defines manpower and personnel as *'logistics, maintenance, and support personnel'*, where personnel at all maintenance levels are needed to perform the provisioning, production, installation, and support of the system throughout the utilisation, retirement, and disposal phases of its life cycle, and defines '*logistics, maintenance, and support personnel'*, as follows:

> *'Personnel required to perform unique logistics and system maintenance activities are included in this category. Such activities include the initial provisioning and procurement of items of support, production-related logistics functions, the installation and checkout of the system and its elements at the user's operational site, customer service functions (field service), the sustaining support of the system (prime mission-related elements and elements of the maintenance and support infrastructure) throughout its planned period of use, and those functions required for the retirement and recycling/disposal of material. Personnel at all levels of maintenance …, mobile teams, and operators/maintainers at special test facilities and calibration laboratories are included. In the evaluation of a particular system, it is important to include only those who can be directly attributed to the support of that system.'*

AR 700-127 (1999:35) defines manpower and personnel as the classification and acquisition of civilian and military personnel with the requisite grades and skills necessary to support a system throughout its life cycle during wartime and peacetime.

According to Hermann (2007) the average age of an artisan in South Africa is 54 years. However, the *'… average age of an aerospace engineer in the United States … is in the mid-50s'.* (McKechnie, 2007) The inherent unreliability of the human element poses challenges where the age range is large and continuing training is lacking. Basic skill levels and prior qualifications are necessary in that specific on-the-job training is required in certain areas of supporting high technology complex systems.

Training of personnel is an important aspect of ILS, where the personnel of an organisation are involved with learning new high technology complex system concepts every day. Furthermore, any high technology complex system requires competent personnel to support and maintain the system, which can only be achieved by constantly training the involved personnel, be it by initial training, on-the-job training or continuous training.

The development of manpower requirements and the respective personnel assignments are required to meet the mission requirements of such a system throughout its intended life cycle. ILS element considerations determine the manpower requirements. Behavioural research and/or human factors engineering (HFE) are applied to optimize the man-machine interface. Requirements include the optimisation of numbers, grades, and skills during the decision and planning process (AR 700-127, 1999:35).

As Finkelstein and Guertin (1988) point out, any new system or product or item of equipment delivered in the military or commercial sector requires personnel with the applicable skills to maintain and operate the product. Military systems are becoming more complex, which requires more highly skilled personnel, yet those entering the military are at a lower educational level than in previous years. In the commercial sector matters are somewhat different: will the consumer be able to use the equipment and understand its operation, and should the equipment fail will it be repaired or replaced, and if it is to be repaired will a qualified technician be able to repair the equipment with the necessary documentation at hand?

The incentive for properly training personnel becomes the reliability of the system, the maintenance concept, and the diagnostic routines designed into the system. Training personnel, and ensuring that the correct skill levels, in the correct place, at the correct time, are doing the job they are supposed to be doing has an impact on the organisation (Finkelstein and Guertin, 1988).

Further descriptions and a deconstruction of the literature regarding this field are provided in Chapter 4. The next section deals with training and training devices.

2.14.8 ***Training and training devices***

These devices as they relate to the support of high technology systems are discussed in this section. Training includes all the techniques, procedures, and processes used to train personnel, whereas training devices include all the equipment used to assist in the training exercise. Training requirements are needed at all levels of maintenance. Training equipment includes the actual equipment, mock-ups, audiovisual equipment, and etcetera.

There are various definitions of the term *'training and training devices'* and *'training and training support'* offered by various authors.

According to Biedenbender, et al (1993:281), *'training and training support'* entails all processes, training instruments and aids, training techniques in order to train maintainers and operators, and can be defined as '*identifying and planning … for processes, procedures, techniques, training devices, and equipment required to train operators and maintainers'.*

In Blanchard's view (2004:13), *'training and training support'* can be defined as the category consisting of instructors, facilities, equipment, and resources needed to train maintainers and operators, whereas training devices include mock-ups, manuals, and software; he defines *'training and training support'* as *'… all personnel, equipment, facilities, data/documentation, and associated resources necessary for the training of operational and maintenance personnel, to include both initial and replenishment (replacement) training. Training equipment (e.g., simulators, mockups, special devices), training manuals, and computer resources (software) are developed and utilized as necessary to support the day-to-day on-site training, distance education (training via the Internet), and education of a more formal nature.*'

For Galloway (1996:27) training and training support is defined similarly to Biedenbender, et al (1993), where all training techniques, processes, training instruments and aids are used in order to train contractors and employees to support the system; this includes on-the-job, group and individual, and initial and subsequent training. He defines this element as *'… the processes, procedures, techniques, training devices and equipment used to train employees and contractors to operate and support the system. It includes: individual and group training; initial, formal and on-the-job training; and the logistic support necessary to sustain it'.*

Finkelstein and Guertin (1988:133), defines training similarly to Biedenbender, et al (1993) and Galloway (1996), where the concept includes training equipment, training devices, training techniques, and processes in order to instruct military and civilian personnel to operate and support a new system. They define this element as *'… the processes, procedures, techniques, training devices and equipment used to train civilian and military personnel in the operation and support of a new product. This includes individual and crew training; new equipment training; initial, formal and on-the-job training; and logistics support training'.*

AR 700-127 (1999:37) defines training and training support as the procedures, processes, training devices, equipment, and techniques used to train personnel who support and operate a system. It further includes the quantitative and qualitative prerequisites to train support and operator personnel throughout the systems life cycle and also encompasses factory training, resident training, instructor training, training teams to use new equipment, key personnel training, and sustainment training. Training and training support includes the development, design, delivery, logistic support, and installation of training features that are embedded, simulators, training aids, and mock-ups.

Additional descriptions and a deconstruction of the literature regarding training and training devices is provided in Chapter 4. The next section deals with computer resources.

2.14.9 *Computer resources*

In this section computer resources as these apply to high technology systems are discussed. The term is variously defined. Biedenbender, et al (1993:281) view such resources as including all resources needed for embedded software operation and support, and define computer resources support as including *'… all computer equipment, software, documentation, personnel, and supplies needed to operate and support all embedded software.'* (Biedenbender, et al, 1993:281)

Galloway (1996:27), in line with Biedenbender, et al (1993) also defines computer resources support as utilising resources for operation and support of *'embedded computer systems'*, and defines this element as the *'… facilities, hardware, software, manpower and skills needed to operate and support embedded computer systems.'*

Langford (1995:453) uses the term *'subsystem'* instead of *'system'*, further mentioning the *'supplies'* necessary for operation, but he does not mention support for the software system. His definition of this element includes *'… all computer facilities, equipment, software, firmware, associated documentation, skilled personnel, and supplies needed to operate an embedded computerized subsystem'.*

AR 700-127 (1999:37-38) similarly defines computer resources as the hardware, facilities, documentation, personnel, software, and manpower necessary to support and operate computer systems; computer resources also include embedded and stand-alone systems.

Blanchard's definition of computer resources varies slightly between the 6th edition (2004) and the 4th edition (1992). Similarities are the use of condition monitoring, diagnostic aids, computer equipment and software usage to ensure effective system usage. Differences include the mention of networks, interconnecting components, preventive and corrective maintenance (Blanchard, 2004), and programme disks and tapes, and databases (Blanchard, 1992).

Blanchard's (2004) 6th edition views computer resources as covering *'… all computers, associated software, connecting components, networks, and interfaces necessary to support the day-to-day flow of information for all logistics functions, scheduled and unscheduled maintenance activities, and special monitoring and reporting requirements such as those pertaining to access to CAD/CAM/CAS data, the implementation of condition monitoring programs, and in support of system diagnostic capabilities'* (Blanchard, 2004:13). However, Blanchard's (1992) 4th edition views computer resources as *'… all computer equipment and accessories, software, program tapes/disks, databases, and so on, necessary in the performance of system maintenance functions at each level. This includes both condition monitoring and maintenance diagnostic aids. The resource to support computer-aided acquisition and logistic support (CALS) requirements are also included.'* (Blanchard, 1992:13).

Computer resources comprise all *'facilities, hardware, software, documentation, manpower, and personnel needed to operate and support computer systems'* (Army Regulation, 1999). Computer resources are required to support the equipment at all levels of maintenance. Furnishing the skills and training required in South Africa in order to support a complex system is challenging, in that very few of the population enjoy access to electricity, computers, information, and documentation.

Additional descriptions and a deconstruction of the said literature are contained in Chapter 4. The next section deals with reliability, availability, and maintainability (RAM).

2.14.10 ***Reliability, availability, and maintainability***

Reliability, availability, and maintainability (RAM) consists of various components, each of which will be described separately. One source, (ECSS, 2002:17) regards dependability as RAM.

1) Reliability defined. While there are various definitions of the term *'reliability'*, Finkelstein and Guertin (1988), regard it as the systems performance characteristics reflecting the ability of the system to perform its primary function within a specified environment and over a specified duration; furthermore, reliability is quantitative in nature and is probabilistic, and they define it as *'… the probability of successful operations for a specific period of time under specific conditions and environments of operation'.* (Finkelstein and Guertin, 1988:53)

Hutchinson (1987:48), in line with Finkelstein and Guertin (1988), regards reliability as probabilistic, holding that the system will perform its function over a specified duration under specific environmental conditions.

From a knowledge management (KM) perspective, Awad and Ghaziri (2004:217) define reliability as the system delivery of trustworthy, accurate, and consistent information, that is, *'… how well the system delivers the information or solution with consistency, accuracy, and integrity. It also means detecting and removing anomalies (such as redundancy, ambivalence, and deficiency).'* (Awad and Ghaziri, 2004:217)

Jones (2006:4.1) views reliability in the sense of a system performing its primary function, in predefined conditions without failure, where reliability projects failures using statistical calculations, and he defines reliability as *'The probability that a system will perform its intended mission without failing, assuming that the item is used within the conditions for which it was designed.'* A further definition of reliability by Jones (1995) is provided in Appendix B.

2) Availability defined. Various definitions of the term '*availability'* exist, with Jones (2006:10.1) viewing it as the probability of the system being in an operable state, at a specific moment in time; in other words the system needs to be operational when required. Langford (1995:71) views availability as the system's readiness to accomplish its primary purpose. Availability can be regarded as the probability that a system will be operational at a given moment in time in order to complete a function (be it a full function or downgraded function). Moubray (1991:254) defines availability (uptime), as '… a *measure of the amount of time the equipment is capable of operating at all'.*

Three definitions of availability are those of operational, achieved and inherent availability, their definitions are provided in Appendix B.

3) Maintainability defined. Numerous definitions of the term '*maintainability'* likewise exist, depending on the authors' background and context of application. Finkelstein and Guertin (1988:72) view maintainability as the responsiveness of the repair of a failed item to its operational state: *'… the ease and rapidity with which a defective item can be restored to its operation condition, It is a function of product design installation, availability of personnel adequate maintenance and test equipment and its environment.'* Hutchinson (1987:53) views maintainability as a probabilistic occurrence, the repair of a failed system within a specific time period.

According to Jones (2006:4:18) maintainability is a statistical prediction, which is influenced by environmental conditions and resource availability: *'The probability that a failed item can be repaired in a specified amount of time using a specified set of resources.'* Langford (1995:55), as with Jones (2006), adds a quantitative measure to the definition, that the system will be restored to its operational readiness, within a specified time period, using various resources. Langford (1995:55) defines maintainability as '*… the measure of the ability of a system to be restored to a specified level of operational readiness within defined intervals with the use of prescribed personnel, facility, and equipment resources.'.*

Blanchard (2004:34) views maintainability as the ability of system maintenance, including design characteristics expressed by means of maintenance cost, maintenance times, and *'maintenance frequency factors'*.

Additional descriptions and a deconstruction of the literature in this respect are contained in Chapter 4. The next section deals with configuration management.

2.14.11 ***Configuration management***

Configuration management as it relates to high technology systems is discussed in this section. Again, numerous definitions of the term *'configuration management'* and *'configuration'* are found in various authors. Configuration management entails identifying the characteristics (physical and functional) of items (be it equipment, products, assemblies, parts, and etcetera), which perform a specific function as defined by a specification (or drawing or other relevant documentation), for which change control is applied to the item throughout its life cycle; that is, configuration management can be regarded as baseline traceability management.

Finkelstein and Guertin (1988:91) describe configuration as the physical nature of an item, fulfilling functional requirements as defined by approved specifications or other relevant documentation, and define it as *'… the physical nature of parts, assemblies, equipment or products, or any combination of these, that are capable of fulfilling the form, fit or functional requirements defined by the applicable formal specifications or engineering drawings'.* Finkelstein and Guertin (1988:91) further define configuration management as the *'… systematic approach that establishes and maintains the identification, control and accounts of the configuration of selected products and component parts'.*

As Finkelstein and Guertin (1988:93) point out, configuration management *'can supply a current description of a developing hardware or software unit, product etc. and provide traceability to previous baseline configurations of that item'.* Finkelstein and Guertin's (1988:93) approach is based on *'US Air Force document AFSCP 800-7: Configuration Management'* ([s.a.], possibly 1972 or 1988; {IHS; 2008}).

From a systems engineering perspective, Langford (1995:529) views configuration management as identifying the physical and functional characteristics of an item throughout its life cycle, and where change control is applied to those characteristics, the definition reads: '… *the systems engineering management process that identifies the functional and physical characteristics of a product during its life cycle, controls changes in those characteristics, reports change processing and implementation status, and records the changes'.* Langford's (1995: 530) approach to configuration management is based on *'MIL-STD-973'* (1992) (DoD Configuration Management).

Blanchard (2004:39) views configuration management from a management perspective, where an item's physical and functional characteristics are identified early in its life cycle, and for which change control is applied through its life cycle; he defines it as *'… a management approach used to identify the functional and physical characteristics of an item in the early phases of its life cycle, control changes to those characteristics, and record and report change processing and implementation status'.* He adds, *'CM is baseline management (i.e., the planning, design, and providing of logistic support for a system with a given and known baseline configuration versus attempting to provide support infrastructure for many different and constantly changing baselines, which can be very expensive).'*

Additional descriptions and a deconstruction of the given literature are contained in Chapter 4. The next section deals with the system product description, equipment list and system/product operational requirements.

2.14.12 ***System operational requirements***

In this section the operational requirements of a high technology complex system as they relate to ILS are discussed. Before any high technology complex system can be supported and maintained, the system operational requirements must be known. According to Blanchard (2004:128, 443), and Blanchard and Fabrycky (2006:59-60), these operational requirements include the system mission, system performance parameters, operational deployment, system life cycle, utilisation requirements, effectiveness factors, and operational environment. These operational requirements are important since they determine the type and complexity of the maintenance tasks, and the resources that are needed to support and maintain the system.

Before any of these operational requirements can be defined, the system function must first be defined (Jones, 2006:2.1). Such aspects, as defined by Jones (2006:2.1-2.7), include environmental issues, the rate of use of system, system hazards for the environment (e.g. waste disposal), physical system environment, support, the total cost of ownership, performance, and the support infrastructure.

Finkelstein and Guertin (1988:102) argue that the maintenance programme (or concept) is developed in conjunction with, and consistent with the systems' operational requirements. In addition the systems' mission time, operational environment, and system performance need to be defined in order to determine the systems' mission success (Finkelstein and Guertin, 1988:63).

A military viewpoint from the United States Department of Defence Systems Management College (2001:35) regarding defining the systems' operational requirements includes the operational deployment or distribution, mission scenario or profile, performance parameters, utilisation environments, effectiveness requirements, and the operational life cycle of the system.

In this section the system operational requirement was discussed. In the next section the system equipment breakdown structure is considered.

2.14.13 ***Equipment breakdown structure***

In order to support and maintain a high technology complex system, the items within the system must be known. Consequently each and every item, down to the lowest level of maintenance, must have a part number, and a serial number (excluding those components which are non-replaceable, and consumables). It is necessary to know the full physical breakdown structure or product breakdown structure in order to standardise support and test equipment, and to determine inventory levels, which represent outputs from the logistics support analysis (LSA). This physical breakdown structure includes all hierarchical levels of the system down to the lowest, and the *'parent/child relationships'* between items and hierarchy levels.

Jones (1995:21.8) proposes a *'system description'*, whereby the physical and functional system characteristics are furnished in detail, from which ILS requirements are identified. Blanchard (2004:162-163) provides a different nomenclature, namely, 'hierarchy of system components', which entails breaking the system down into sub-levels of components in a hierarchical relationship. Blanchard and Fabrycky (2006:5) state that '*if two hierarchical levels are involved in a given system, the lower is conveniently called a subsystem.*'

Kelly (1989:22) defines a 'hierarchy' as *'… hierarchical relationships between systems. A system is composed of subsystems of a lower order and is also part of a suprasystem. Thus, there is a hierarchy of the components of the system.'* In addition Kelly (1997:31) argues that '*an analytical model of its structural and process flow characteristics …*' of an industrial system can be useful in describing its maintenance strategy.

Mitchell (2002:17) proposes a nine-layer 'enterprise asset hierarchy', which consists of the following hierarchy levels (highest level to lowest level):

1) Enterprise;
2) Facility/Plant;
3) Unit/Platform;
4) System;
5) Subsystem;
6) Equipment group;
7) Equipment component
8) Assembly; and
9) Part.

In order to perform analysis on a system and its components it is advisable to know where each component fits into the hierarchy of the overall system, this ensures the user knows what each component is and also where the component is located (Moubray, 1997:327).

The next section deals with obsolescence of equipment and components.

2.14.14 ***Obsolescence***

Obsolescence of equipment and components is discussed in this section. Planning for this eventuality is important as it could result in a system becoming non-operational. Obsolescence is *'… the state when a part is no longer available from the original manufacturing source'* (MoD Corporate Technical Services, 2004:1-1). Boyle (2005:20) argues that manufacturers have had to deal with obsolescence since the start-up of the manufacturing industry. Obsolescence affects many systems with long life cycles, and though traditionally a defence industry concern, now embraces other industries including nuclear, medical, power, telecommunications, railways, and petrochemical firms (MoD Corporate Technical Services, 2004:i). Obsolescence can also be regarded as Diminishing Manufacturing Sources and Material Shortages (DMSMS), which similarly concerns:

> *'… the loss or impending loss of manufacturers or suppliers of critical items and raw materials due to discontinuance of production'* (ARINC, 2000:1-1).

According to the United States Defense Microelectronics Activity (DMEA) (2001:1) legacy systems and contemporary high technology complex systems are feeling the effects of obsolescence. In order to reduce these consequences, DMSMS risk management strategies have been implemented by users of legacy programs (DMEA, 2001:1). Traditionally responses to obsolescence have been reactive (Burrows, 2003). In the past, components manufactured to military specifications have been accorded higher performance specifications and were capable of operating in harsh conditions and environments; these features are currently still being requested in specific systems and applications (Boyle, 2005:20).

Obsolescence and DMSMS can be regarded as the point in such a system's life cycle when spare and repair parts are no longer available;, this lack can be due to various reasons, such as the supplier no longer being in business, or having stopped production of the specific item (Marshall and Lambert, 2007:558). According to Howard (2002:1), obsolescence also affects non-electronic components, although the effect may not be apparent for a few years, since non-electronic systems may be supportable for some time.

Haub (1997, cited in Meyer, Pretorius and Pretorius, 2003:122), argues that obsolescence not only affects all equipment and products, but also S&TE, processes, software, logistics products, specifications, and standards. Typically, if a component becomes obsolete, so does the next-higher assembly or application (Boyle, 2005:20).

Costs associated with obsolescence include deterioration of inventory items, and obsolete items being replaced by a more technologically advanced product. According to Hutchinson (1987:104), such costs should also *'…be approached with caution and allocated on a per-unit basis'.*

Finkelstein and Guertin (1988:203) contend that obsolescence occurs due to the equipment design of the manufacturer, or worn-out equipment, and that it is designed into a product to encourage sales sooner than when the customer was expecting to purchase, adducing arguments similar to those of Marshall and Lambert (Finkelstein and Guertin, 1988:203).

In order to achieve a lower total cost of ownership (TCO), DMSMS management needs to be implemented contractually during the life cycle of a system, and *'… must be accepted at the highest programmatic levels …'* (ARINC, 2000:1-2). Finkelstein and Guertin (1988:204-205) propose an obsolescence plan, which is considered more fully in section 4.3.12. In brief, such a plan identifies which equipment should be phased-out, or disposed of, and how .

Obsolescence, as it pertains to high technology systems, its costs and planning for it, were discussed in this section It is clear that it may be much more complex than the ILSS literature assumes. In the next section disposal of material, system and/or equipment are investigated.

2.14.15 ***Disposal of material/system/equipment***

All systems and equipment eventually pass the operational/maintenance phase of their life cycle and need to be disposed of in various ways. Once high technology systems reach the end of this phase, they are withdrawn from service, and are perceived as being in the stage of *'retirement'*, where they are for example mothballed, cannibalised, or disposed of. A modular nuclear reactor is typically designed to have an operational life of 40 years, and is thereafter decommissioned, where the fuel is stored safely within the building for another 40 years. Disposal plans are required to manage such activities. Currently numerous countries hold the developer of systems responsible for the legitimate *'end-of-life disposal'* of their developed systems (INCOSE, 2006:3.9).

For Jones (2006:11.3), disposal entails the system being removed from operation by retiring or salvaging it, or removing and disposing of resources which are no longer needed for support, including those not needed by a new or other system. Jones (1995:18.4, and 2006:11.6) maintains that the disposal of equipment or a system is an element of cost which is more often than not ignored; however, the system or equipment might possess a resale or salvage value offsetting the disposal cost. Jones suggests that the typical disposal costs are refurbishment, recycling, system disposal, archiving and data management, closeout of inventory, demilitarisation, waste management (hazardous material disposal), and packaging, handling, storage and transportation (PHS&T) (Jones, 2006:11.6)

Integrated logistics support activities are necessary in the material recycling or disposal, and during the system retirement, phases. These include removing obsolete items from inventory, recycling them for reuse on other applications, and the breaking-down and disposing of the items that cannot be reused (Blanchard, 2004:117).

Blanchard (2004:387) devises a system retirement plan which includes the phase-out and disposal of a system including the ILS requirements. This plan is discussed more fully in section 4.3.13. Disposability refers to the extent of the recycling that an item can undergo for another use or be disposed of without degrading the environment, that is, without generating water, air or noise pollution, radiation, or solid waste.

Retirement and disposal is the final stage within the system's life cycle. The equipment/system/product needs to be designed for disposability, and procedures need to be in place to cover the system's disposal, recycling or decomposition using existing ILS resources or others. One should ensure that these methods and their results are in accordance with ecological, political, social, environmental and safety requirements, and economically feasible (Blanchard, 2004).

In this section disposal of material, systems, and/or equipment was discussed. In the next section risk management as it relates to a high technology complex system is dealt with.

2.14.16 ***Risk management plan***

The Project Management Institute (PMI) (2000:127) argues that a project's risk can have a positive or a negative outcome; the risk may include threats and opportunities. Koller (2005:5) makes a similar suggestion. According to Moubray (1997:95), *'… there is an element of risk in everything we do'.* This can include a project deliverable being late or even being delivered earlier, an item being designed and manufactured according to an outdated specification, and even an item being disposed of, for example, a radioactive waste facility not being monitored for damage and leakage. The United States commercial nuclear industry regards its nuclear reactors as complex and redundant entities with high inherent reliability (Jones, R., 1995:7). Reliability is designed into complex redundant systems; however, maintenance reduces the system's reliability, owing to maintenance-induced failures which may result from the maintenance tasks and frequencies not being considered during the design phase (Jones, R., 1995:12).

Risk can be regarded as consisting of a probability of occurrence, severity (consequence or outcome), and a severity factor (DSMC 1989:15-1; Koller 2005:5). According to Koller (2005:1), *'… the risk/uncertainty (R/U) environment within most corporations can be relatively chaotic …'*. Moubray (1997:95) states that risk assessment asks *'… what could happen if the event under consideration did occur. … how likely it is for the event to occur at all. The combination of these two elements provides a measure of the degree of risk'.* Koller (2005:5) argues that a risk is eliminated when the probability associated with it and/or its consequence is reduced to a level where it no longer constitutes a threat to business success.

Assessing whether a maintenance risk factor is associated with an item involves determining if the item is a significant one, where safety and major consequences are at stake. According to Nowlan and Heap (1978) an item is a significant item if its failure could result in operating safety being affected or incurring economic consequences. Jones (2006:13.2-13.3) mentions that a maintenance significant item (MSI) is an item potentially requiring support, and that reliability-centred maintenance (RCM) and failure modes, effects, and criticality analysis (FMECA) assist in identifying MSIs. For an item to be classified as an MSI, firstly, it must require maintenance, that is, it must be supportable; secondly it must be capable of being removed and replaced; or disassembled and reassembled without being damaged during the maintenance process; and thirdly all the applicable resources must be identifiable and information regarding them must be available (Jones, 2006:13.3).

According to PMI (2000:144), risks need to be monitored and controlled, and risk plans are developed and executed accordingly, in order to minimise the associated risk. Furthermore Blanchard (2004:179) insists that the aspects of uncertainty and risk must be integrated within a systems' risk management plan; in particular, risk can be regarded as discrete data concerning a parameter in a probability distribution form. However, uncertainty (Blanchard, 2004:179) is probabilistic, and does not consist of discrete data, and he therefore defines uncertainty as *'… a situation that may be probabilistic in nature but one that is not supported by discrete data'.*

Operating complex systems within a developing country increases the need for a risk management plan, especially where the consequence of failure is significant.

A risk plan should include at least the methodology of how risk management will be performed, roles and responsibilities, budgeting, timing, scoring methods and interpretation thereof, risk thresholds, reporting, and tracking (PMI, 2000:130).

Risk affects all aspects of ILS related to a high technology system, including manpower and personnel, skills, knowledge, training and training devices, maintenance, S&TE, PHS&T, computer resources, obsolescence, phase-out, disposal, configuration management, supply support, data and documentation, and facilities.

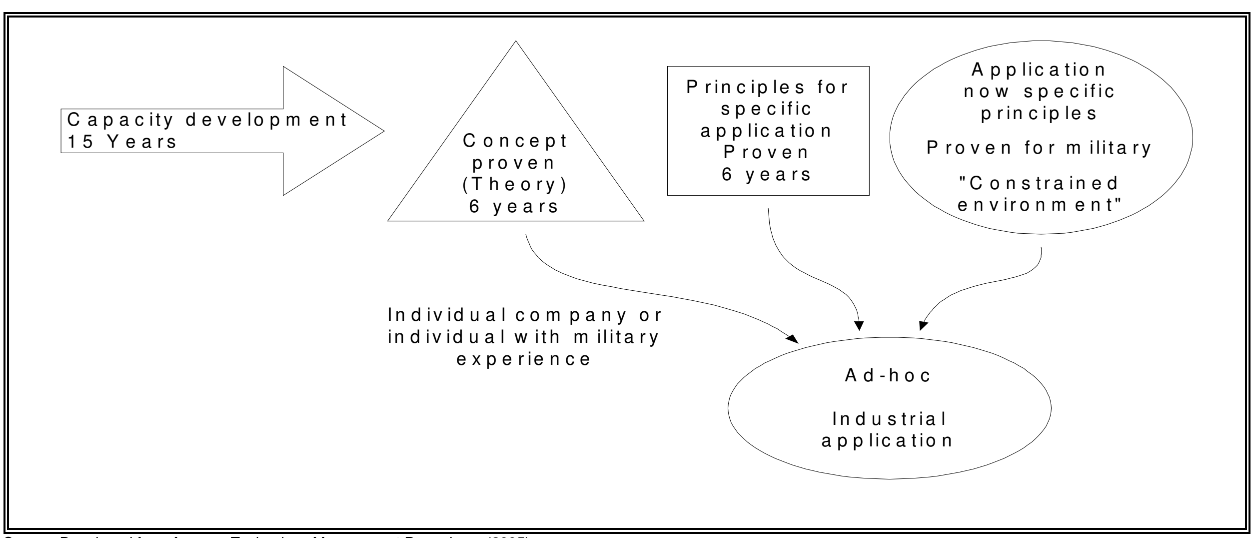
Risk management was discussed very briefly in this section. In the next section the transfer of technology from military to industrial systems is discussed.

2.15 Transfer of technology from military to industrial systems

Occasionally the situation arises where a military system must be migrated to an industrial environment. In this section the concept of military applications being developed into industrial ones, and how the research concept is developed, will be examined. We will also be briefly looking at the various companies and systems used in the study and how they are associated. Integrated logistics support, although stemming from a military type organisation is now being applied to an industrial setting.

ILS is no longer limited (as in the past) to military systems; it can be applied to shipping, rail systems, commercial aviation, and the petroleum industry (Jones, 1998).

Typically the transfer of technological applications from a military environment to an industrial application takes five years. Capacity development in a military context takes approximately 15 years. From capacity development the concept is proven in theory and takes approximately six years. The principles are proven for a specific application and typically last six years. All these principles can be applied in an ad-hoc industrial application. A typical transfer from a military to an industrial application is depicted in Figure 2–4 below.



Source: Developed from Armscor Technology Management Procedures (2005).

Figure 2–4: Typical transfer from military to industrial applications

In this section the transfer of technology from military to industrial systems was discussed. Financial/budget constraints as they apply to logistic support are discussed next.

2.16 Financial/budget constraints for logistic support

In this section financial/budget constraints regarding military expenditure are discussed. Military expenditures have decreased during 1985 and 1990 (Gupta, de Mello and Sharan, 2001). South Africa's military spending compared to selected countries of the world is also provided in Table 2–10.

Governments and military departments of the major countries of the world spend millions of their currencies on military expenditure, for offensive and/or defensive purposes. Competition amongst arms producers has increased due to the decrease in military spending worldwide since the mid 1980s (Gupta, Schiff and Clements, 1996, and International Monetary Fund {IMF}, 2000, in Gupta, et al, 2001:752).

'According to the World Economic Outlook database of the IMF, the share of military expenditures in GDP fell gradually from 5.1% in 1985 to 3.4% in 1990 and to 2.1% in 1999. As a share of total spending, military outlays fell from 14.2% in 1990 to 10.0% in 1999' (Gupta, et al, 2001:756-757). Furthermore, according to Deger (1986, cited in Dakurah, Davies and Sampath, 2001:652), *'There is no clear cut prediction of the direction of causation between military expenditures and economic growth'.*

In 2003 world military expenditure reached $956 billion (current dollars), and increased by 18% (in real terms) over two years, that is by 11% in 2003 and 6.5% in 2002, furthermore 16% of the world's population is from high-income countries, which in turn account for approximately 75% of the world's military expenditure (Sköns, Perdomo, Perlo-Freeman & Stålenheim, 2004a). Table 2–10 details South Africa's and Ecuador's military spending compared with selected countries of the world (CIA World Factbook, 2004a, b, and c). All figures are 2003 unless otherwise stated.

Table 2–10: Military expenditure ($) compared to GDP

COUNTRY	MILITARY EXPENDITURE $ (MILLION)	MILITARY EXPENDITURE (% OF GDP)	GDP $ (MILLION) Est.
Bermuda	4.03 (2001)	0.11 (2000/2001)	2,330
China	60,000 (est.)	3.5 – 5 (FY03, est.)	6,449,000
Ecuador	650	2.4	4,565,000
France	45,238.1	2.60	1,661,000
Japan	42,488.1	1.00	3,582,000
North Korea	5,217.4 (FY02)	22.90	29,580
Sao Tome and Principe	0.5	0.80	214
South Africa	2,653.4	1.70	456,700
United Kingdom	42,836.5	2.40	1,666,000
United States	370,700	3.30 (FY03, est.)	10,990,000
World	Not available	2.00 (1999, est.)	51,480,000

Source: CIA World Factbook, 2004a, b &c.
FY: Financial Year.
Est.: Estimated.

Table 2–11 details global defence expenditure in millions of dollars, against percentage of GDP and number of armed forces for 2002.

Table 2–11: Global defence expenditure against % of GDP

REGION	DEFENCE EXPENDITURE		NUMBERS IN ARMED FORCES (000)
	US$m	% OF GDP	
NATO, (Canada, USA and NATO Europe)	515,235	2.6	3,748.6
Canada	7,771	1.1	52.3
USA	329,616	3.3	1,414.0
NATO Europe	177,848 185,619 [sic]	1.9	2,282.3
Non-NATO Europe	24,109	1.6	1,085.9
Russia	48,040	4.8	988.1
Middle East and North Africa	57,892	7.2	2,852.0
Central and South Asia	21,364	2.6	2,460.3
East Asia and Australasia	141,073	2.1	6,681.8
Caribbean, Central and Latin America	26,857	1.7	1,267.5
Sub-Saharan Africa	8,147	2.6	1,393.7
Global totals	**842,717**	**2.6**	**20,477.9**

Source: IISS. *The Military Balance.* Table 33, International comparisons of defence expenditure and military manpower, 1985, 2001 and 2002. (2003-2004:335-340)

According to Lannin (2006) the United States' spending in Afghanistan and Iraq is estimated to increase world military spending in 2006, after reaching US $1.12 trillion in 2005. The Stockholm International Peace Research Institute (SIPRI) ([s.a.]) states that 48% of total global arms spending in 2005 was due to the United States, which accounted for 3.5% of the increase, and it is unlikely that the trend will decrease (Lannin, 2006). Britain, China, France and Japan accounted for between four and five percent each of global arms expenditure (Lannin, 2006).

According to Baldor (2006) the yearly cost of repairing, upgrading, and replacing military equipment in Afghanistan and Iraq is *'expected to more than triple next year to more than $17 billion…'* For the years 2002 to 2006, $4 billion per year on average was spent by the Army in yearly equipment costs. *'The push for additional equipment funding comes after the House last week passed a $427 billion defense spending bill for the fiscal year beginning Oct. 1, which includes $50 billion for military operations in Iraq and Afghanistan. A separate $66 billion emergency funding bill for the two wars was approved earlier in the month.'* (Baldor, 2006)

According to Le Roux (2004:2), *'To ensure coordinated action and efficiency at national level, there are five interrelated components that need to be considered in the public expenditure management cycle. These are:*

1) Sectoral strategic planning;
2) Reviewing the previous year's performance;
3) Determining priorities and what is affordable for the entire public sector;
4) Allocating resources by sector; and
5) *Using resources efficiently and effectively and according to agreed priorities.'*

The total cost of ownership can be viewed as *'the sum of all expenses and costs associated with the purchase and use of equipment, materials, and services'*. (Monczka, Trent and Handfield, 2002:438-439)

In this section military and public expenditure were discussed. In the following section Chapter 2 is reviewed.

2.17 Summary of literature review – current relevant literature

A summary of the literature review is offered in this section. Chapter 2 began with discussing the seminal literature sources on operations management; next the supply chain, supply network and supply chain management were discussed, including the drivers in the supply chain: subsequently the extent to which the logistics and supply chain is linked to the study was presented. Integrated logistics systems were presented next, followed by a brief history of logistics, definitions of logistics and definitions of ILS.

Following the definitions of ILS, the evolution of the integrated logistics concepts was described. Available models of ILS: military, military expenditure and the developing world context (including environmental and political factors) were then discussed. This was followed by a consideration of complex systems, high technology, and knowledge management. Next in this chapter the various ILS elements were provided, and definitions described and explained. The chapter concludes with a note on the transfer of technology from military to industrial systems.

In Chapter 4 the ILS literature will be deconstructed and the ILS elements will be cross-tabled against the applicable authors (Table 4–2). Considering the 1967 author DODD 4100.35 (1967) only certain aspects of ILS were discussed. From 1967 more authors covered ILS aspects. These authors include Langford (1995), Blanchard (1992, 1998, and 2005), US Army Regulation (1999 and 2005), and Jones (1995, 1998, and 2006). As more knowledge of the ILS elements has been developed over the years, the ILS elements have been included in the academic literature. In the next chapter the research design is dealt with.

'Any fool can make things bigger, more complex, and more violent. It takes a touch of genius-and a lot of courage-to move in the opposite direction.'

– Albert Einstein

CHAPTER 3 RESEARCH DESIGN

3.1 Introduction

In the previous chapter the literature review was presented. It put forward the definitions of logistics and integrated logistics support (ILS), a brief historical background of logistics and the available literature review of ILS. The literature consulted included military standards and specifications. While these are not academically refereed, they are peer reviewed. As in the past, they still serve as strenuous guidelines for producing military components, equipment and high technology systems today. These military standards and specifications are also used in industry (for example power generation and civilian navigational aids), where academic literature may not have been written about the subject matter, or where such literature is not able to be obtained It is clear from the above that there is a lack of available literature, especially literature relevant to industry and to work done on existing high technology systems.

In this chapter we discuss the research design of the study, that is, Mode 1 and Mode 2 research. It explains how Mode 2 research is related to the study. Figure 3–1 serves to demonstrate the approach to research. A discussion of the three phases of research, namely, phase 1, phase 2 and phase 3, including the integration of the three phases, follows. Lastly, the statistical technique used to conduct the quantitative analysis is discussed.

The research methodology used for the study contains an element of explanatory research, given the need to explore the definition and produce a clear specification. In the process of using explanatory research, sufficient knowledge was gained to enable descriptive research, which is what most part of the study is based on. In turn, the descriptive research provides the context of ILS and the framework required to develop an ILS in high complexity.

The research uses an inductive approach, starting with literature reviews and moving towards a more conceptual framework. The use of substantive reasoning and analysis aims at prediction and causal explanation.

Through applied research it will be possible to generate findings with relevance to other areas of interest and to have various trade-offs and uses in the developed framework.

All academic research is conducted to create reliable and valid knowledge, which is shared with students and other individuals interested in the subject matter. The utilisation of much of the research of an academic nature of management seems to be problematic, and it is often description driven (van Aken, 2004). Within a high technology industry where technology changes rapidly, management thinking, processes and procedures have to respond by evolving and improving at the same pace.

The objective of academic research, especially at doctoral and postgraduate level is to bring about new ideas and thoughts into the specific domain being researched. Furthermore, academic research should contribute to the body of knowledge and to the specific field. According to Huff (2000, in van Aken, 2005:19), academic research's primary objective is developing '*knowledge for knowledge's sake'*. One criterion for quality of the information is that this knowledge needs to be held valid and reliable by peers; another criterion is of course relevance.

The focus of the professional doctorate research is *'improving practice within the profession that is the subject of the research'* (Murray, 2006:38). This research design is therefore aimed not only at proving the validity and reliability of results, but also at providing results relevant to the body of management knowledge.

According to Gibbons (2002:3), Mode 1 *'refers to knowledge production'.* Further reference is made to Mode 1 and Mode 2: *'in Mode 1 it is conventional to speak of science and scientists, it has been necessary to use the more general terms knowledge (or research) and practitioners (or researchers) when describing Mode 2.'*

Following from Table 3–1, Mode 1 can be seen as adding new knowledge to a specific domain, entails peer reviews by academia, is uniform in nature, and structured. Mode 2, however, is seen as reaching a wider audience with regards to quality control, that is, not only academia but also industrial peers (for example military standards). The research is applied not only in the specific domain, but can be applicable to other scenarios, and is more diversified. It follows then that Mode 2 is a suitable approach to this study, as the research conducted is within a high technology industry in a developing country, and the research findings can be applied to other industries, other developing countries and first world countries. Furthermore, Mode 2 is aimed at solving relevant and complex field problems, (van Aken, 2005:20).

Table 3–1: Differences between Mode 1 and Mode 2

Mode 1	Mode 2
Problems postulated and resolved by academia and specific community	Knowledge produced is applied
Disciplinary	Trans-disciplinary
Skills homogeneity	Skills heterogeneity
Hierarchical	Flatter organisation structure
Less reflexive and socially accountable	More reflexive and socially accountable
Peer review – quality control	Wider audience – quality control

Source: Gibbons (2002:3)

Mode 2 has five characteristics (Nowotny, Scott and Gibbons, 2003:186–187):

1) It is *'generated within a context of application'*;
2) It is *'… 'trans-disciplinarity', by which is meant the mobilization of a range of theoretical perspectives and practical methodologies to solve problems'*;
3) *'… much greater diversity of the sites at which knowledge is produced, and in the types of knowledge produced [sic]'*;
4) *'… it is highly reflexive'*; and
5) *'… is seen in novel forms of quality control.'*

The application of knowledge gained in an academic environment for advanced postgraduate degrees, can be applied outside an academic environment. Mode 2 research is used to relate academic research at a management level within an organisation, where the aim is on *'the so-called field-tested and grounded technological rule …'* (van Aken, 2005:19). As in the case of the research conducted and reported within this thesis, an ILS framework can be developed and then applied within management and leadership hierarchies in an organisation within a high technology industry in a developing country.

From a systematic point of view, grounding this theory can be considered as theory generation. Glaser (1998:3) purports that grounded theory *'is the systematic generation of theory from data acquired by a rigorous research method'.* This study is the generation of a framework that can be used in other settings.

Grounded theory was formalised in the social sciences domain by Glaser and Strauss (1976a) while they were researching *'dying in hospitals'* and subsequently wrote *'Awareness of Dying'* in 1967 (Glaser, 1998:21). Glaser (1998:4) mentions that grounded theory has an integrated verification method using constant comparison modification. He also states that grounded theory *'is the discovery of what is there and emerges….It will always be as good as far as it is taken, especially when developing new categories and their properties."*

Grounded theory as stated by Glaser (1998:7) is *'formative, relatively inexpensive and a source of very rich ideas'.* Glaser (1998:8) further states that *'all is data'*, ranging from books, brief comments, observations, spurious variables, magazines, interviews, documents, newspapers, prejudices of others, self influences, and any other form of data. Furthermore, Glaser (1998:11) mentions that grounded theory *'stands on its own as a theory of a method which yields techniques and stages that can be used on any type of data and combination thereof'.*

As expressed above by Glaser (1998:8) that *'all is data'*, the *'data'* consulted ranged from academic books, academic articles and publications, conference proceedings, military standards, to case studies. Deconstruction of the literature review and of the cases was conducted and relevant areas requiring more focused research were identified. In other words the theory generated can be applied to settings other than that in which it evolved.

Grounded theory enables one to derive a theory *'by using multiple stages of data collection and the refinement and interrelationship of categories of information'.* (Strauss and Corbin, 1990a, in Webb and Auriacombe, 2006:599). According to Webb and Auriacombe (2006:599), grounded theory has no *'clearly defined demarcated ending point. The research … ends when the researcher decides to end it.''*

Grounded theory is process driven, resulting in a theory of the process (Cresswell, 2002, in Leedy and Ormrod, 2005). Although originating in Sociology (Glaser and Strauss, 1967b, in Leedy and Ormrod, 2005), it is also being used in education (Strauss and Corbin, 1994, in Leedy and Ormrod, 2005). Strauss and Corbin (1990b:24, in Neuman, 2006:60) further mention that grounded theory is *'a qualitative research method that uses a systematic set of procedures to develop an inductively derived theory about a phenomenon'.*

Prescriptive knowledge is solution-oriented and driven by field problems, enabling the analysis of organisational difficulties and the development of action plans. Descriptive knowledge focuses on existing circumstances and is theory-driven. The concern is that often *'developing prescriptive knowledge is regarded as rather un-academic*' (van Aken, 2005:21).

However, design science develops knowledge used by professionals in their specific field in order to design solutions for their specific field related problems (van Aken, 2005:22). This type of research is therefore highly applicable in a professional doctoral degree.

In this section the research design was introduced, whereby 'Mode 2 Research' and grounded theory as it pertains to the study was discussed. In the next section the approach to research is discussed.

3.2 Approach to research

This specific research study starts by identifying the relevant management concern and management problem. This was presented in chapter 1, namely, in today's high technology environment most operations systems are complex and consist of many individual complicated sub-systems. Figure 3–1 demonstrates the research approach. The approach to research was first discussed in chapter 1, paragraph 1.9 and depicted by figure 1–1 – it will not be elaborated upon further here. The complexity of these operations systems is driven by increased technology development and the increase in reliability requirements on systems with regards to the consequence of failure.

These complex systems need to be supported to deliver functions for which they were designed. In the real world, and especially in developing countries, the complex systems utilised have many constraints to the successful implementation of an ILS System. Some of these constraints:

1) The systems do not come from the same developer or from the same generation of technology;
2) The systems are used beyond their expected life cycles;
3) The systems suffer from component obsolescence, and are either upgraded and/or refurbished to extend their system life cycle; and
4) In the developing world, the realities are more complex and so too are the delivery of these functions. This is, however, true of most areas.

The approach to research was discussed in this section, and the constraints of successful implementation of an ILS were presented. In the next section the three phases of research, that is, phase 1, phase 2, and phase 3 research are discussed.

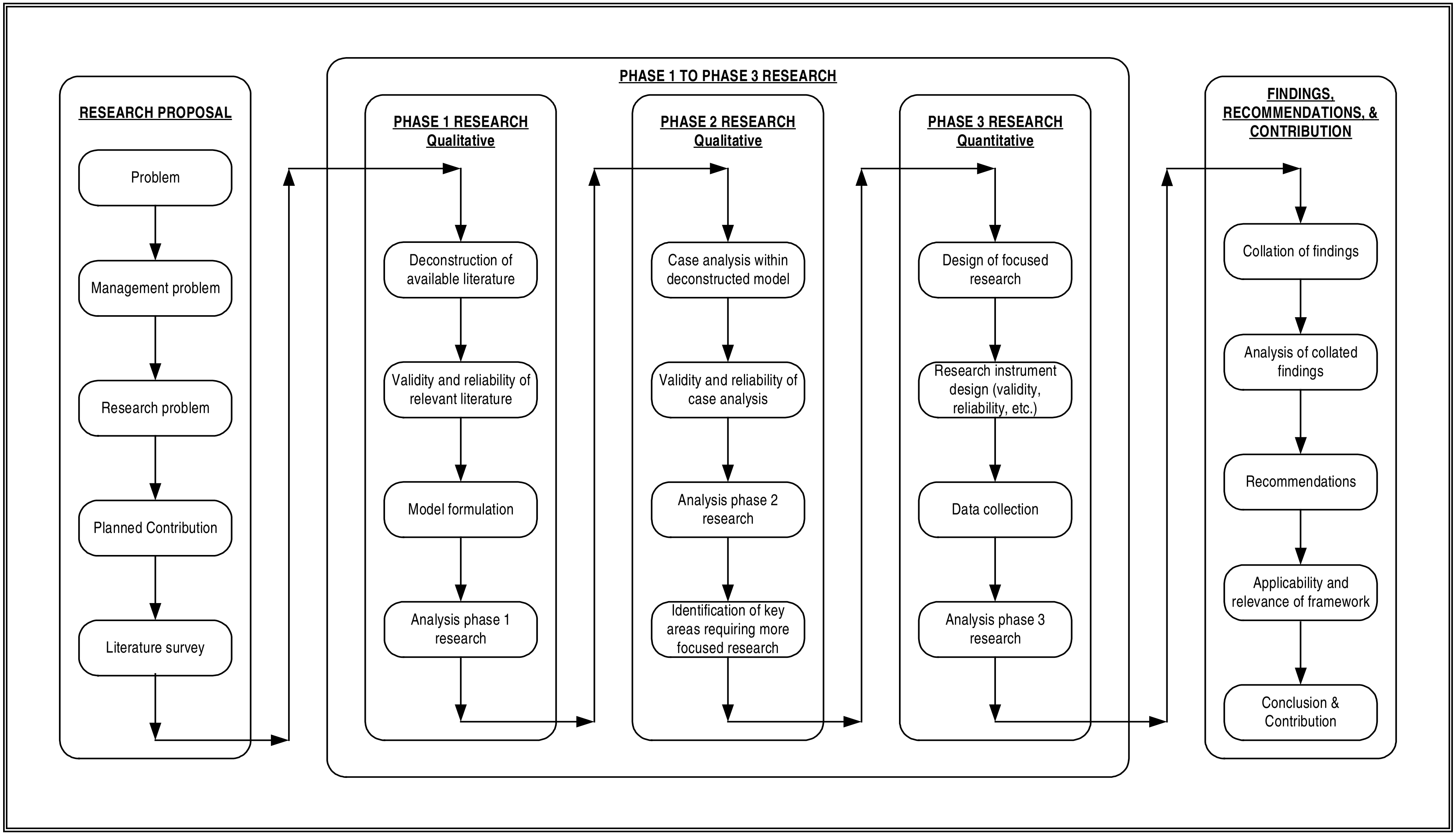


Figure 3–1: Approach to research (research overview)

3.3 Phase 1, phase 2 and phase 3 research

In this section a discussion of the three phases of research follows. The first phase, or phase 1 pertains to the deconstruction of the literature review. The second phase, or phase 2 concerns the deconstruction of the case studies used in the study. Finally, phase 3 describes the quantitative research instrument and statistical analysis, that is, the questionnaire, and statistical techniques used to analyse the questionnaire data.

Before we discuss the deconstruction of the literature review, we first need to discuss the meaning and relevance of the term *'deconstruction'*. What do we mean by *'deconstruction'*? Firstly, the definition of '*deconstruction'* from three dictionaries is provided.

1) The Oxford English Dictionary (1989) views deconstruction as disassembling something that has been constructed, and from a literary sense, it is viewed as critical analysis of literature, and is defined as:

   'a. The action of undoing the construction of a thing.
   b. Philos. and Lit. Theory. A strategy of critical analysis associated with the French philosopher Jacques Derrida (b. 1930), directed towards exposing unquestioned metaphysical assumptions and internal contradictions in philosophical and literary language.' (The Oxford English Dictionary, 1989, in Royle:2–3).

2) Secondly, the Collins English Dictionary (2004) views deconstruction as a method of analysing literature, where the meaning of the text is found in the difference between words instead of the meanings of the words themselves, and is defined as:

   'a technique of literary analysis that regards meaning as resulting from the differences between words rather than their reference to the things they stand for.' (Collins, 2004:412).

3) Thirdly, the Chambers Dictionary (1998) views deconstruction as a process of literature analysis where there is no specific meaning of a piece of text, whereby readers must discount any preconceived notions regarding the specific text, and is defined as:

   'a method of critical analysis applied esp [sic] to literary texts, which, questioning the ability of language to represent reality adequately, asserts that no text can have a fixed and stable meaning, and that readers must eradicate all philosophical or other assumptions when approaching a text.' (Chambers Dictionary; 1998; in Royle; 1).

According to Derrida (1985: 3), deconstruction is not a critique or analysis, it is also not a method, nor an operation or an act. The following aspects of deconstruction are important in the context of the study:

1) Often described as a technique of literature and philosophy, it questions basic conceptual contrasts (often oppositional, binary or hierarchical) through close examination of logic and language of literary and philosophical text (Derrida, [s.a.], cited in Answers.com, 2008);

2) An extension of the interpretation of deconstruction – the challenge to look at the source of the meaning in text and questions the boundary between literature and criticism (de Man, 1983, Johnson, 1981, Miller [s.a.], and Hartman [s.a.], cited in Answers.com, 2008);

3) Deconstruction is a perplex school of thought, which causes much critique. It is also often used as an example of how absurd language departments have become, so that deconstruction is regarded by conservatists as a Marxism equivalent, especially since de Man had written pro-Nazi articles during WWII (Answers.com, 2008);

4) *'In popular usage, the term has come to mean a critical dismantling of the definition of tradition and traditional modes of thought'* (Britannica Concise Encyclopedia). Deconstruction does not always suggest unfriendliness towards the analysis subject (Answers.com, 2008), (analogy-deconstruct implies de~struct);

5) To a deconstructionalist, meaning includes that which is left out of text or ignored, as well as that which is identified in the text (Culler, 1982, Gasche, 1986, and Kamuf, 1991, cited in Columbia University Press, 2003); and

6) A deconstructive thinker must have a high level of comfort with suspended or deferred decision and must also be willing to work with terms where precise meaning has not been (or cannot be) established (Derrida, 1981).

Interpretation of deconstruction for the purposes of this study, is outlined further by the following authors:

1) Spatialisation of contexts (Barnett [s.a.], in Geography Dictionary; 2004)
2) Omissions from text (Columbia Encyclopedia, 2003);
3) Critical dismantling of thoughts (Britannica Concise Encyclopedia, 2006);
4) Analytical reading (Johnson, 1981);
5) Dissecting critical thought (Allison, in Derrida; 1973);

6) Critical interpretation of an author's intentions (de Man [s.a.], Johnson; 1981, Miller; [s.a.], and Hartman; [s.a.], in Baldick; 2001; 2004).

7) Comfort with terms which have not been defined precisely (Bass; 1981, in Derrida; 1981).

Qualitative research attempts to assess the human dimension of research. Kincheloe (1991:143): *'As qualitative researchers direct their attention to the meanings given to events by participants, they come to understand more than what a list of descriptions on a table of statistics could support.'* He further suggests that *'qualitative thinking involves the feeling and appreciation dimension of human activity which, of course, borders on the aesthetic dimension. Thus, qualitative research attempts to appreciate human experience in a manner which is emphatic to the human actors who feel and live it' (*Kincheloe, 1991:145).

In this section, phase 1, phase 2, and phase 3 research was discussed. In the next sub-section, phase 1 research is elaborated on.

3.3.1 *Phase 1 research*

During phase 1 of the study the management concern was identified, the research problem was established, and the research proposition was substantiated. Phase 1 of the research consisted of reviewing the available and relevant literature with regards to logistics and ILS in particular. The deconstruction of the literature review was assessed in chapter 2 and extensive deconstruction of the literature is evaluated in chapter 4. The model was also formulated during phase 1. Relevant literature was consulted, including academic books, academic articles and publications, conference proceedings, United States Military Standards, United States Army Regulations, United Kingdom Ministry of Defence Standards, NASA documents, *'International Space Station Alpha'* (AIAA, 1995:36), European Cooperation for Space Standardisation and Defence Systems Management College (DSMC) Systems Engineering Management Guide. Military standards have in the past been used as a standard to procure high technology and military systems; academic or industrial related books have replaced some of these standards.

Standardisation is used as a benchmark to provide guidelines for specific items, be it a system to be manufactured, or a process to be followed. These guidelines are either used as is (rarely), or tailored to suite the specific environment in which it is applied (normally). From a military perspective, the United States Department of Defence DOD 4120.24-M (2000:75) provides a definition of standardisation: *'The process of developing and agreeing on (by consensus or decision) uniform engineering criteria for products, processes, practices, and methods for achieving compatibility, interoperability, interchangeability, or commonality of materiel."*

Furthermore, different organisations and associations define the word 'standard' differently, the Institute of Electrical and Electronic Engineers (IEEE) (IEEE-STD-610, 1990, in Rigby, 2007b) defines a standard as *'mandatory requirements employed and enforced to prescribe a disciplined uniform approach to software development, that is, mandatory conventions and practices are in fact standards'.'*

The ISO/IEC Guide 2:2004 published by the International Organisation for Standardisation (ISO)/International Electrotechnical Commission (IEC), (in World Standards Services Network, 2007) defines a standard as *'a document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context'.*

ISO (2007) provides on their website a description of what one can expect within their standards. These standards capture all precise criteria or technical specifications within a document, in order to provide a standardised guideline to stakeholders; their definition follows:

> *'An ISO standard is a documented agreement containing technical specifications or other precise criteria to be used consistently as rules, guidelines, or definitions of characteristics to ensure that materials, products, processes and services are fit for their purpose. It is a living agreement that can have a profound influence on things that deserve to be taken seriously - such as the safety, reliability and efficiency of machinery and tools, means of transport, toys, medical devices, and so on' (ISO, 2007).*

Military standards are used as stringent guidelines when applied to military equipment. Industrial organisations use military standards, either to manufacture new systems for the military, or as guidelines for certain contract requirements. As noted by van Opstal (1994:10), many industrial organisations need to modify their production lines in order to accommodate the manufacturing of military components according to military specification. Van Opstal (1994:11) also mentions that there are approximately 32,000 military standards and specifications. The definition of a standard according to the United States Department of Defence DoD 4120.24-M (2000:74): *'A document that establishes uniform engineering or technical criteria, methods, processes and practices'.'*

Many military standards, specifications, and handbooks have become obsolete. In 1994 United States Secretary of Defence, William J. Perry, issued a memorandum stating that the US Department of Defence should move towards using performance and commercial standards and specifications. Furthermore, he issued a policy change, dictating the use of commercial and performance documentation. As a last resort only, were military standards and specifications to be used, provided a waiver was obtained (Perry, 1994). McNally (1998:297) mentions that the implementation of Perry's memorandum was *'overzealous'*, as some standards and specifications were cancelled without a commercial standard being available.

The number of military standards and specifications in circulation in the USA at the time of the Perry Memo (1994) numbered approximately 45,000; these have subsequently been reduced to roughly 28,300 (Poston, 2003:2). Under the *'Milspec Reform',* an estimate of 9,600 military standards and specifications were cancelled, of which approximately 3,100 were cancelled and replaced with non-government documentation, while close to 6,500 were cancelled without being replaced (US DoD, 2001:10–11). In comparison, China only had 15 military standards issued in 1983. By 1998 they had 5,700 military standards – a subsequent shortage of standards till the late 1990s (Cheung, 2007:3–4).

Kratz (2005:91) issued a memorandum that waivers were no longer required when citing military standards and specifications within contracts and solicitations. While MIL-STD-1369 (ILS Programme Requirements) has been cancelled (Perry, 1994, ANSI, 2007), it is still being used by military and industrial organisations within South Africa. Even prior to the waiver issued by Kratz (2005), the MIL-STD-1369 was used along with other military documentation and available literature (books, articles, and etcetera) in industrial and military contracts. Jones (2006:xv) mentions that although the military specifications, handbooks and standards have been cancelled, they are still utilised as a reference. In some instances, industrial technology and advancements have surpassed military achievement, hence the use of commercial off-the-shelf (COTS) components for their military systems (Shertzer, 1998:2). South Africa is a case in point where COTS components are used in military systems.

China plans to intermix its military and industry knowledge in order to share technology such that both industry and the military benefit from the technology transfer (Cheung, 2007:1).

These military standards and specifications, although not academic in nature, are peer reviewed and used in the military and industrial context. Military and industrial organisations in South Africa use US military standards as well as UK Ministry of Defence standards. The primary difference between the US and UK standards relate to their implementation and structure (Rigby, 2007a). Furthermore, Rigby (2007a) defines the US and UK standards as follows:

1) US standards are *'prescriptive, pragmatic, structured top-down and aimed at providing a method for use in rigid contractual applications, requiring the acquirer to approve baselines and participate in "milestone" reviews',* whereas

2) UK standards *'generally define philosophies and guidance notes for those responsible for projects to perform effectively, efficiently, and economically without being to prescriptive on methods and the contents of the documentation'.*

According to Kaminski (1996:Slide 9), one should carefully select standards that are *'widely accepted in the marketplace, are consensus based, and are in tune with current and emerging technology'.*

Traditionally, ILS has been incorporated late in the life cycle. In today's rapidly changing high technology environment, ILS is used to influence the design of complex systems. Furthermore, the life cycles of systems are being extended beyond their original designed life (Blanchard and Trovato, 2006, in Jones, 2006:xiii). A case in point where ILS influences the design, is one specific project for the design of a high technology complex system in South Africa: ILS is used to influence the geometry of large components, assisting in making maintenance of the components easier and less tedious for the maintenance staff.

Jones (2006:xv) comments that ILS is an *'internationally accepted analysis methodology and management process'*. ILS is used on many procurement programmes in industrial and military organisations.

The extensive ILS literature was analysed by means of deconstruction. This deconstruction has been necessary to obtain clarity and meaning of the various authors' definitions and contexts within which they define their specific terminology of ILS. The definitions of the specific ILS elements as proposed by the various authors were presented, described and compared. Similarities and dissimilarities between the definitions were discussed.

From the above discussion, it is evident that standardisation is used within industry, in order to benchmark and provide guidance for products. Standards are documented and contain specific guidelines which are tailored to suite customer and project requirements. Furthermore, military standards have more stringent guidelines when applied to military products and systems. Following the Perry (1994) and Kratz (2005) memoranda, military standards and specifications are used on military, government and industrial contracts. The academic and military literature will be used as a basis for the literature review and literature deconstruction. In chapter 2, some of the definitions of ILS were provided and discussed. Chapter 4 focuses on the deconstruction of the ILS literature. The definitions of the ILS elements are provided, discussed, and deconstructed, that is, the definitions are analysed, and similarities and dissimilarities are scrutinised. In addition, more salient aspects of each ILS element are provided, discussed, and deconstructed – such aspects include specific ILS element plans.

3.3.2 ***Phase 2 research***

Phase 2 of the research consisted of assessing case studies of various high technology complex systems (industrial and military) within the South African (developing country) context. The case studies included key areas requiring more focused research, including focus group interviews. The case studies were deconstructed and evaluated for key areas requiring further focused research.

The specific cases were selected after the fact that ILS originated in the military environment, hence the case studies of two military high technology systems. However, ILS has over the years also been applied to industrial systems, such as petrochemical, power generation, and satellite earth stations. Case studies of specific industrial systems have been used to compare their integrated logistics support systems (ILSS) to case studies of similar systems within a military environment.

A case study analysis approach has been used for the study of the various systems and organisations. Yin (2003:1) states that *'case studies are the preferred strategy when "how" or "why" questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real-life context'.* Eisenhardt (1988:534) describes the approach to case study research as *'a research strategy, which focuses on understanding the dynamics present within single settings'.*

According to Yin (2003:40), there are different types of case study designs, ranging from a *'single case design'* and a *'single unit of analysis'* to *'multiple case designs'* and *'multiple units of analysis'.* A single unit of analysis and a multiple case design have been used for the study. Case study researchers focus their attention on one or many entities in great depth (Yan and Gray, 1994, in Lee, 1999).

The use of multiple case studies justifies the validity and reliability of the study. Multiple cases regard the evidence as more credible, and the study can be considered as more resilient (Herriott and Firestone, 1983, in Yin, 2003:46).

The unit of analysis is at a system level as this is where all the components of ILS has been analysed, that is, maintenance, support and test equipment, manpower and personnel, training and training devices, supply support, packaging, handling, storage and transportation, data and documentation, facilities, and computer resources.

MIL-STD-280 [1969] as cited in Jones (1995:1.9–1.12) defines equipment levels from the lowest level to the highest level as follows:

1) Part;
2) Sub-assembly;
3) Assembly;
4) Unit;
5) Group;
6) Set;
7) Sub-system;
8) System; and
9) Super system.

In addition to the equipment levels as defined by MIL-STD-280 [1969], Jones defines an additional level as *'equipment'*, which *'is of a lesser scale than a system…'*. MIL-STD-280 does not define *'equipment'*. MIL-STD-280 [1969] in Jones (1995:1.12) defines a system as containing *'the total package of parts through sub-systems and is capable of performing a complete operational mission…. The concept of a system can also include the personnel required to operate and maintain the equipment and the supporting equipment required to sustain operations."*

Mitchell (2002:17) proposes a 'nine layer asset hierarchy' from a physical asset management perspective in an industrial setting, where these nine layers are as follows (highest level to lowest level):

1) Enterprise;
2) Facility/Plant;
3) Unit/Platform;
4) System;
5) Subsystem;
6) Equipment group;
7) Equipment component
8) Assembly; and
9) Part.

The population used for the study came from different organisational levels within the various companies. Similarities and differences were expected between the cases, and qualitative and quantitative analysis techniques were used to explore and develop the concept framework.

Negative evidence (for example preconceived notions and omissions) has been addressed where necessary through workshops and detailed interviews with people in the area of radar, navigational aids, satellite, and a power generation development project. The focus groups and professional industry panel contributed to this.

The deconstruction of the case studies is evaluated in chapter 5. Phase 2 also included the identification of key areas requiring more focused research. These key areas include:

1) Manpower and personnel;
2) Training and training devices;
3) Support and test equipment (S&TE);
4) Supply support;
5) Technical data and documentation;
6) Computer resources;
7) Facilities;
8) Packaging, handling, storage and transportation (PHS&T);
9) Maintenance;
10) Configuration management;
11) Reliability, availability, and maintainability (RAM) - dependability;
12) Obsolescence; and
13) Disposal.

3.3.3 *Phase 3 research*

Phase 3 of the research started with the design of the focused research, concentrating on the design and distribution of questionnaires. A pilot study questionnaire will be used to ascertain whether the respondents understood the actual questions and statements, as well as the respective question asking methods. Furthermore, the pilot study questionnaire served to determine the most relevant questions for the final study questionnaire. The pilot study questionnaire is shown in appendix E. The pilot study questionnaire was developed in Microsoft Word.

The pilot study questionnaire comprised six A4 size pages with 45 questions, and three questions for additional comments. Before the pilot study questionnaire was distributed to the intended respondents, it was distributed to two colleagues for a dry run test. Following the dry run test, the pilot study questionnaire was distributed over a four-week period to the intended respondents.

Permission was requested from numerous organisations to participate in the empirical research, however; only some of the organisations were willing to participate in the completion of the questionnaire. Three organisational levels (or job levels) were targeted with the pilot, namely, engineering, maintenance, and management personnel.

The actual pilot study questionnaire was distributed to approximately 5.6 percent (28 questionnaires) of the total respondent sample frame. 22 pilot study questionnaires were received back – a response rate of 78.57%. Statistical analysis was conducted on these 22 received questionnaires.

The pilot study questionnaire was made available in two ways:

1) By e-mail, and completed electronically, or
2) By e-mail, printed and completed by hand.

An additional week was granted for the return to improve the response rate.

The respondents, who received the e-mail-based version of the pilot study questionnaire, returned the completed questionnaire in three different ways:

1) The respondents completed the pilot study questionnaire in Microsoft Word, and returned the completed questionnaire via e-mail; or
2) The respondents printed the pilot study questionnaire, completed it by hand, scanned it into an electronic format, and returned it via e-mail; or
3) The respondents printed the pilot study questionnaire, completed it by hand, and physically returned the questionnaire.

The intended respondents to the paper-based questionnaire received the questionnaire at one nodal point via e-mail, printed the questionnaire, completed it by hand and physically returned the questionnaires.

The final study questionnaire was developed and tailored following the statistical analysis of the pilot study questionnaire. Two final study questionnaires were distributed:

1) One questionnaire was distributed to the military organisation respondents (Appendix F); and
2) One questionnaire was distributed to the industrial organisation respondents (Appendix G, and Appendix H).

The reason for the two variations of the questionnaire (military and industrial) was that the military organisation regarded some of the information required in answers to certain questions to be of a sensitive nature. The final study questionnaire for the military organisation was tailored further, and approval from the military organisation was obtained. The military organisation final study questionnaire consisted of 25 questions. The two final study questionnaires were identical up to question 25, after which the questionnaire targeting the industrial organisations continued up to question 34.

The military organisation's final study questionnaire was a paper-based questionnaire, and comprised four A4 pages, the first of which was the covering letter. The three remaining pages contained the questions and statements. The military organisation's final study questionnaire was printed on 160g/m^2 A3 paper, the questionnaire was formatted so that once printed in duplex form on the A3 sheet of paper and folded lengthways, it formed an A4 booklet. The purpose of the 160g/m^2 paper was to ensure that the questionnaire was of a more durable professional nature, and that the colour ink would not result in show-through, as would have been the case with a double-sided printed 80g/m^2 paper. The covering letter page was printed in colour and the remaining three pages were printed monochrome.

Like the pilot study questionnaire, the military organisation's questionnaires targeted three organisational levels, namely, engineering, maintenance, and management. The military organisation's questionnaires were distributed to numerous departments and units and a specific unit operating one of the high technology systems within the military organisation. The military organisation's questionnaires distributed within Pretoria were delivered and collected by hand, while those distributed outside of the Pretoria area were delivered by a courier company. The same courier company collected all but one of these sets of questionnaires from the respondents. Of those collected, one was door-to-door, and three were door-to-counter. One set of questionnaires was returned via the postal service.

The distributed military organisation's questionnaires were packed in separate envelopes and included a covering letter from the organising department, which informed the various respondents of the purpose of the questionnaire and the study, and that permission had been granted to distribute the questionnaires within the military organisation. Most of the military organisation's questionnaires were distributed in this way. It was, however, necessary to pack some questionnaires seperately, as these were intended for one of the departments, one of the units and the unit involved in a specific high technology system. These separate questionnaires were packed in an envelope and for each questionnaire, a covering letter from military organisation's authorising department was included, as well as a letter from the Office of the Chief of the specific military organisation. The military organisation's questionnaires were distributed over one calendar month.

One specific unit returned their completed questionnaires within two days. Three of the units took two to three weeks to return their completed questionnaires. Two of the units' questionnaires were received after three weeks. The remaining respondents were granted an additional week to complete the questionnaires for collection.

The reason for two separate sets of delivery methods was that one specific military organisation's member was responsible for arranging the distribution of 124 questionnaires via the organising department, and another member of the military organisation was responsible for arranging the distribution of the other set of 38 questionnaires. In total, 162 military organisations' questionnaires were distributed and 122 completed and returned – a response rate of 75.31%.

The final study questionnaire for the industrial organisations was web-based (Appendix H). Only 65 questionnaires were completed by the industrial organisations from a total of 404 distributed questionnaires, which produced a response rate of 16.1%. One organisation could not access the website through their web browser due to security reasons, hence the questionnaire was made available in a word processing format as well (Appendix G). The University of South Africa (UNISA), Graduate School of Business Leadership (SBL) was kind enough to develop the website and allowed the use of a Unisa SBL uniform resource locator (URL) for the questionnaire. The Unisa SBL also maintained the database. The questionnaires, both web-based and those formatted in Microsoft Word, were distributed over three calendar weeks.

The website was designed and launched once some of the paper-based questionnaires were returned. From these returned questionnaires, it was clear that certain errors occurred when done by hand. To avoid such errors, the website was designed in such a way that the questionnaire could not be submitted if all the questions were not completed (text fields and radio buttons). Specific questions (question numbers. 9, 10, 19 to 23, and 27 to 34) were coded to enable the respondent to answer the question correctly and not to bias the answers. A separate message box appeared explaining to the respondents that the answers could not be the same; this is shown in Appendix H. For question 2 the word *'other'* was added, as some of the respondents at one organisation were from East Asia. Question 3 was coded so that only one home language could be selected – again, if *'other'* was selected, a separate text box opened. For questions 4, 8, and 11, the respondents could only select one option.

Once the *'Submit'* button was pressed/selected, the website validated the answers to verify that all questions were completed. If some questions were not completed, a message appeared on the screen, informing the respondent of questions not answered and the respondent was taken back to the specific question that needed completion. If all the questions were completed, a separate message box appeared informing the respondent that their response had been submitted and thanked them for their participation. The respondent then selected/pressed the *'OK'* button, which triggered another box informing them that the window being viewed would be closed, and if they wanted to close the window, to select *'OK'*. The browser then closed (these boxes are all shown in Appendix H).

3.3.4 ***Statistical Analysis***

The statistical analysis used in the study is discussed in this section. The process started with a review of data and information, followed by descriptive and inferential statistics, parametric and nonparametric statistics, and finally a discussion of inferential nonparametric statistical methods.

The definition of data and information as used in statistics is very specific and in some cases different from that used in other fields of study. According to Keller and Warrack (2003:26–28):

1) A variable is a characteristic of a sample or population;
2) Variable values are possible variable observations;
3) Data are observed values;
4) Real numbers are classified as interval (or numerical or quantitative) data;
5) Categories of data are classified as nominal (categorical or qualitative) data;
6) Ordinal data *'… appear to be nominal, but their values are in order'.*

Nominal data are categorical data, that is, values describe categories and not numbers (Keller and Warrack, 2003:26), for example, male and female. A nominal scale labels items (Howell, 1995:15). Cooper and Schindler (2001:205) state that nominal data are a *'… determination of equality …'* and have no distance, origin or order, but have a classification. According to Leedy and Ormrod (2005:28), nominal scales enable the researcher to determine the percentage values and the mode of the data.

Ordinal data have values in order and appear to be nominal (Keller and Warrack, 2003:27), for example, most important (1) to least important (5). Furthermore, Keller and Warrack (2003:32) define a frequency distribution as counting *'… the number of observations that fall into each of a series of intervals, called classes, that cover the complete range of observations'*. Cooper and Schindler (2001:205) state that ordinal data are an order and classification, but have no unique origin or distance and they are a determination of lesser or greater value.

According to Leedy and Ormrod (2005:28), ordinal scales enable the researcher to determine the percentage values, mode, percentile rank and median of the data. Likert scale is an example of ordinal data (Pellissier, 2007:10).

A Likert scale is a variation of the summated rating scale: respondents are asked to rate their attitude, opinion, behaviour, or perception towards statements where the statements are unfavourable or favourable (Cooper and Schindler, 2001:234; and Leedy and Ormrod, 2005:185). In the next section descriptive and inferential statistics are dealt with.

3.3.5 ***Descriptive and inferential statistics***

According to Keller and Warrack (2003:3), descriptive statistics are used to *'extract information from the sample'*, and deal with organising and presenting data conveniently and in an informative way, whereas inferential statistics summarise data by using numerical techniques, which draw inferences or conclusions regarding *'characteristics of populations based on sample data'*.

Inferential statistics are used to determine whether significant differences between certain variables existed (Howell, 1995).

After analysing the descriptive statistical analysis, an inferential statistical analysis was done to determine if there were significant differences between certain specific responses.

Inferential statistics are used to determine whether a criterion within populations differs by using sample data. According to Howell (1995:7), inferential statistics are used to *'estimate parameters of two or more populations, mainly for the purpose of finding if those parameters are different'.*

According to Leedy and Ormrod (2005:257), the Kruskal-Wallis test is a nonparametric statistic technique used to *'compare three or more group means when the data are ordinal'* (for example ranked). Furthermore, Miller and Freund (1985:2) state that statistical inference *'concerns generalizations based on sample data'.* Keller and Warrack (2003:3) mention that inferential statistics are used to *'draw conclusions or inferences about characteristics of populations based on sample data'.*

3.3.6 ***Parametric and nonparametric statistics***

Parametric statistics are used when the data are a ration or interval scale, and (the data) reflect a normal distribution (Leedy and Ormrod, 2005:257). Nonparametric statistics are used when the two assumptions are violated.

Nonparametric tests are used where *'it is doubtful whether the assumption of normality can be met'* (Miller and Freund, 1985:271), that is, nonparametric tests are used where the distribution shows non-normality. Nonparametric tests are used to test hypotheses with ordinal and nominal data (Cooper and Schindler, 2001:495). It does therefore limit certain statistical inferences, but *'exact inferences can be made when assumptions underlying so-called standard methods cannot all be met'* (Miller and Freund, 1985:272).

Nonparametric techniques are used when there are ordinal data and the mean *'is not an appropriate measure of location'* – therefore, differences in population means cannot be tested. However, population characteristics can be tested *'without referring to specific parameters'.* Nonparametric statistics test whether there is a difference in population locations, rather than differences in population means (Keller and Warrack, 2003:559).

According to Neuman (2006:349), the mean (arithmetic average) can only be used for ratio- or interval-level data. The mode of a distribution is the most frequently occurring observation; the median is the central observation, whereas the mean is the arithmetic average (Keller and Warrack, 2003:93–96). The median is the 50^{th} percentile or middle point of a distribution, where half of the observations fall above and half below the median. It is used with interval, ratio, or ordinal data, but not with nominal data (Howell, 1995:50–55). In a normal distribution, the mode, median, and mean all equal each other.

3.3.7 ***Inferential statistics***

A discussion on the statistical analysis technique used to analyse the responses to the questionnaire follows. A contingency table that compares two or more populations was used to analyse the responses. A contingency table is often referred to as a cross-tabulation table or cross-classification table, and a contingency table is used to list the *'frequency of each combination of the values of the two variables'* (Keller and Warrack, 2003:63). A contingency table is further used to determine the dependence of one variable on the other variables (Howell, 1995:363).

The Chi-Square test, which is a test statistic, was used for the contingency table. The null hypotheses specifies that there is *'no relationship between the two variables'* (Keller and Warrack, 2003:538); or the two variables are independent (Miller and Freund, 1985: 263). The alternative hypotheses specifies that the *'two variables are dependent'* (Keller and Warrack, 2003:538); or the two variables are not independent (Miller and Freund, 1985: 263).

For the analysis used in this thesis the Chi-square statistic has been tested at the five percent significance level. If the probability of the P value was greater than five percent, then the null hypothesis would not be rejected and there was no dependence between the two variables. Where the P value was lower than five percent, the null hypothesis was rejected, and the two variables were dependent.

Cramer's V is used to measure the strength of association of categorical variables, which can be represented in a contingency table (Unisa, 1992:256). According to PlanetMath (2008), Cramer's V is *'a statistic measuring the strength of association or dependency between two (nominal) categorical variables in a contingency table'.* The strength of the association is determined by the value of the calculated statistic – if V is close to 1 the association is strong, and when V is close to zero the association is weak (PlanetMath, 2008).

3.4 Integration of the three phases of research

The three phases of research will be collated into a table. The ILS elements, which require further study, will be cross-tabulated against the findings of phase 1 research, phase 2 research, and phase 3 research. The table is presented and discussed in chapter 7.

3.5 Summary of Research Design

From the deconstruction of the literature review and the case study analysis, further key areas were identified, which required more focused research. The research instrument used for this was a questionnaire containing specific questions. A pilot study questionnaire was distributed to a sample of relevant individuals to gain insight into the specific questions asked and also to establish whether the specific format of the questions was understood. From these results, an analysis was conducted and a final questionnaire compiled and distributed to 566 respondents. The final questionnaire consisted of two separate questionnaires. One questionnaire was paper-based and was submitted to military organisations, while the other questionnaire was web-based and aimed at industrial organisations. The military questionnaire needed security clearance as sensitive information was required in answers to some of the questions. The industrial questionnaire was similar to the military questionnaire with some additional questions. The questionnaire results were analysed statistically and results and conclusions drawn from the analysis.

In the next chapter we conduct phase 1 of the research, which is the deconstruction of the ILS literature.

'If you wish to find, you must search. Rarely does a good idea interrupt you.'

– Jim Rohn.

'The answers you get from literature depend on the questions you pose.'

– Margaret Atwood.

CHAPTER 4 PHASE 1 RESEARCH: DECONSTRUCTION OF LITERATURE – INTEGRATED LOGISTICS SUPPORT

4.1 Introduction

Phase 1 of the present study, the deconstruction of integrated logistics support (ILS) literature, is presented in Chapter 4 (this chapter). Firstly, the concepts of deconstruction are discussed as they pertain to this study. The literature review in Chapter 2 is further elaborated on in this chapter, including a deconstruction of the literature and a discussion of the ILS elements in great detail.

4.2 Deconstruction defined and used

Deconstruction is often described as a method of philosophical and literature analysis that questions basic conceptual distinctions (often oppositional, binary or hierarchical) through close examination of the language and logic of literary text (Derrida, 1973, 1981, 1985). An extension of this definition holds that deconstruction constitutes a challenge to look at the source of meaning in text and questions the boundary between literature and criticism (de Man; 1983, Johnson; 1981, Miller; [s.a.], and Hartman; [s.a.], cited in Answers.com, 2008).

Deconstruction is a complex school of thought attracting much critique, for instance being regarded by conservatives as equivalent to Marxism, especially since de Man had written pro-Nazi articles during WWII (Answers.com, 2008).

'In popular usage, the term has come to mean a critical dismantling of the definition of tradition and traditional modes of thought.' (*Britannica Concise Encyclopedia*). Deconstruction does not always suggest unfriendliness towards the subject of analysis (Answers.com, 2008), that is, deconstruct does not imply de~struct.

To a deconstructionist, meaning includes, what is left out of text or ignored, as well as what is evident in the text (Culler; 1982, Gasche; 1986, and Kamuf; 1991, cited in *The Columbia Encyclopedia*, 2003).

In this section the concept of deconstruction was briefly described. This section is an extension of Chapter 3, where the concept of deconstruction was described in detail. In the next section the deconstructed ILS literature is provided.

4.3 Deconstruction of literature

Table 4–1 below depicts a summary of the literature review. Within Table 4–1 the ILS elements are cross-tabled against the available ILS authors in the literature. As early as 1967, only a few elements were being used, however as the years progressed more ILS elements became more apparent. A more detailed listing detailing the aspects covered per ILS element and author is provided in Table 4–2.

Table 4–1: Summary of literature review

AUTHOR / ILS ELEMENT	DODD 4100.35 in Carpenter (NASA), 1967	NASA - Space shuttle program logistics management plan, 1974	Palguta, Bradley and Stockton (NASA), 1987	Hutchinson, 1987	Finkelstein and Guertin, 1988	MIL-STD-1369-A, 1988	Langford, 1995	Blanchard, 1992, 1998 and 2005	Army Regulation 700-127, 1999 and 2005	Jones, 1995, 1998 and 2006
Maintenance	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Support and test equipment (S&TE)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Supply support	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Packaging, handling, storage and transportation (PHS&T)	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
Technical data & documentation	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Facilities	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Manpower & personnel	Y	Y	Y	N	Y	Y	Y	Y	Y	Y
Training & training devices	Y	N	Y	Y	Y	Y	-	Y	Y	Y
Computer resources	N	N	Y	N	Y	Y	Y	Y	Y	Y
Reliability, availability and maintainability (RAM)	N	Y	N	Y	Y	Y	Y	Y	Y	Y
Configuration management	N	N	N	N	Y	Y	Y	Y	Y	Y
System/product operational requirement	N	N	N	N	N	Y	N	Y	Y	Y
Obsolescence	N	N	N	Y	Y	N	N	Y	N	Y
Disposal	N	N	N	N	Y	N	N	Y	Y	Y

Legend: ‘Y’ = discussed by author, ‘N’ = not discussed by author

Source: Carpenter (1967), NASA (1974), Palguta; et al (1987), Hutchinson (1987), MIL-STD-1369 (1988), Finkelsetin and Guertin (1988), Langford (1995), Blanchard (1991; 1998; and 2005), AR 700-127 (1999 and 2005), and Jones, J. (1995; 19988; and 2006).

Table 4–1 provided the background information concerning the deconstruction of the ILS literature, and whether the relevant authors furnished information regarding the respective ILS element. In the sub-sections that follow, each of the ILS elements will be discussed in depth. Additional definitions of the ILS elements will be provided and described. Maintenance support is discussed in the sub-section that follows.

4.3.1 *Maintenance support*

Within this section the deconstructed literature regarding this ILS element include, a discussion of the maintenance philosophy, maintenance concept, and maintenance plan. As with the definitions of logistics and ILS, there are numerous definitions of these topics, each of which will be discussed.

The maintenance philosophy is used to generate a maintenance concept, which in turn is used to generate a maintenance plan. Such a philosophy represents the organisation's outlook regarding what maintenance should achieve, including where the maintenance will be achieved, for example, a vehicle-servicing workshop will usually maintain vehicles at a normally fixed location. The maintenance philosophy for a high technology complex system will contain a policy as to whether a failed item will be repaired or discarded, and will determine if preventive or corrective maintenance for specific maintainable items will occur.

A maintenance concept embraces maintenance tasks to be performed at the different maintenance levels (or lines), repair policies for the levels of maintenance, maintenance task scheduling, organisational responsibilities, support elements, maintenance and support environments, requirements for effectiveness, and resource availability (Jones {1995:6.2}; Blanchard {1992:19}; Langford {1995:466}; and Biedenbender, Vryn and Eisaman {1993:199}). Blanchard (1992:19) and Langford (1995:466) further point out that such a concept includes criteria such as effectiveness. Finkelstein and Guertin (1988:101-103) mention that this concept requires a comprehensive system analysis.

Murthy, Atrens and Eccleston (2002:287) concur that a significant amount of the total cost of operating equipment in various industry sectors is the actual maintenance of the equipment. A multidisciplinary approach is consequently required for effective management of maintenance, especially when it has strategic significance from a business perspective. Such an approach displays the following important characteristics:

1) Commercial and technical issues integrated;

2) Mathematical models towards a quantitative approach;
3) Relevant information usage; and
4) Continuous improvement concerning the management of maintenance.

The outputs of the maintenance concept become inputs towards devising planned maintenance. This includes supporting a specific system or item of equipment by maintaining it, including making room for the necessary maintenance tasks. Maintenance planning further includes creating maintenance support concepts; it also involves various analysis techniques including level of repair analysis (LORA), failure modes, effects, and criticality analysis (FMECA), etcetera. In addition it involves creating a system maintenance structure. The appropriate support and actions to ensure that the system achieves its operational objectives also need to be determined. Repair criteria and maintenance tasks must be specified.

Various authors (Jones {1995}; Biedenbender; et al {1993:293}; Army Regulation {AR} 700-127 {2005:34-35}; MIL-STD-1369-A {1988:36, 58, 97}; DEF STAN 00-60 {2004:25}) suggest that maintenance planning involves generating maintenance concepts and defining maintenance requirements for the system over its life cycle at all levels of maintenance. It occurs during the acquisition process (AR 700-127 {1999:34}).

The maintenance concept, maintenance planning and the LSA results represent inputs to the maintenance plan and, according to Blanchard and Fabrycky (1990:466), *'A detailed plan for maintenance is developed from the maintenance concept, the ongoing maintenance planning effort accomplished throughout system design, and the results from the logistics support analysis.'*

LORA is performed to determine at which level the maintenance on a specific item will be performed. LORA assists in deciding the lowest possible level of repair that takes place for individual assemblies, sub-assemblies and components, etcetera. (Finkelstein and Guertin, 1988) LORA is also performed to determine where maintenance will be carried out: '*… LORA is used to evaluate a maintenance action to determine if it is economical and where the task can be accomplished most cost-effectively.'* (Jones, 1995:15.1)

A repair policy is set in place to determine whether an item which has failed, should be discarded at failure or actually repaired. Repair policies are defined to assess whether an item of equipment is non-repairable, partially repairable or fully repairable (Blanchard, 1995:116, 118, 120-121). Biedenbender, et al (1993:199) concur with Blanchard (1995) in that they propose three repair policies: discard or nonrepairable; partially discard; or repairable as a piece/part or as a whole. Langford (1995:468-469) also defines three categories (as Blanchard, 1995) but instead of using the word *'repairable'*, Langford (1995:468) uses the word *'reparable'.* Langford names his three categories as *'nonreparable item'*, *'partially reparable item'*, and *'fully reparable item'*.

Repair policies/constraints determine the above factors and the responsibility for each level of maintenance at O-level and maybe a contractor at D-level. Blanchard (1992:116) defines a repair policy as specifying *'… the anticipated extent to which repair of an equipment item will be accomplished (if at all).'* Determining whether a failed item should be repaired or discarded involves assessing different criteria. Decisions to repair or discard components, assemblies, modules, etcetera need consideration from both economic and non-economic points of view where various factors influence either decision and a trade-off study is normally conducted (Langford, 1995:476-477). Jones (1995:15.3) argues for a *'discard at point of failure'* approach where the repair cost offsets the discard cost.

Depending on the organisation and system there may be one, or more, levels or echelons or tiers of maintenance. Jones (1995:6.4) proposes three levels of maintenance, viz. at organisational, intermediate and depot level. Some organisations only recognise two levels of maintenance viz. organisational and depot, while other organisations may employ four levels, naming them one, two, three and four. Blanchard's nomenclature of depot level maintenance includes the supplier or manufacturer (Blanchard, 2004:141). The end user of the equipment performs the lower levels (simple tasks, or black box changing) of maintenance while the original equipment manufacturer (OEM) or contractor performs the higher levels (component replacement, depot) of maintenance. Organisational level maintenance involves troubleshooting, removing and/or replacing major components, and occasional equipment servicing, whereas intermediate level maintenance involves testing assemblies or units removed by the organisational level maintenance organisation, and replacing modules that have failed. Depot level maintenance repairs assemblies that cannot be repaired or are not able to be repaired at the organisational or intermediate level , where major refurbishment and overhaul are required (Jones, 1995).

Maintenance actions can either be preventive (scheduled servicing or inspections, i.e. daily, weekly, monthly, etc.), corrective (unplanned or unscheduled maintenance) or predictive (in terms of monitoring condition). Blanchard (2004:58) considers preventive and corrective maintenance and further includes as part of corrective maintenance *'all software maintenance that is not initially planned, such as adaptive maintenance and perfective maintenance.'* Langford (1995:468) further includes *'false failures'* within the category of corrective maintenance, wherein after testing it was shown that a fault never occurred, but was incorrectly indicated due to operator error, faulty diagnostics, etcetera.

Smith and Hinchcliffe (2004:20) define preventive maintenance as *'… the performance of inspection and/or servicing tasks that have been preplanned (i.e., scheduled) for accomplishment at specific points in time to retain the functional capabilities of operating equipment or systems.'* Smith and Hinchcliffe (2004:20) further define corrective maintenance as *'… the performance of unplanned (i.e., unexpected) maintenance tasks to restore the functional capabilities of failed or malfunctioning equipment or systems.'* Levitt (2003:201) defines predictive maintenance as *'Maintenance techniques that inspect an asset to predict if a failure will occur.'*

To determine which tasks should be performed as scheduled maintenance, a Reliability-Centred Maintenance (RCM) analysis is performed (the literature on this topic is extensive and includes Jones {1995 and 1995, 2nd reprint}; MIL-STD-2173 {[s.a.]}; Moubray {1992 and 1997}; Nowlan and Heap {1978}; Blanchard {1992 and 2004}; and Smith and Hinchcliffe {2004}).

A maintenance task analysis determines what support elements are necessary to perform a certain maintenance task. A maintenance task involves what is to be done after the policy is defined as to who undertakes maintenance at which level. A maintenance task analysis identifies the necessary resources (i.e. tools, manpower, spare parts, test equipment, time, facilities, and training). Each maintenance task is broken down into various sub tasks and the resources are then identified in order to perform the specific task (Jones, 1995 and 2006; Blanchard, 1992 and 2004).

An FMECA determines all likely failures (or possible failure modes) of a system or item of equipment, the effects of these failures and the criticality of these failures (Jones, 1995; MIL-STD-1629, 1980; and Blanchard, 1992 and 2004). The maintenance tasks (e.g. to calibrate, install, lubricate, etc.) are derived from the FMECA (these tasks are defined in MIL-STD-1388-2B), (Jones, 1995). (Incidentally MIL-STD-1629 {1980} was cancelled in 1998, AMSC Notice 3, 1998. MIL-STD-1388-2B was replaced by MIL-PRF-49506.)

A failure modes and effects analysis (FMEA) is similar to an FMECA except it does not contain the *'criticality'* component, where a *'failure mode'* is defined as *'… any event which causes a functional failure'.* (Moubray, 1997:53)

Various authors offer different viewpoints on and definitions of what constitutes a maintenance plan: this depends on their background, and knowledge. These definitions are described in the paragraphs that follow, and some of the full ones are provided in paragraph C.1 in Appendix C.

Planned maintenance can be regarded as determining the maintenance plan requirements, which include the levels of maintenance, the corrective and preventive maintenance actions, and evaluation of the maintenance concept. The U.S. Department of Defense Directive 4100.35 (cited in Carpenter, {1967:23}) defines planned maintenance as a management activity to restore failed equipment to an operable state at all maintenance levels for corrective and preventive maintenance; where the latter includes actions such as inspection, calibration, repair, storage, handling, servicing, corrosion control, modification, testing, and overhaul. NASA's (1974:4.1) Logistics Management Plan for the Space Shuttle Program stipulates that a maintenance plan be developed, evaluated, approved and updated; and provides for the evaluation and establishment of maintenance concepts, identification and analysis of support deficiencies, demonstration of maintenance support and evaluation thereof, and prototype maintenance demonstration evaluation.

Jones (1995:6.3) considers a maintenance plan as detailing how system maintenance will be performed. The UK MOD TLSD ([s.a.]) also views it as how maintenance will be performed, at what depth and level maintenance will occur, and at what periodic frequency the preventive maintenance will occur. Blanchard (1992 and 2004) describes the maintenance plan as including the infrastructure to support a system during utilisation (or consumer use phase) and throughout its life cycle. Palguta, Bradley and Stockton's (1987:73) viewpoint of a maintenance plan is that it sets the requirements for maintenance

Hutchinson (1987:196) views the maintenance plan as a document detailing maintenance support planning, which contains the maintenance requirements as identified by means of a logistic support analysis (LSA), and details the resources, methodologies and procedures necessary to support the system throughout its life cycle.

Finkelstein and Guertin's (1988:110) perspective is that such a plan contains the recommended maintenance levels, the responsibilities assigned to the various levels of maintenance, as well as which form of repair will be performed at these maintenance levels; furthermore the maintenance plan may alter from time to time, as the LSA will be reviewed constantly.

From a military perspective the U.S. MIL-STD-1369-A, (1988: 74) views the maintenance plan as including the maintenance concept of the system: it identifies the tools, skills, support and test equipment required at all levels of maintenance, expresses the weakness and strengths of the various support alternatives, and the effect of the support concept on the system; furthermore it includes the development of a depot maintenance plan and the assessment of centralized supply support and repair by single service support organisations in specific geographical areas. The U.S.

Department of the Army Pamphlet 700-55 (1989:9) views the maintenance plan as identifying the required levels of maintenance to be used, that is, the amount and type of maintenance to be performed at each level to maintain the system effectively and economically.

In this section the concepts of maintenance philosophy, maintenance concept, maintenance plan, preventive maintenance and corrective maintenance were deconstructed and discussed. LORA, FMECA, and RCM analysis techniques were also briefly described. In the next section a deconstruction of the ILS literature regarding support and test equipment is offered.

4.3.2 ***Support and test equipment***

A high technology complex system requiring any form of maintenance requires S&TE in order to perform the maintenance actions, be it a screwdriver or a complex electronic device such as an oscilloscope, which needs to be compatible with the system it is supporting. Test equipment can be categorised partly by its utilisation for actual maintenance or testing, while other categories include its application, cost, availability or complexity (Jones, 1998: 8.1).

These items of S&TE also require support, that is, some of these items need to be calibrated periodically. Scheduled as well as unscheduled maintenance needs to be supported by the S&TE. Since technology advances continuously, the S&TE must also keep up with technological advancements. Special test equipment becomes problematic as it itself requires special logistics support to maintain it. S&TE requirements need to be defined for all maintenance levels including scheduled and unscheduled maintenance: these items of S&TE also require logistics support and need to be compatible with the equipment on which they will be used (Blanchard, 2004). There are two categories of support and test equipment: common (general) and special (peculiar), (Hutchinson, 1987:25 and 192-197, and Blanchard, 1992:12), Jones (2006:17.1) defines 'these categories. Numerous authors provide different terms for this specific topic falling within the scope of S&TE and these are described below.

NASA – CASI (1974:5.1) identified as early as 1974 the necessity for S&TE events, where S&TE trade-offs need to take place, a support and test equipment concept must be established, a support equipment plan must be devised and approved, support equipment designed, the availability of support equipment verified, and the support equipment procured.

S&TE includes equipment to support an end item; including the support equipment logistics support acquisition (Biedenbender, et al, 1993:280). Further items of S&TE may include power units, special tools, special purpose vehicles, and test benches, to support a system or for diagnostic purposes (Carpenter, 1967:23-24). Galloway (1996:27) views support equipment as all the equipment necessary to support a system, including tools and multiple-use, maintenance, ground handling, and test equipment. S&TE also includes power-operated and manual equipment and the devices needed to support a system, (Langford, 1995:445). Monitoring, diagnostic, checkout, and handling equipment, even the work benches used to support the system are all classified as S&TE (Hutchinson, 1987:192).

From a military perspective U.S. AR 700-127 (1999:36) defines support equipment as including the acquisition and planning of the logistic support for this equipment; all the equipment (fixed and mobile) necessary to perform support functions, excluding equipment already integrated into the system. Categories of support equipment are defined as including tools, calibration equipment, automatic test equipment (ATE), maintenance and handling equipment, metrology, off- and on-equipment support equipment required for maintenance, test equipment, special inspection equipment, and plant equipment required for depot maintenance. Similar to this definition, UK MOD TLSD ([s.a.]) views S&TE as the fixed or mobile equipment needed to support a system, including tools, test equipment, calibration equipment, and metrology.

S&TE requirements for a system, as well as their impact on the other ILS disciplines and maintenance requirements for unscheduled and scheduled maintenance must be planned, developed, and identified. S&TE constraints need to be defined. The identification of the reliability of special handling devices, specified tools, checkout and test equipment, and monitoring equipment for unscheduled and scheduled maintenance is necessary, as is a trade-off study concerning manual versus automated equipment. (MIL-STD-1369-A, 1988:13, 22, 39, 59, and 76).

The test equipment used at the various levels of maintenance is not a matter of guessing what item to buy and at which level of maintenance to use it. Various factors play a critical role in determining these aspects. A depot level oscilloscope will not necessarily be purchased and used at organisational level. S&TE used in a depot level facility or workshop requires various factors of consideration. A trade-off analysis against which specific criteria are measured needs to be performed. S&TE evaluation involves a trade-off analysis of what S&TE is required and what S&TE is available at the various maintenance levels or is to be procured: these initial requirements are identified by means of the supportability analysis (SA) (Blanchard, 2004:358). S&TE should be designed or selected to fulfil the unique requirements and capabilities of maintenance and operating personnel and the product's operating environment, by means of the LSA process which determines the S&TE requirements, including standardisation of S&TE (Hutchinson, 1987:25 and 192-197).

Blanchard's 5th (1998:24 and 160) and 6th edition (2004:31 and 191) mentions that supportability analysis replaces LSA. The 4th edition (1992) mentions LSA. MIL-STD-1388-1A (1983) the DoD's

LSA guidelines, was subsequently replaced by MIL-HDBK-502 (1997), '*DoD Handbook Acquisition Logistics'*, which refers to SA. However, many companies and/or systems today still use LSA.

An S&TE plan should include aspects such as a full listing of all S&TE used at all levels of maintenance by the system, logistics support, software requirements, an acquisition and procurement plan for all new S&TE and COTS S&TE, a test, evaluation and integration plan ensuring compatibility between the S&TE and the system, and evaluation of S&TE to evaluate testing accuracy.

Such a plan includes a list, description, and quantity of all the support equipment (including test, measurement, and diagnostic equipment {TMDE} and tools) needed to operate and maintain the system, including any material handling, transport, power generating, lifting, test, and repair equipment (Department of the Army Pamphlet 700-55, 1989:9). Palguta, et al (1987:76) write of the necessity for a support equipment plan whereby software and support equipment requirements are identified and acquired in order to offer support at all maintenance levels.

Blanchard (2004:384) furnishes a more detailed description of what constitutes a test and support equipment plan, which includes:

1) A listing of recommended S&TE, calibration equipment, ground handling equipment, and critical tools for all maintenance levels;
2) An acquisition and procurement plan for the design, development, testing, production, and delivery of new items for end-users, including make-or-buy decisions and results, contractual requirements of suppliers, provisions for quality assurance, requirements concerning warranties, and the maintenance requirements of newly acquired items;
3) An acquisition and procurement plan for commercially off the shelf (COTS) S&TE and accessories. Other items that should be contained in this plan include the contractual requirements of suppliers, provisions for quality assurance, requirements concerning warranties, and the maintenance requirements of newly acquired items. Special provisions concerning defence systems associated with Government furnished equipment (GFE) should be considered;
4) An acquisition plan for computer resources to support the new and COTS S&TE;
5) An integration, evaluation, and testing plan ensuring compatibility between the S&TE and the primary system elements; and
6) An S&TE delivery plan, including installation and inspection at each location.

Blanchard and Fabrycky (1990:467) propose an additional point for inclusion in the S&TE plan, which includes data collection and analysis procedures, S&TE evaluation procedures, S&TE utilisation, S&TE maintenance, and S&TE reliability.

From a military perspective, the S&TE plan must include the maintenance, identification, logistic support, development, calibration requirements, and repair of the S&TE being used for the maintenance and operation of the system. The plan must also address all automatic test equipment (ATE) aspects used for system support. This further includes the ATE language used and any additional requirements for computer resources. The plan should also include provisions for equipment/system design with respect to built in test equipment (BITE) and interface connectivity, built in test (BIT), and external test points (MIL-STD-1369-A, 1988:97-98).

The UK MOD TLSD ([s.a.]) perceives a support equipment plan as setting the boundaries for the management activities in order to assess and conduct S&TE tasks, providing for all types of S&TE in order to support a system during corrective and preventive maintenance activities, but also considering minimising *‘special to type’* test equipment and special tools.

This section dealt with S&TE, beginning with various definitions. A number of selection factors were discussed as viewed by different authors, and finally the contents of an S&TE plan were discussed. In the next section supply support is dealt with.

4.3.3 ***Supply support***

Within this section the deconstructed literature regarding this topic is discussed. Numerous authors provide varying terms supporting this regard. The purpose of supply support is to ensure that the correct spares are at the correct location, at the correct time, and in the correct quantities in order to support a system. Without this a system cannot be maintained, and it will not attain its operational objectives (Jones, 1995:9.1). Supply support can be regarded as a management function using specific methodologies for the acquiring, receiving, cataloguing, transferring, storing, disposal, issuing, preserving, and packaging of not only secondary items, but also primary items, and also includes the initial provisioning of spares and the replenishment of spare and repair parts.

Clarity regarding the definition of *'spares'* and *'repair parts'* is necessary. Carpenter (1967:24) defines spares as assemblies or components for maintenance purposes, whereas repair parts are non-repairable components used to repair spares:

> *'Spares are components or assemblies used for maintenance replacement purposes in major end items of equipment. Repair parts are those* "bits and pieces", *for example, individual parts or nonreparable assemblies required for the repair of spares or major end items.'*

However, spares as defined by Hutchinson (1987:175) consist of spares (repairable), repair parts (non-repairable and disposable), and consumables; he defines spares as consisting of:

> *'… assemblies, subassemblies, components, parts, repair kits, and raw materials that are required or are anticipated as being required as the replacement for failed items during manufacturing, operation, maintenance, repair, or overhaul.'*

Hutchinson (1987:175) proposes that provisioning is *'… the process by which spares are identified'.* Here the provisioning process can be defined in relation to the ILS of the product as *'… the identification, documentation, procurement, and delivery of spares and repair parts'.* (Hutchinson, 1987:179)

NASA – CASI (1974:6.1) identifies supply support events as including supply support trade-offs, supply support concepts, developing requirements for a supply plan, establishing requirements and criteria for provisioning, evaluation of support and provisioning proposals, approval of the provisioning plan, preparation of provisioning test documents, approval of provisioned test items, procurement of spares and repair parts, and of particular stock for training, testing, and operational support, verification of suitability of repair and spare parts, validation and updating of the provisioning plan, identification of deficiencies in supply support, and procurement of repair and spare parts picked out by modification or change decisions.

Palguta, et al (1987:82) regard supply support as a management activity to identify initial and replenishment spares and repair parts, including assessing the needs for acquiring, storing, receiving, issuing, disposing, and transferring spare and repair items. Another set of authors (Finkelstein and Guertin, 1988:117) views it as a management activity to support preventive and corrective maintenance including packaging, storage, preservation, issue, cataloguing, disposal, receiving, and transfer of all repair and spare items. Galloway (1996:27) considers supply support as a management activity to procure, store, dispose, issue, transfer, catalogue, and record receipt of secondary items, including initial support. Biedenbender, et al (1993:280) also define supply support as a management activity, determining the requirements to support a system, not only for initial stock but also for replenishment stock.

Blanchard (1992 and 2004) adopts a wider perspective on supply support, which in the 6th edition (2004) of his book includes the terms *'spare/repair parts and associated inventories'*. Blanchard (1992 and 2004) describes supply support as including all repair parts, consumables, specific stock and inventory, and spares to support the main system, S&TE and other support infrastructures (handling and transportation equipment, facilities, training equipment, documentation, warehousing, associated personnel, and material distribution) which are needed to support the main system at all locations and maintenance levels during the utilisation and post-utilisation phases, taking into consideration the various lead times associated with the above mentioned items.

From a military perspective, U.S. AR 700-127 (1999:35) defines supply support as a management activity in order to determine the guidelines to receive, issue, acquire, store, disposal, catalogue, initial support provisioning, transfer, acquire; replenish; and distribute the necessary items. (MIL-STD-1369-A, 1988: 13, 22, 39, and 75) proposes that supply support consists of developing the supply support concept; ascertaining limitations and constraints; planning and developing supply level projections; storage sites; and replacement rates; requirements for TMDE; safety; surety; ordnance; facility requirements; security; the identification of operating hours; utilisation rates and failure rates. Furthermore it includes any applicable plan for the acquisition, cataloguing, preservation, packaging, receipt, issue, storage, and disposal of petrol, oil and lubricants, special tools, common tools, repair parts, secondary items, and ammunition.

A crucial consideration in achieving satisfactory equipment and/or system availability is to determine the '*range (number of different items) and depth, or scale (quantity of each item)*', of procured and stored spares to support maintenance; such methodologies include statistical projections or past experience, although each method does have its errors in estimation, and solving this problem requires being as accurate as possible and then adding sufficient safety-stock for an error margin (Jones, 1995:9.1 and 2006:18.1).

Concepts such as the inventory cycle, economic order quantities, etcetera can be found in operations management literature, and will not be discussed in this thesis.

Spares decisions are based on the probability of failure and the consequences of such a failure. Forms of inventory include one of repair and spare parts for maintenance, and one for production materials. The functions of an inventory include balancing demand and supply, geographic specialization, and safety stock. Inventory risk includes wholesale, retail and manufacturing risk.

Holding an inventory is necessary, since one needs to determine what should be stocked, the quantity to order, and when to reorder or order inventory. Inventory costs include storage, opportunity, transportation, order, and obsolescence costs. Various inventory-controlling systems exist, including those of economic order quantities (EOQ), order point, discrete lot sizing, materials requirements planning (MRP), just-in-time (JIT), and Kanban. The sparing decision is often based upon the availability of the spare or repair part, operating environment, and the location of the product (Hutchinson, 1987:92, 94-96, 103-104, 107-111, 114, 121, 125, & 176).

Hutchinson further explains sparing determinants as being dependent upon the LSA, and as including the '*determination of source, maintenance, and recoverability (SMR) codes*' and '*the determination of required sparing quantities*'. (Hutchinson, 1987:183)

According to Moubray (1991:101), a '… *factor which profoundly influences the consequences of failure is the availability of spares*'. Repair and spare part requirements depend on the variety or range of spares, the optimum quantity of each item, evaluation of quantities and selection based on the products' effectiveness, where an item's criticality is not necessarily based on its cost of acquisition, but rather on its function within a system, and where the risk of not having an item in stock encourages cannibalisation of items from other similar systems (causing further deterioration of the system), and/or the commencement of high priority supplier orders (Finkelstein and Guertin, 1988:117-119). It takes time to procure spares: if this could be performed instantaneously, it would not be necessary to maintain a stock of spares, but since spares procurement takes time (lead time), the latter determines the length of time necessary to repair an item, and the seriousness thereof (Moubray, 1997:32). Reliability centred maintenance analysis of maintenance requirements determines the resources (including spares) required to maintain the equipment (Moubray, 1997:20).

Langford (1995:367-8) suggests that inventory management in terms of certainty is ideal and a theoretical inventory cycle depicts just that; however, in the real world, uncertainty prevails. He therefore proposes six reasons for an inventory:

1) *'Promote production efficiency;*
2) *Provide a buffer against seasonal demands;*
3) *Assure availability of supplies;*
4) *Provide a hedge against price increases;*
5) *Reinforce stock locations near market centers; and*
6) *Accommodate unanticipated surges in sales.'*

A supply support plan identifies the repair and spare parts that are necessary to support a system and its respective S&TE at all levels of maintenance. It also describes how and where these spare and repair parts will be stocked. Palguta, et al (1987:76) define a supply support plan as describing repair parts and spares requirements for the system, where the maintenance plan and LSA are used as inputs to determine these requirements. Furthermore, the supply support plan includes provisioning requirements and procedures. Blanchard (2004) mentions that the supportability analysis (SA) determines the supply support requirements, and a supply support plan will identify and describe these necessary requirements; he (Blanchard, 2004:383) further proposes that a supply support plan should include the following:

1) A list of the repair parts, consumables, and spares needed for all maintenance levels;
2) An acquisition and procurement plan for commercially off-the-shelf (COTS) and new non-stock items to support the main system, including facilities, training devices, software, and S&TE;
3) Warehousing activities required to support the system;
4) Data collection and analysis plan in order to reduce waste, and improve the procurement cycle.

From a military point of view, MIL-STD-1369-A (1988:99) points out that a '*repair parts plan*' is based on the LSA: it includes an applicable spares and parts pricing formula, a spares and parts delivery schedule, recommended provisioning dates, a spares and repair parts procurement plan, the estimated number of spares and repair parts, risk and problem areas, and the packaging and preservation of spares. The Department of the Army Pamphlet (700-55, 1989:10) similarly refers to a spares support plan that lists all the repair parts and spares necessary for maintenance of the system.

Supply support was discussed in this section. In the next section packaging, handling, storage, and transportation are considered.

4.3.4 ***Packaging, handling, storage and transportation***

Within this section the literature regarding packaging, handling, storage and transportation (PHS&T) is discussed and deconstructed. Numerous authors provide different terms for this specific topic. The purpose of PHS&T is to ensure that an item is packed (including packing preservation and packaging) sufficiently in order to eliminate or reduce damage, adequate handling mechanism need to be used to move the packed item from one point tot another, this can be manually or using a crane or forklift. Furthermore the item needs to be stored in a storage location (fixed or mobile, and permanently or temporarily), which preserves the item for a certain period of time in a environmentally controlled environment. Finally the item needs to be transported either by air, sea, rail or road, and needs to reach its destination in a serviceable condition. The PHS&T requirements may be dictated by an item's design (Jones, 1995:13.2).

PHS&T's purpose can be seen as a methodology of activities ensuring that an item of equipment reaches its destination in a serviceable condition (Jones, 1995:13.1). Biedenbender, et al, (1993:282) regard PHS&T as specific ways of packaging, handling, storing and transporting of items of equipment for system support. PHS&T requirements for items within the military environment need to be packed to endure harsh environmental conditions, including shock levels and impacts, harsh operational facilities, climatic extremes, and shelf life constraints characteristically of military operations. (Langford, 1995:325).

According to Finkelstein and Guertin (1988:142-146) *'physical distribution and transportation'* (PD&T) '… *costs are the largest component of any commercial firm's total outlay …*', since PD&T complexities include selecting which carrier to use, meeting regulations, selecting modes, and obtaining best rate price structures; in addition PD&T concerns four essential matters:selecting a mode of transportation (truck; air; water; pipeline; or rail), carrier selection; scheduling; and routing, stocking the finished goods inventories, and control of inventory.

Blanchard (2004:14) views PHS&T as materials, policies, procedures, equipment and supplies, etcetera. necessary to support a system including its personnel, S&TE, and other logistic support elements in terms of PHS&T.

Galloway (1996:27) uses the term 'PHS&T' but not *'storage'*, though he does consider *'storage',* and *'preservation'* in his explanation, defining this as *'… the resources, processes, procedures, design considerations and methods of ensuring that the system and its support items are preserved, packaged, handled, and transported correctly. It includes environmental considerations, and preservation requirements for long- and short-term storage and worldwide transportation.'*

Finkelstein and Guertin (1988:144) regard '*physical distribution and transportation'* (PD&T) as the storage, transportation, handling, warehousing, administration, disposal, and obsolescence management which are necessary to support a system.

Packaging involves all the actions necessary to ensure an item is ready for shipment, including preservation, packaging levels, packing, the use of reusable containers, packaging data, and labelling (Jones, 1995: 13.9-13.10, 13.13 and 13.15). Moubray (1991:59) suggests that inadequate, incompatible or erratic packaging materials cause problems in packaging plants. Aspects that need consideration when packing an item are protection, sales promotion, storability, transportability, consumer security, identification and labelling, consumer communication, and environmental factors; furthermore other areas of expertise include production, materials handling, marketing, purchasing, legal counsel, traffic management, engineering, and storage (Langford, 1995:326-328).

From a military perspective the UK MoD, Defence Standard 00-60 (2004), mentions that special care and protection should be taken into consideration when packing Items containing electrostatically sensitive devices; furthermore all packages must withstand vibration, a topple test and a drop test, as well as environmental tests for rain, sand, immersion, wind, dust, and pressure. From another military point of view the U.S. AR 700-127 (1999:38) regards PHS&T as ensuring that the system and its support equipment are packaged, marked, preserved, packed, stored, transported, and handled for long-and short-term purposes, including equipment for materiel-handling purposes, customs requirements, container considerations, precautions concerning special movement (where standard off the shelf equipment cannot fulfil the requirement) and the mobility of the unit.

Handling and transportation requirements need to be defined for maintenance and operational functions, including the handling and transportation environments, the modes of transportation, reusable container requirement, and packing requirements (Blanchard, 2004:448).

NASA – CASI (1974:7.1) identifies *'transportation and handling events'* as a management activity, but does not mention packaging, or storage. These *'events'* include estimates of transportation and handling support capability, evaluation of support alternatives, establishing concepts, establishing criteria for evaluating handling and transportation, and the devising and approval of a handling and transportation plan (NASA – CASI, 1974:7.1).

Handling involves moving of an item of equipment over a short or long distance, manually or using some form of *'material-handling equipment'* (e.g. pallet jacks, cranes, forklifts, dolleys, and roller systems, etc.), in addition the equipment may weigh a considerable amount and its physical dimensions may hamper the physical manual movement of the item (Jones, 1995:13.15). These aspects need to be considered when designing the system or equipment and also when designing its handling system. Langford (1995:330-331) suggests some basic principles for material handling equipment/systems which include:

1) Minimum handling;
2) Handling materials over short distances;

3) Keeping routes on the same level as far as possible to avoid lowering and lifting;
4) Once in motion, keep materials moving;
5) Automatic and mechanical means of handling materials where possible;
6) Standardizing equipment that handles materials;
7) Gravity should be used where practical;
8) For mechanized systems, maximize investment in movement rather than stationary equipment; and
9) The ratio of '*dead weight to payload*' should be minimized.

Storage requirements depend on the quantity of material to be stored including the type of facility, where the storage facility size depends upon various factors, such as the reliability of the product, the technological content of the product, the replacement time of additional repair and spare parts, and the quantity of the product distributed (Hutchinson, 1987:22-23). The storage of items can be undertaken in warehouses, open areas (covered or not), a permanent or temporary storage environment, special facilities, and controlled environments (Jones, 1995:13.18).

Distribution and warehousing aspects that need to be considered are those of information transfer, movement, and storage (which includes public and private warehouses, where the former include bulk-storage, bonded, general merchandise, household goods, temperature-controlled, and commodity warehouses) (Blanchard, 2004:99-100). A warehouse can be evaluated according to certain quality indicators, which include shipping accuracy, and accuracy of inventory, (Frazelle; 2002:60-62, as cited in Blanchard; 2004:100).

Transportation includes the materials moved into the firm and the physical distribution of the finished goods to suppliers. In addition, transportation also exerts a considerable amount of influence where the firm is located (Hutchinson, 1987:21-22, 62, 69). Legal groupings of carriers include contract, private, common, and exempt carriers (Blanchard, 2004:94; Langford, 1995:343; and Hutchinson, 1987:67-68). Third party logistics firms/companies serve as partners with major carriers and provide a co-ordinating service (Blanchard, 2004:95-96):

Transportation cost and time are critical measures in determining whether and which type of transportation mode should be used, such as a highway (motor vehicles), railroad, air, waterway (ocean and inland) or air: intermodal transportation is any combinations of the above (Blanchard, 2004:94).

Various characteristics can affect the transportability of an item; these include its physical properties (length, width, and height), dynamic limitations (acceleration, deflection, securing, vibration, leakage, and skin loading), environmental (pressure, temperature, sterilization and cleanliness, and humidity), and hazardous effects (radiation, explosives, personnel safety, biologic or etiologic, and electrostatic) (Jones, 1995:13.2, 13.7-13.8).

A PHS&T plan describes all the policies, procedures, and requirements for PHS&T, preservation, and transportability requirements for the main system, its S&TE, and its other logistic support elements including spares and repair parts, personnel, etcetera. Palguta, et al (1987: 77), propose that a PHS&T plan should contain all necessary procedures required to transport, pack, store, handle and preserve a system and its system support.

Blanchard (2004:385), argues that a PHS&T plan should include at least the following:

1) A list of items (including dimensions, weight, cost-effectiveness) that need transportation, including the specific transportation mode;
2) Packaging methodology to be used for shipment (container types, environmental protection issues, and security measures); and
3) Safety provisions, precautions, and criteria for the storage, preservation, and handling of items.

The European Cooperation for Space Standardization (ECSS-M-70-A, 1996: 32) holds a different viewpoint regarding the contents of a PHS&T plan, viewing it as containing:

1) Considerations for manufactured hardware items (handling systems, transportation and storage means, containers, etc.);
2) Implementation of PHS&T services during deployment, utilisation and delivery phases; and
3) Required procedures for PHS&T services.

From a military point of view, the U.S. Department of the Army Pamphlet 700-55 (1989: 9-10) argues that a PHS&T plan identifies and describes packaging requirements for the transportation of the system/equipment. It specifies the material handling equipment to be used to load, store, transport, or unload, and prescribes the necessary data requirements (e.g. turning radius, lift height, and lift capability). It also specifies the type of storage (e.g. environmentally controlled, secure, and covered) needed for the system/equipment. Characteristics for transportability and transportation need to be described, which includes the modes of transportation. The UK MOD TLSD ([s.a.]) regards a PHS&T plan as containing applicable specifications, and regulations describing PHS&T requirements throughout a system's life cycle.

According to MIL-STD-1369-A (1988:22, 41, 78, and 99), an PHS&T plan should consist of the establishment of the functional requirements, actions and analysis (i.e. of constraints and modes) necessary to transport, store, package, preserve and handle all support items and equipment, including documentation defining all handling equipment, transportation (requirements, constraints, and responsibilities), packaging, storage (i.e. environmental storage conditions, and storage of hazardous materials and explosives), transportability criteria (i.e. transportation requirements for hazardous materials and explosives), preservation and labelling, and identification of potential problems in terms of sensitivity, fragility, overweight, outsize dimensions, or special requirements.

In this section various authors' descriptions of PHS&T and PD&T was described. Material handling system principles are suggested, and the section ended with descriptions of what a PHS&T plan should consist of. Technical data and documentation are discussed in the next section.

4.3.5 ***Technical data and documentation***

Within this section the literature regarding this topic is considered. Numerous authors provide different terms for it. Technical data and documentation can be regarded as all the necessary supporting data media and documentation (e.g. manuals, specifications), and other forms of information which are necessary to support a high technology complex system and its infrastructure. Galloway (1996:27) views technical documentation as encompassing all types of documented information to support computer software and hardware, whereas Carpenter's (1967:23) nomenclature in this regard is *'technical logistic data and information'* and includes all data and documentation obtained from contractors, Government [U.S.] agencies or departments, or prepared by Departments of Defence.

Finkelstein and Guertin's (1988:133-4) perspective on technical data and documentation is that it comprises the information supporting the design, operation, maintenance and support of a system or product. They do not consider computer programs as technical data; however the documentation and related software of the computer program are considered as such data. Biedenbender et al (1993: 281) considers technical data as technical/scientific data associated with a system, and, similarly to Finkelstein and Guertin (1988), do not regard computer software (or financial documents) as technical data, but they regard software documentation in this light.

Blanchard (2004:13) provides another term for technical data and documentation: he names it '*technical data, reports, and documentation*' and considers it as all the necessary procedures, data, instructions, and databases in order to support a system, including the continuous and repeated activity of collecting data, data analysis, and reporting regarding the performance of a system throughout its life cycle. Data as interpreted by Blanchard (1992:12) means data covering the main system, S&TE, training devices, facilities, and handling and transportation equipment. Blanchard (2004:367 and 385) further defines technical data as including all maintenance and operating procedures, calibration procedures, overhaul instructions, installation procedures, change procedures, change notices, checkout procedures, checklists, etcetera for the main system, S&TE, training devices, handling and transportation equipment, and software.

Langford (1995:417) provides yet another term for technical data and documentation, '*Logistics Technical Documentation*', which includes specifications (research, engineering and development, process, material and functional product specifications; product fabrication; and military applications), engineering drawings, parts lists, installation drawings, and technical manuals (component and equipment, system-level, and consumer manuals or booklets).

The technical manual as defined by Jones (1995:10.1) refers to documentation that instructs the user of equipment regarding how to maintain, operate, support and install the equipment; it includes installation manuals, maintenance manuals, and operator's manuals for all maintenance levels, such as repairs parts, illustrated parts catalogues, lists of special tools, and calibration procedures.

Technical publications should not just be associated with a book or a manual, but encompass all media (microfilm, computer displays, video tapes, etc), which assist the user to effectively and efficiently support a product, including set-up, assembly instructions, and operating instructions (Hutchinson, 1987).

Technical writers who are the authors of technical publications should write with the reader in mind (i.e. not to write at a level which the end user will not understand); furthermore the parts on which maintenance will be performed need to be identified, as well as the tools and S&TE requirements, and the personnel involved; furthermore, the location of these activities also needs to be known as this is where the activities will be performed (Hutchinson, 1987).

AR 700-127 (1999:36-37) defines technical data as consisting of the technical or scientific information needed to convert system requirements into logistics support and engineering documentation, and includes component lists, lubrication orders, identification orders, technical manuals, calibration procedures, software documentation, hazardous material documentation, tie-down and lifting references and/or pamphlets, safety procedures for explosives, provisioning documentation, repair parts lists, special tools lists, drawings, specifications, technical data packs, allocation charts, work requirements for depot maintenance, supply and technical bulletins, product support data and technical manuals providing guidance for transportability as well as human factors engineering (HFE) data, man-machine interface data, and psycho-physiological data.

Technical data is developed by taking a number of steps: engineering technical data consists of design data, maintainability, LSA, human factors and reliability. From this a technical data plan is developed, from which the preparation of various items takes place, including system operating procedures, maintenance procedures, installation and test procedures, maintenance and operating checklists, change procedures and notices (Finkelstein and Guertin, 1995).

NASA – CASI (1974:8.1) identifies technical data events as including the performance of trade-offs, establishing concepts, identifying deficiencies and developing a technical data plan, while according to Palguta, et al (1987:76) a technical data and documentation plan furnishes planning requirements for the technical data and documentation needed for operational support, maintenance, and training with respect to the system.

Blanchard (2004:385) lays down the minimum contents of a technical data plan, which include:

1) Describing the requirements for the technical data of each system item at each activity level;
2) Scheduling the development of significant data items;
3) Planning the acceptance of maintenance and operator procedures; and
4) Planning the preparation of change notices and the implementation of revisions into the manuals.

From a military point of view U.S. MIL-STD-1369-A (1988:22, 43, 77, and 100) suggest that a technical data plan should include computer resources, firmware, software, and concepts regarding maintenance support, incorporating the scope of required information (e.g. manuals, drawings, maintenance instructions, provisioning information, facilities, and operating instructions), including the identification and brief description of all the technical publications necessary for the support of operation, installation, supply, overhaul, maintenance, modification, and training with regards to the equipment/system. The U.S. Department of the Army Pamphlet 700-55 (1989:9) suggests that the technical manual plan should list all technical manuals needed for the support of the system, as well as its delivery to the end-user, but they also include the use of a translator, and verification of translations.

Technical data and documentation, including plans, were considered in this section. In the next section facilities are discussed.

4.3.6 ***Facilities***

In this section the literature regarding facilities is discussed. Numerous authors provide different terms for this specific topic and these are also discussed. Facilities can be regarded as any area which is used to support the system, be it a permanently fixed building, a tent, a cabin, a container, a hangar, open ground, etcetera. Galloway (1996:27) defines facilities as the acquisition, management and planning of the temporary or permanent property assets and real estate needed for system support. Jones (1995) suggests that the types of facilities include mobile, permanent, supply, special, training and maintenance facilities.

NASA – CASI (1974:9.1) identifies facilities as an ILS requirement including the evaluation of requirements for facilities and their support capability, identification of deficiencies with respect to facilities, and modification thereof, their construction, performance of facility trade-offs, establishing of a facilities concept, and developing and maintaining a facilities plan, including updates thereto.

The maintenance facility needs to be assessed for space for the required workload to be performed there; the repair actions that are expected should also be analysed; one needs to analyse the workload within the facility, while the requirements for personnel depend on the tasks performed at the facility. For overseas operations, the acquisition of a facility can take a while, and due to this long acquisition phase, new facilities should be identified as early as possible in the system's life cycle. Within an existing facility a gap analysis should be conducted; thereafter an analysis of the new requirements needs to be performed. Training facilities may call for special requirements, from computer space to sizeable and complex equipment with additional special requirements (Finkelstein and Guertin, 1995).

Blanchard (2004:448) argues that facility requirements need to be defined for the operation and maintenance of a system at all levels, as do shelf-space and storage requirements and environments, and warehousing requirements with regard to material distribution and flow. Furthermore the requirements for the environmental system need to be determined, including the requirements for a clean space (Blanchard, 2004:448 and 515).

Constructing a new facility can take a considerable amount of time, including studies to establish and define life cycle costs (LCC) impacts, improvements and locations, environmental impacts, space requirements, frequency and/or duration of use, security restrictions, and requirements for health and safety standards (AR 700-127, 1999:38).

Deciding where to locate one's facility is a difficult task and many factors need to be taken into consideration. Langford (1995) identifies four analysis areas:

1) The facility's mission or purpose (distribution or service centre, inventory storage, or production facility);
2) Locational gravitation (closeness to input source, or its output);
3) Economic considerations (transfer costs of raw materials, of finished items, and production costs); and
4) Sociopolitical criteria (dynamics of the workforce, attitudes of the community, ecology and environment, local infrastructure, political indicators and quality of life).

Various factors influence the effectiveness of a maintenance facility, and Langford (1995:475-6) regards these as condemnation rate, procurement lead time, reparable generation, restoration and referral rates, administrative lead time, logistics pipeline time, and turn around time.

From a military viewpoint, requirements for a facility need to be identified early in the life cycle of the system; additionally, S&TE facility requirements also need to be identified as soon as possible. A description of planned or known constraints and requirements for calibration, training facilities, storage, personnel facilities, utilities, and maintenance must be carried out (MIL-STD-1369-A, 1988:14, 45, and 79).

A facilities plan details the necessary requirements concerning buildings, storage, maintenance, plant, warehousing, etcetera. to support the main system and the support and test equipment and the necessary training space requirements. It identifies the facilities necessary for operation, storage, supply, testing, training, and maintenance, the identification of utilities, and the requirements for Petrol, Oil, and Lubricants (POL) storage (Department of the Army Pamphlet 700-55, 1989:10).

Palguta, et al (1987:77) define a logistics facilities plan as a document providing the information pertaining to the equipment and facilities needed to maintain, train, install, checkout, support, and store resources.

Blanchard (2004:386) argues that a facilities plan is developed in order to determine all the plant, warehouse, maintenance, property facilities needed to support the system, including personnel training, logistics and operational functions. This plan should meet enough criteria to ensure that the design of the facility is compatible with the main system and the supporting elements. The quantitative and qualitative information must be adequate for facility planners to:

1) Identify facilities and utility requirements;
2) Determine needs for capital equipment;
3) Assess adequacies and inadequacies of existing facilities;
4) Estimate of the cost of acquiring a facility and capital equipment.

This section discussed facilities as these relate to the support of high technology systems. In the next section manpower and personnel is discussed.

4.3.7 ***Manpower and personnel***

In this section the literature regarding manpower and personnel is discussed. Numerous authors' opinions in this respect (and that of training, where applicable) are described in this section. Some authors keep manpower and personnel, and training and training devices, separate, while others combine the elements and name the element *'personnel and training'*, which will be discussed in the following section (4.3.8). In this section the terms manpower and personnel, and personnel will be discussed. Manpower and personnel define the human resource requirements needed in order to support a high technology complex system. The driving force for personnel becomes the reliability of the system, the maintenance concept, and diagnostic routines designed into the system (Finkelstein and Guertin, 1988).

Jones (1995:7.1-7.2, and 2006:16.3-16.4) discusses the [U.S.] military structure applicable to personnel and the respective classification structure, which is categorized by skill speciality and grade (rank). The grade structure consists of three categories, viz. a commissioned officer, a warrant officer and an enlisted person (non-commissioned officer and lower-grade personnel). The skills speciality on the other hand ensures that the personnel assigned to a specific job possess the necessary experience and training to actually perform the job. The commercial sector uses a semiformal method of identifying skills by position and title, which is based on experience and/or training. Jones (2006:16.3) mentions the old adage of *'blue collar'* and *'white collar'* as a method of classifying people in an organisation.

Finkelstein and Guertin (1988) maintain that any new system or product or item of equipment delivered in the military or commercial sector calls for personnel with the applicable skills to maintain and operate the product. Military systems are becoming more complex, which requires higher skilled personnel, and those entering the military are at a lower educational level than in previous years. In the commercial sector things are a bit different, will the consumer be able to use the equipment and understand its operation, and should the equipment fail will it be repaired or replaced, and if it is to be repaired will a qualified technician be able to repair the equipment with the necessary documentation at hand.

Behavioural research and/or Human Factors Engineering (HFE) are applied to optimize the person-machine interface. Requirements include the optimisation of numbers, grades, and skills during the decision and planning process (AR 700-127, 1999:35).

In the military, personnel may have gained a certain skill level on a system, but technology continuously changes, and they may not have kept abreast of the new advances in technology, and will most probably require additional training if an upgrade were to be done on their system or if their system were replaced. Test and support equipment and other similar tools could therefore be built into the equipment to assist the maintenance personnel and simplify their work. The personnel needs for a system consist of the type and number of people needed, as well as their respective skill levels and how much additional training or education will be necessary. The lower the skill level, the more complex an item of equipment becomes to maintain (Finkelstein and Guertin, 1988).

Requirements and constraints will include gender mix, the cost of personnel, human performance, reserve and guard strength, inventory management, retention, any space constraints, and recruiting. Further to these, other areas for consideration include system safety, vulnerability and survivability, training, training devices, HFE, health hazard assessment, design equipment, support equipment, and personnel documentation. Identification of specific manning categories (e.g. maintenance, skill levels, operational support, administrative requirements, and restrictions) is necessary. One should also identify personnel performance variables (factors or constraints) affecting psychological considerations, workload, quality, environment and training (MIL-STD-1369-A, 1988:13, 23, 47 and 75).

According to Langford (1995) logistics personnel management is governed by the following elements:

1) The corporate mission, which consists of the company's organisational structure;
2) The logistics mission comprises the logistics governing factors, defining logistics functions and logistics organisation;
3) Logistics HR development concerns human resources qualifications (education, experience, human characteristics, technical skills, and professional certification), training and recruitment, and descriptions of logistics positions;
4) Human resources motivation encompasses motivation of personnel, optimisation of HR productivity, and performance profiles; and

5) The ability to adjust as corporate objectives and roles are redefined.

Logistics personnel requirements require a vast range of people with the different skills and backgrounds required to perform a variety of functions. The personnel requirements can be integrated into four categories: *'logistics requirements and planning', 'system/product design support', 'supportability analysis', and 'Transportation, distribution, and computer support'* (Blanchard, 2004:425-426).

Blanchard (2004) identifies three skill levels within his definition of maintenance task analysis (MTA), which is an essential part of supportability analysis (SA): basic, intermediate, and high skill (supervisory) skill level, although this nomenclature could vary between organisations and industries (Blanchard, 2004:509-510).

Error analysis, as Blanchard (2004:289-290) points out, occurs when human action exceeds acceptability limits. Errors of omission occur when human beings fail to perform a required task, while an error of commission occurs when the task is incorrectly performed. Possible causes of error are listed below:

1) *'Inadequate work space and work layout;*
2) *Inadequate design of facilities, equipment, and control panels for human factors;*
3) *Poor environmental conditions;*
4) *Inadequate training, job aids, and procedures; and*
5) *Poor supervision'.*

By analysing the tasks' frequency and complexity, the quantities of personnel and skill levels can be identified (Blanchard, 2004:285).

Palguta, et al (1987:76) combine manpower and personnel, and training, into one discipline and define it as a *'logistics support personnel and training plan'*; they reason that this plan should contain the quantitative and qualitative information to identify the requirements for maintenance personnel.

Manpower and personnel were discussed in this section beginning with definitions, general background information was provided and finally a '*logistic support personnel and training plan'* as defined by Palguta (1987) was discussed. Training and training devices are investigated in the next section.

4.3.8 ***Training and training devices***

Within this section the literature in this regard is discussed. Numerous authors employ different terms, which are also discussed.

NASA – CASI (1974) combines manpower and personnel, and training, into one discipline and names it *'personnel and training'*, pointing out that these issues require direction by management in the form of estimates of the personnel and training required, the establishment of a concept for personnel and training, and a plan detailing the requirements for personnel and training to be developed, implemented and updated continuously. A training package must be prepared, instructor-training needs to take place, maintenance and operational personnel need to receive training, training and personnel requirements may call for updating, skill levels need to be verified as well as the availability of trained personnel for maintenance and operations; any training and personnel deficiencies must be identified, the training package itself may need updating, and additional training may have to be conducted.

According to Jones (1995), qualified and trained maintenance and operator personnel are needed to support a system. A training programme ensures that personnel are qualified and that the training effort is developed in parallel with all the ILS disciplines. Such a programme must be developed in an extensive manner, and should contain all the relevant information to maintain and operate the equipment in an operational scenario. Four categories of training exist: training for operator personnel, maintenance personnel, supervisory personnel and instructors. Training consists of two phases, viz. initial training and sustainment training. The former provides training to maintenance and operator personnel to maintain or operate the system. As initial training is completed, then sustainment training begins and provides suitable personnel to maintain or operate the system.

The training concept is developed early in the system's life cycle. This consists of development and then of the presentation of training. A training programme consists of a training plan, training requirements, and methods of training (lectures, self-study, on-the-job {OTJ} training, and performance). Training materials include instructors' guides, OTJ handbooks, student guides, testing and training aids. Support includes training facilities, equipment and instructors. Types of training equipment include the actual system; or similar equipment, simulators, mock-ups, and audio-visual equipment (Jones, 1995).

Hutchinson (1987) does not distinguish between manpower and personnel, and training, using the nomenclature '*personnel and training'*. His view is that there is a distinct difference between training and education. According to Hutchinson (1987) training is specific and task-oriented, whereas education is more general and concept-oriented. Training is '… *specifically designed and developed …'* in accordance with the system or equipment, maintenance instructions, support and test equipment and technical publications (Hutchinson, 1987:24). Scheduled training must occur in order to ensure the availability of maintenance and operator personnel (Hutchinson, 1987).

Training prerequisites include identifying the training types (courses for maintenance and operator training; the length and content of O, I and D-level maintenance courses would differ for each level) and the student population (education, knowledge and prior skills). A training philosophy needs to be set in place, with training objectives (Hutchinson, 1987). The preparation for the training programme includes determining the actual scope of the training, the prerequisites for the course, instructor training, and instructor course preparation. Course supporting materials should include a training plan, an outline of the course, lesson guides, a training guide to be used for hands-on training, audio-visual aids, student material, and an examination (Hutchinson, 1987).

According to Finkelstein and Guertin (1988), training is necessary for maintenance, supervisory and operator personnel. To match the skill levels for operating products with educational requirements is important, especially for personnel already working at the company. The breadth and depth of training can be established if the maintenance personnel's knowledge base is known. Training devices are needed to support the actual training being performed. The two levels of training about which the manufacturer of a system should be concerned involve maintenance and operator personnel. Training will be required at all levels of support and is normally split between theory and hands-on/practical training. Training in the use of support and test equipment is just as important as training on the actual system. Determining the amount of training that is required involves the breadth, depth, and type of training programmes needed to support the system. Course documents that are normally needed by the student and instructor include a training plan, technical manuals, course outline, instructor's guide, and presentation material. Since military devices are becoming more complex, the man machine interface of the system must be kept as simple as possible (Finkelstein and Guertin, 1988).

The requirements (skill levels and quantities) for maintenance and operational personnel need to be defined. The establishment of the attrition rates of personnel is important, as is their effectiveness. Specification of maintenance and operational training requirements is of importance as are training programs, and requirements for training data. Training programs need to be planned. (Blanchard, 2004).

Training and training devices includes planning and developing training, training devices, training support, and training aids requirements. Training plans will include skill levels, training requirements, and quantity of personnel required. Personnel need to be trained in order to conduct installation, test and evaluation, checkout, maintenance, and operation of the system/equipment. The training program needs to identify its constraints, parameters and requirements, including the development of training devices and training aids. Training requirements need to be identified, as well as the identification of simulator requirements or specific devices or aids. Preparation of a training package, which includes the identification of maintenance and operational personnel tasks, establishment of learning levels and standards of performance, define requirements for cross training, identification of requirements for training aids, training devices, training courses and their associated support equipment, selection and training of instructors. Train personnel on simulator prototypes, prototype equipment, and simulator to support assembly, operation, installation and testing. Description of aptitude, training and skill requirements for personnel to maintain, operate and support the equipment/system. Course requirements include course length, course title, entrance requirements, functional area, class size, required training material and purpose of the course. (MIL-STD-1369-A, 1988:13, 23, 49, 62, 75, 77, and 100)

A training and personnel plan includes the number and type of personnel as well as the extent of training required to operate, receive, overhaul, deprocess, and maintain the system and support equipment (Department of the Army Pamphlet 700-55, 1989: 9). According to Blanchard (2004:384-5), a personnel and training plan consists of:

> *'The specific requirements for maintenance and support personnel in terms of quantities, skill levels, and job classifications by location are determined through the SA process. These requirements are compared with the quantities, skills, and job classifications currently within the user's organisation, and the results lead to the development of a personnel training plan (i.e., the formal training necessary to bring the user personnel skills to he level specified for the system). Although maintenance training is emphasized here, system operator training is sometimes included. This plan should cover the following:*
>
> 1) *The training of system operators – type of training, length, basic entry requirements, brief program/course outline, and output expectations. System operator requirements are often determined through system engineering and/or human factors program requirements.*
> 2) *The training of maintenance personnel for all levels – type of training, length, basic entry requirements, brief program/course outline, and output expectations.*
> 3) *Training equipment, devices, aids, simulators, computer resources. Facilities, and data required to support operator and maintenance personnel training.*

4) *Proposed schedule for initial operator and maintenance personnel training and for replenishment training throughout the system life cycle (for replacement personnel).'* (Blanchard, 2004:384-5).

Training and training devices as these relate to high technology systems were discussed in this section. In the following section computer resources are considered.

4.3.9 ***Computer resources***

Various authors provide different terms for this specific topic; these are also discussed.

Computer resources include all constraints, considerations, management procedures, issues, criteria, and requirements with respect to embedded or stand-alone computer software, firmware, and hardware, including the preparation of an ILS computer resource plan and ILS information management (MIL-STD-1369-A, 1988:23, 50, and 77).

Computer software should be organized into one or more *'hardware configuration items (HWCIs)'*, *'Computer Software Configurations (CSCIs)'*, or another type of software, where a system, prime item or segment typically consists of CSCIs and HWCIs. CSCIs typically contain *'top-level computer software components (TLCSCs)'* and each TLCSC contains *'lower-level computer software components (LLCSCs)'*, which in turn contain *'units'*, which are the *'smallest logical entities'* (Langford, 1995:455).

The factor of the reliability of computer resources comprises software reliability, reliability considerations, and sources of failure (specification, code, or design). Computer program error categories include: operational, logic, data handling, data input, data definition, data output, interface, computational, database, documentation and rejections of trouble reports (Langford, 1995).

Finkelstein and Guertin (1988) maintain that changes in computer programs must be properly maintained, documented, implemented and co-ordinated, where the computer software should be properly annotated, documented and identified. Diagnostic routines assist by checking all software applications used by the system. Diagnostic programs themselves need to be evaluated and any deficiencies corrected before the next deployment of the system. One should establish a baseline for software configuration. It is also important to know the location of all the products: therefore, periodic audits of the system should take place, and an audit trail be maintained. The support planning determines the support equipment, facilities and documentation training needed for all software.

Langford (1995:44) is of the view that, during the program development phase of computer resources, the following items should be considered with respect to the design and development of computer resources:

1) Identification and description of all computer software and computer programs needed for the main system;
2) Identification of all programming (computer) language specifications, specific requirements, and interfacing requirements with other computer programs, maintenance and operational software;
3) Definition of quality control and configuration management principles and procedures regarding software;
4) Determining and establishing software needs with regards to maintenance and operating functions;
5) Scope of software must be identified
6) Compatibility of operating and support software with the main system, interfaced systems and maintenance software; and
7) Testing, verification, and validation of the software regarding performance, maintainability, and reliability.

Palguta, et al (1987), refer to a *'Logistics Information System Plan'* which details all files, data elements, associated software and hardware, and reports which supply logistics support resources with historical data, control, status, management visibility, evaluation of performance, trends, allocation, and accountability.

A computer resources plan should identify equipment/system computer requirements, including software and firmware, and the capturing of data. It should further include a *'software configuration management plan'*, *'computer software change evaluation procedures'*, *'software corrective action procedures'*, documentation management plan, and *'computer software change control procedures'*. Methodology for the acquisition, testing, and evaluation of computer software, as well as the methods used in detecting software errors and the correction of errors, must be devised (MIL-STD-1369-A, 1988:14).

Blanchard and Fabrycky (1990:468) define a computer resources plan as providing a list of software programs for maintenance, including the modification procedures for such software programs. Blanchard (2004:386) provides a more detailed description of a computer resources plan which includes:

1) Identifying all software and computer programs needed to support the system;
2) Defining the programming (computer) language specifications, and requirements for compatibility with the existing programs;
3) Procedures for new software procurement or development;
4) Applying quality assurance and configuration management principles with respect to software, including change control procedures and management; and
5) Requirements for interfacing software and hardware.

Computer resources as these pertain to high technology systems were discussed in this section. Definitions of computer resources were given, and the computer resources plan was discussed. In the next section reliability, availability and maintainability are dealt with.

4.3.10 ***Reliability, availability, and maintainability (RAM), Dependability***

In this section the literature in this respect is discussed. Different definitions are also considered. One source (ECSS, 2002:17) regards dependability as *'reliability, availability and maintainability'*.

According to Smith and Hinchcliffe (2004:40) there are three specific constraints under which performance occurs satisfactorily: time, operational environment, and function.

The reliability of a system can be regarded as the likelihood of a system functioning as specified, under prescribed operational condition for a stipulated time frame. Langford (1995:43) defines reliability as *'… the probability that a system will perform its intended function for a specified interval under stated conditions.'* Blanchard (2004:47) defines not only a system, but also a *'product',* and includes *'the accomplishment of a mission' as a required function in a specific time frame.* Smith and Hinchcliffe (2004:40) use the word 'device' instead of system or product.

Reliability engineering requires some form of a checklist of items, such as identification of failure rates, use of *'standard high-reliability parts'*, keeping the design simple, parts meeting reliability requirements, identification of parts with *'excessive failure rates'*, a determination of wearing-out and shelf life characteristics (Blanchard, 2004:456).

NASA – CASI (1974) defines reliability and maintainability (R&M) events requiring logistics management direction as capability estimates regarding logistics support, undertaking trade-off studies of R&M, R&M requirements, evaluation criteria for R&M, performing R&M evaluation, defining R&M design guidelines, updating of the R&M plan requirements, allocation of R&M design goals, demonstration of the attainment of R&M goals and the adjustment of these (NASA – CASI, 1974). Where reliability can be regarded as the *'mean time between failures (MTBF)'* (Finkelstein and Guertin, 1988:55; Hutchinson, 1987:49; Jones, 2006:4.5; and Blanchard, 2004:33).

Various reliability activities must be performed during different life cycle phases, such as selection of components and their application, prediction of reliability, reliability block diagram or analysis, design reviews, FMECA, test and evaluation, and *'critical useful life analysis'* (Finkelstein and Guertin, 1988:56). Since systems have become more complex over the years, resulting in more equipment, which ultimately decreases the MTBF (Finkelstein and Guertin, 1988).

The three measures of availability are those of inherent, achieved and operational availability. Inherent availability can be regarded as a theoretical measure of how ready a system will be when needed (Jones; 1995:5.2 and 2006:10.2; Langford: 1995:72; and Blanchard, 2004:72). Blanchard (2004:72) further mentions that measures of inherent availability exclude maintenance actions and delay times. Achieved availability is similar to inherent availability, except that it includes scheduled maintenance (Blanchard, 2004:73). Operational availability is the actual measure of the system's availability (Jones; 1995:5.3 and 2006:10.5, Langford; 1995:82, and Blanchard; 2004:73).

According to Jones (2006:4:18) maintainability is a statistical prediction, which is influenced by environmental conditions and resource availability. He defines it as *'The probability that a failed item can be repaired in a specified amount of time using a specified set of resources.'* (Jones, 2006:4.18) Langford (1995:55), as with Jones (2006), adds a quantitative measure to the definition, that the system will be restored to its operational readiness, within a specified time period, using various resources. Langford (1995:55) defines maintainability as '*… the measure of the ability of a system to be restored to a specified level of operational readiness within defined intervals with the use of prescribed personnel, facility, and equipment resources'.*

Logistics delays cause major problems concerning mean time to repair (MTTR), since these are factors over which the maintenance personnel have no control. Langford (1995:64) defines a logistics delay as pertaining *'… to the time other than the actual repair time and scheduled maintenance time which contributes to the downtime of the equipment'.*

Langford (1995:64) further proposes that logistics delays are times *'… other than actual repair time and scheduled maintenance time which contributes to the downtime of the equipment …'* and are a *'… result of all delay factors that are not attributable to actual maintenance actions …'*. Logistics delay times include (Langford, 1995):

1) Administration activities;
2) Time for ordering and shipping;
3) Appropriation of the necessary skills;
4) Technical data research; and
5) Time for reviews and decisions.

Blanchard (1986:329) proposes a reliability and maintainability plan which should at least include prediction tasks, design reviews, requirements to test reliability, liaison tasks, programme functions pertaining to maintainability and reliability, analysis, requirements to demonstrate maintainability, and production phase activities regarding maintainability and reliability.

ECSS (2002:17) mention that a dependability plan shall be developed, implemented, and maintained, by the contractor throughout the life cycle of a system, describing how the programme dependability requirements [ECSS-Q-30B] will be complied with.

The various aspects of RAM: reliability, availability (inherent, achieved, and operational), and maintainability have been discussed. In the next section configuration management is discussed.

4.3.11 ***Configuration management***

In this section the literature is discussed. Configuration management consists of four functions: configuration identification, configuration control, configuration status accounting, and configuration auditing (Finkelstein and Guertin, 1988; Langford, 1995; and Blanchard, 2004).

1) Configuration identification

Langford (1995) mentions that an item selected for configuration management purposes is called a configuration item (CI). The process of identifying CI's relates to the need of controlling all or some of its physical or functional characteristics or the control of its interfaces with other CI's, therefore maintaining the engineering design and developing the applicable ILS products (Langford, 1995).

Finkelstein and Guertin (1988:94) offer a guideline in a checklist format to select CI's:

i) *'Is it a critical high risk, and/or a safety item?;*
ii) *Is it readily identifiable with respect to size, shape and weight (hardware)?;*
iii) *Is it newly developed?;*
iv) *Does it incorporate new technologies?;*
v) *Does it have an interface with hardware or software developed under another contract?;*
vi) *With respect to form, fit or function, does it interface with other configuration items whose configurations is controlled by other entities?; and*
vii) *Is there a requirement to know the exact configuration and status of changes to it during its life cycle?'*

If the majority of the above questions were answered *'yes'*, then the item should be classified as a CI.

2) Configuration control

According to Langford (1995) various forms of documentation exist with respect to change control, which provide the means for approving, disapproving, evaluating, initiating, implementing and releasing changes. These forms could be used for change proposal submissions, requests for modifications, and problem reporting. Engineering Change Proposals (ECP's) are recognised within the DoD, comprising Class I and Class II changes. Class I changes are major whereas Class II changes are minor (Langford, 1995). CI changes can only be enforced and approved by a configuration control board (CCB) and follow a stringent configuration control procedure (Finkelstein and Guertin, 1988). Blanchard, (1992:260) also uses the term *'change control board'*. Both Langford (1995:533, 535) and Finkelstein and Guertin (1988: 227-228) furnish an extensive listing of types of Class I changes.

According to Finkelstein and Guertin (1988) priorities are assigned to Class I changes, as follows:

i) Emergency priority;
ii) Urgent priority; and
iii) Routine priority. (Finkelstein and Guertin, 1988)

When temporary differences occur between the CI and the design specification and where the non-acceptance of permanent changes happen, deviations and waivers come into effect to allow these temporary differences (Langford, 1995). These terms are described below.

i) Deviation. *'… a written authorization granted during engineering development, prior to production, that permits a departure from a particular performance or design requirement stipulated by the functional baseline documentation.'* (Langford, 1995:535)

ii) Waivers. *'… a written authorization granted during production or when a system is pending delivery to the user.'* (Langford, 1995:535)

3) Configuration status accounting (CSA).

Finkelstein and Guertin (1988:94) define configuration status accounting as:

> *'… an engineering management information system that provides traceability of configuration baselines and changes thereto and facilitates the effective implementation of changes'.* (Finkelstein and Guertin, 1988:94)

Langford defines CSA along the same lines of thought, proposing that CSA includes:

> *'… the listing of the approved configuration identification, the status of proposed changes to configuration items, and the implementation status of approved changes after the functional and product baselines have been established. It consists of reports and records resulting from changes that affect the configuration item'.* (Langford, 1995:536)

4) Configuration audits

According to Finkelstein and Guertin (1988:99-100), configuration audits are:

> *'… used to validate that the developmental requirements have been achieved and that the product's configuration is identified. This is accomplished by comparing the configuration of the CI with its technical documentation'.* (Finkelstein and Guertin, 1988:99-100)

Two types of configuration audits are performed, as described below:

i) Functional Configuration Audit. *'The functional configuration audit (FCA) is a means of verifying that development of a CI has been completed satisfactorily and that the item functions as required'.* (Langford, 1995:540)

ii) Physical configuration audit. *'The physical configuration audit is the means of establishing the product baseline as reflected in the product configuration identification, and is used for the production and acceptance of units of a CI'.* (Langford, 1995:541)

Blanchard (2004:402 and 404) proposes a configuration management plan that he defines as follows:

> *'Configuration management is the process that identifies the functional and physical characteristics of an item during its life cycle, controls changes to these characteristics, and records and reports the processing of changes and their implementation status. It is a process of baseline management (considering the functional, allocated, and product baselines), defining the system configuration at any point during the design and development process. This definition, and the monitoring of changes, is critical to the logistics area.'* (Blanchard, 2004:402 and 404).

Configuration management and various definitions were discussed in this section. Finally a configuration management plan was described.

4.3.12 ***Obsolescence***

Obsolescence as described in section 2.15.14 is further elaborated on in this section. It was pointed out that planning in this regard is important.

According to Hutchinson (1987:104), obsolescence costs are *'… associated with inventory items that deteriorate while in storage and are not covered by insurance. They can also include losses when the item becomes obsolete through the introduction of a new model or design. Obsolescence costs should be approached with caution and allocated on a per-unit basis'.* However, insurance is a risk transfer method that also translates into cost for the company.

As Finkelstein and Guertin observe (1988:203), obsolescence can be intentional or the result of poor planning.

According to Pooler, Pooler, and Farney (2004:205) as technology advances, it results in nightmares for many industries and organizations, owing to the fact that components' life cycles are shorter than in the past, yet the actual system's life is increasing. This results in systems requiring more upgrades: in other words, previously components with a longer life cycle would have resulted in possibly two upgrades in a system's life cycle. At present, even though components have a shorter life, five or more typical upgrades might occur.

Another cause of obsolescence and escalating obsolescence management costs is the mismatch between the component's lifecycle and the system's lifecycle (Feng, Singh, and Sandborn: 2007:1). In addition, an organisation should ensure that the technology that it selects does not become obsolete in a short period (Water Environment Federation, 2005:214).

Numerous authors consider solutions to or mitigating factors regarding obsolescence. The *'logic trouble-shooting diagram'* or maintenance task analysis are techniques which can be used to determine obsolescence effects; the latter records replacement parts, S&TE data, and other relevant ILS information (Finkelstein and Guertin, 1988:205). It is important to note that *'effective maintenance programs'* are a fundamental input to obsolescence planning (Finkelstein and Guertin, 1988:205). In addition Blanchard (1983) proposed a *'maintenance analysis data'* section in his book *Logistics Engineering and Management* which furnishes information relating to the contribution of maintenance factors to obsolescence planning (Finkelstein and Guertin, 1988:205). Blanchard's (2005) concept of *'maintenance task analysis'* is similar in many respects to this author's (1983) *'maintenance analysis data'*.

Performance based logistics (PBL) constitutes a method to specify requirements for the availability of supply support or effectiveness, or even a requirement for operational availability (Jones; 2006:24.3, and Blanchard, 2004:10). PBL along with engineering change proposals (ECP's) and value engineering (VE) can be regarded as potential strategies to mitigate obsolescence (Acquisition Community Centre, 2004).

The United States Department of Defense (2006:3-9) perceives four principal factors in a successful DMSMS programme: commitment by management, an accurate bill of materials (BOM), financial resources, and a *'program centered around a team and predictive tool(s)'*.

However, Livingston (2000:7-9) proposes alternatives to DMSMS, which include: substitution, emulation, alternate source, *'life-of-type (LOT) buy'*, design modifications, and redesign. According to Howard (2002:6) a dual-path (short term and long term) approach should be considered when seeking a solution to non-electronic obsolescence. This dual-path approach entails (Howard, 2002:7):

1) Buying from stock;
2) Overhaul or repair;
3) Form, fit and function interface;
4) Redesign;
5) Reverse engineering;
6) Reclamation; and
7) Manufacturing in accordance with the technical data pack

ANSI (2007) furnishes a guide for obsolescence management including a cost-effective process to manage obsolescence, applicable to all phases of a product's life cycle.

Finkelstein and Guertin (1988:204-205) point out that *'phase-out and disposal requires an obsolescence plan …',* which comprises the following:

1) Identification of inventory and equipment requiring phase-out;
2) Determining the phase-out rate;
3) Deciding on criteria to be used to dispose of items in the development and design process;
4) Determining which components and equipment can be reused, or sold;
5) Ensuring disposal methods are in accordance with statutory regulations, including environmental, social, and ecological requirements;
6) Identifying the integrated logistics support (ILS) requirements required for phase-out, where the logistics support analysis (LSA), functional and feasibility analysis comprise important planning inputs;
7) Ensuring criteria for compliance with disposability are established in the design phase and detailed in the logistics support plan (LSP);
8) Assessing the ILS effectiveness with regards to obsolescence;
9) Evaluate the factors of obsolescence that result in it occurring earlier than expected. The following should be taken into consideration, amongst other matters:
    i) manufacturing defects;
    ii) *'inherent reliability characteristics'*;
    iii) operator-induced failures;

iv) secondary failures (for example, power);
v) mishandling errors;
vi) MTBF (mean time between failures) consistencies;
vii) *'lack of maintenance-induced failures'*;
viii) wear-out characteristics.

A logistics support plan (LSP) typically details information on supporting the system during operation and maintenance (such as within the case studies in this study). Blanchard (1986:447-461, cited in Finklestein and Guertin, 1988:200-201) argues that an LSP is developed from the preliminary LSP, and provides for all ILS related activities during the system's entire life cycle. The LSP should include the following:

1) Detailed sustainability and maintenance plan;
2) Reliability, [availability], and maintainability [(RAM]) plan;
3) *'Test and support plan'*;
4) Supply support plan;
5) *'Physical distribution and transportation plan'*;
6) Technical data plan;
7) Facilities plan;
8) Personnel and training plan;
9) System retirement plan; and
10) Detailed management plan.

Different support plans are applicable to the different phases of a system's life cycle. These include a logistics support plan (LSP), an integrated support plan (ISP), an integrated logistics support plan (ILSP), and separate ILS element plans. Factors influencing the plan which are applicable in each phase depend on the system requirements and operational environment, the country where the system is being utilised, the industry, contractual obligations, budget constraints, the end-user, and the experience and knowledge base of the end-user and contractor organisations. The operational systems used in the present case studies utilise an LSP which is discussed further in section 5.4.

Obsolescence, DMSMS, and the LSP were discussed in this section. Disposal is dealt with in the following one.

4.3.13 ***Disposal***

Disposal as described in section 2.15.15 is further elaborated on in this section. Planning for disposal of equipment is important since the latter affects the system, the costing of the system throughout its life, as well as environmental and social costs.

In 1988, Finkelstein and Guertin (1988:205) argued that waste management was a new field of study but that Leenders, et al. (1985) were an exception.

However, since 1988, the field of disposal and waste management has received a significant amount of attention. According to Leenders and Fearon (1997:415) *'… disposal problems have become more complex and important, as companies become larger, more diversified in product lines, and more decentralized in management'.* Apart from issues already mentioned, organisations which specialise in disposal or salvage operations often neglect the support and maintenance of the actual disposal equipment.

Environmental legislation may require that disposal and waste management costs be included in life cycle costing. According to Blanchard (1992:341) *'… system phaseout and the disposal of material are definite parts of the life cycle'.*

All organisations generate disposable material. Finkelstein and Guertin (1988:206-208) suggest that disposal categories include obsolete equipment and material; surplus material; waste; rejected services and products; safety stock; and scrap.

Leenders and Fearon (1997:421-426) propose similar disposal categories adding hazardous waste.

Disposing of materials or a system may offer a *'salvage saving potential'*, whereby reducing the number of disposable items results in a cost savings and a return on investment (Finkelstein and Guertin, 1988:206). According to these authors (1988:208), owing to more stringent regulations regarding waste management and improvements in environmental and ecological protection, waste management and disposal options are limited; consequently they (Finkelstein and Guertin, 1988:208-209) suggest strategic disposal options, which include dumping; selling to a dealer or other organisation; utilising within the organisation (using as is); returning to supplier; and *'reclamation for intra-plant use'*.

Leenders and Fearon (1997:429-431) list similar disposal options, adding that one could destroy, donate, or discard the item or material.

The majority of problems related to the effective disposal of items may be the result of a lack of initial planning; obtaining the services of a ILS professional who can plan and manage the disposal element of ILS has often been neglected, and *'as a result, no one has integrated all the various elements of* [integrated] *logistics support'* (Finkelstein and Guertin, 1988:210). Potential social responsibility opportunities must be explored, but be balanced with environmental and financial responsibility. According to Leenders and Fearon (1997:431-432), disposal procedures are required to protect the organisation against potential loss as a result of careless disposal methods.

Blanchard (2004:387) devises a system retirement plan, which includes equipment phase-out and retirement, disassembling and salvage of appropriate items, ILS; PHS&T; S&TE; facilities; data; and personnel requirements, amongst other ILS requirements. In addition the expenses of retirement, phase-out, and disposal comprise a necessary component of the product/total system's cost (Blanchard, 2004:82 and 468). Jones (2006:11.7 and 11.8) argues that an average system's disposal costs amount to one percent of total cost of ownership costs, and that disposal does not dictate decisions regarding the future cost of ownership; however, the total cost does consist of disposal costs, investment costs, research and development (R&D) costs, and operation and support (O&S) costs.

In this section disposal, material disposal and the cost element of disposal were described. In the next section the deconstructed literature summary is presented.

4.4 Summary of deconstructed literature

In this chapter the literature was discussed, and is presented in Table 4–2. In the next chapter a deconstruction of the case studies is offered.

Table 4–2: Deconstructed literature review

AUTHOR / THEME	DODD 4100.35 IN CARPENTER	PALGUTA, BRADLEY AND STOCKTON	MIL-STD-1369-A	ARMY REGULATION 700-127	BLANCHARD	JONES	HUTCHINSON	FINKELSTEIN AND GUERTIN	NASA	LANGFORD
MAINTENANCE	Philosophy. Plan. Procedures. Quality control. Preventive and corrective maintenance at each level. Serviceable condition, operable condition. Operable condition. Planned maintenance. Contract	Integrated planning. Maintenance requirements.	Evaluation of projected requirements. Maintenance concepts. Maintenance philosophies. Integrated contractor support or contractor logistic support. Maintenance actions. Maintenance capabilities. Maintenance planning. Testing & evaluation criteria. Performing activity for each level of maintenance. Maintenance program. Specified requirement. Maintenance concept. Planned maintenance tasks. All levels of maintenance. Maintenance concepts. Maintenance parameters. Maintenance constrictions. Maintenance actions. Maintenance functions. Systematic application of analysis. LORA. Qualitative and quantitative constraints. Update maintenance concepts. Maintenance planning integrated with LSA & LSAR. Maintenance plans. Maintenance engineering analysis: LSA, frequency, location, MTTR, design trade-off analysis.	System actions & support to attain system objectives. Specific criteria for repair. Maintenance levels. Interservice maintenance requirements. Contractor mix. Extent, duration and use of interim contractor support. Actions and support required for material fielding. Warranty considerations. Maintenance concepts. Maintenance requirements. Maintenance development. Maintenance planning. LORA. Minimize use of hazardous materials and the generation of waste.	Maintenance Planning. Levels of maintenance. Maintenance functions for each level. Level of repair policies. Criteria for the level of repair decisions. Criteria for test and support equipment at each level of maintenance. Criteria for personnel quantities and/or skills for maintenance. Responsibilities for maintenance. Effectiveness factors. Maintenance categories: Corrective & Preventive. Maintainability factors. Maintenance concept. RCM. LSA. Maintenance requirements	Maintenance planning. Concept for the maintenance program. Detailed maintenance actions. Maintenance plan. Levels of maintenance. O-level, I-level, D-level. FMECA maintainability information. Maintainability analysis. Maintainability allocations. Maintenance tasks/analysis. Maintenance types: Corrective & Preventive. LORA. RCM. LSA.	LORA. Maintenance plan. Maintenance concept. Levels of maintenance Preventive, scheduled, unscheduled, corrective	Concept or plan of product maintenance. Define the repair philosophy. Maintenance concept is developed to be consistent with the operational requirement. Maintenance support. R&M, & diagnostics defined. Assembly, module, part or component repair per level. LORA. Testing categories: no testing, internal testing, external testing, automated testing, semi-automated testing, manual testing. Physical considerations. Maintenance concept, then diagnostics routines and appropriate test points then location of test equipment. Levels of maintenance support. General overall repair policies and/or constraints. Maintainability analysis. Maintainability predictions. LSA	Maintenance planning. Maintenance concepts. Maintenance plan requirements. Maintenance plan. Maintenance engineering analysis.	Corrective, preventive maintenance. Organizational, Intermediate, Depot maintenance. Maintenance concept: levels of maintenance, governing philosophy (repair, remove-and-replace), responsibilities for each level, effectiveness factors (R&M), maintenance environment. Reparability (able to be repaired, recovered, or remedied) of components: Design influences - nonreparable, partially, fully), Economic influences - repair, next higher maintenance level, discard. Maintenance activity indicators: System supportability indicators (MTBM, MTBR, etc.) and Facility effectiveness indicators (TAT, Logistics pipeline time, etc.) Screening for repair or discard. Factors favoring repair: economic (inventory, transportation), noneconomic (reliability database, market responsiveness, weight, volume). Factors favoring discard: Economic (design, engineering, unit production cost), noneconomic (modification, skills, facilities). Maintenance reporting

AUTHOR / THEME	DODD 4100.35 IN CARPENTER	PALGUTA, BRADLEY AND STOCKTON	MIL-STD-1369-A	ARMY REGULATION 700-127	BLANCHARD	JONES	HUTCHINSON	FINKELSTEIN AND GUERTIN	NASA	LANGFORD
SUPPORT AND TEST EQUIPMENT (S&TE)	Facilitate or support maintenance actions.	Identifies and provides common support equipment and software requirements.	Plan, develop & identify all support equipment. Trade-off analysis. Support equipment constraints. Support equipment standardization. Support equipment interoperability. Reliability identification of S&TE. Requirements to perform scheduled and unscheduled maintenance. Logistic support requirements of S&TE. LSA requirements. Initial support and test equipment planning. Integrated S&TE plans. Availability.	All S&TE (mobile & fixed). SE for on-and off-equipment maintenance. Special inspection equipment/depot maintenance plant equipment. Planning and acquisition of logistic support for equipment. Environmental considerations influencing SE design and selection.	Support scheduled and unscheduled maintenance. Support and test equipment requirements for each level of maintenance. Support and test equipment items compatibility with the main equipment Reliability and maintainability features in the support and test equipment compatibility with those equivalent features in the main equipment? Logistic support requirements for the selected support and test equipment.	SE-special item (*special to type*), common, Operational SE. SE can be classified by its use for testing or actual maintenance or availability, application, complexity, or cost. Common support equipment. Special support equipment.	Unique requirements. Expected operating environment of the product. Capabilities of operating and maintenance personnel. Test equipment derived from LSA. S&TE must be designed or selected to complement the product, operating environment, and limitations of product support personnel. Test and support quantities. Common or general. Special or peculiar. S&TE Requirements: Levels of maintenance, corrective and preventive maintenance. Types of product failures. Selection Process: Need, elimination-design changes, simpler items, environmental, inside or outside, mobile-how frequent, scope & complexity, measurement parameters, accuracies & tolerances, existing S&TE at same location, COTS. Quantity determination per level of maintenance.	Scheduled and unscheduled maintenance. Support equipment planned & developed at same time as the product. Verification and validation of main equipment. Support the support equipment. State-of-the-art technology. Simplicity of design. Life cycle planning of support equipment. SE: some requirements, modified, developed, developed as peculiar to the end item, BIT and diagnostic SE in the end item, automated or semi-auto SE. SE trade-offs. Revisions to SE requirements. Calibration requirements. Special test equipment. Special training programmes. Special test equipment requires support. Develop test equipment so that prime item can be tested during production phase. BIT & diagnostic capabilities replaces special test equipment. Special test equipment adds a level of complexity to the support. Test equipment selection: Maintenance technician, physical factors, R&M, Logistics, Application.	Perform S&TE trade-off. Establish SE concept. SE Plan requirements. SE plan evaluation criteria, Approve SE Plan. Update SE requirements, design SE, Verify availability of SE. Identify SE deficiencies. Procure additional SE. Modify SE.	All equipment (manual and power-operated) and assistance devices. S&TE evaluated for three levels of maintenance. Standard equipment availability and consideration instead of newly deisgned equipment. S&TE compatible with prime, host equipment. R&M of S&TE equivalent to those of prime equipment. Logistics support requirements for S&TE must be defined. Test and maintenance software requirements must be clearly defined. S&TE allocation should be based on the minimum, essential capability necessary to support the prime system. Automatic self-test provisions should be incorporated in the prime equipment where cost-effective and technologically feasible. Direct fault signals (visible or audible) should be incorporated in the system to provide indications of malfunctions. Continuous performance-monitoring features should be incorporated in the prime system, where appropriate. System test points should be incorporated in the system design to enable fault isolation beyond the limitations of the self-test features. Test points in the system must be accessible and must accommodate the level of maintenance being accomplished. System test points should be functionally grouped to facilitate sequential testing steps, signal flow, testing of similar functions, or frequency of use, in the case of limited access. Test points should be provided for direct test of reparable items in the system. Test points should be adequately identified, labeled, and illuminated (where possible). At the system level, every malfunction should be detectable by means of a simple "no-go" indication. This feature validates the thoroughness of testing the system. The maintenance software must be designed so as to provide accurate diagnostic data.

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SUPPLY SUPPORT	Spares. Repair parts.	Spare and repair parts requirements. Provisioning procedures and requirements. LSA process and the maintenance plan in the development and definition of spare and repair parts requirements.	Plan, develop projected supply levels, replacement rate & storage site. Life cycle support. Initial provisioning. Ordnance, safety, security, surety & facility requirements. Timely provisioning distribution & inventory replenishment of spares, repair parts & supplies. How supply support and provisioning program shall be conducted. Specified requirements. Identification of planning inputs. Identification of utilization rates, maintenance level or category, operating hours, failure rates and repairable program planning. Identification of provisioning requirements, technical documentation and maintenance planning inputs, such as Source Maintenance and Recoverability (SMR) codes. Identification of the relationship of supply support to the outfitting and fitting out of the system/equipment and its supporting resources. Identification of appropriate LSA requirements.	Acquire. Catalogue. Receive. Store. Transfer. Issue. Dispose of secondary items. Provide for initial support. Acquire, distribute, and replenish inventory. Impact of human-factor engineering. Availability of principal and secondary items. Special disposal or demilitarization information or instructions.	Spare/repair part requirements for each level of repair. Types and quantity of spare/repair parts compatibility with the LORA Types of spare/repair parts that are appropriate for the estimated demand of a given location. Spare/repair part requirements optimized to the maximum extent possible? Test and acceptance procedures for spare/repair part/units. Risk of stock-out in terms of mission requirements and cost. Inventory safety stock levels. Provisioning cycle. (Order frequency). Supply availability requirement.	Operation and maintenance actions. Spare and repair parts. Identification and acquisition of the materials necessary to support the operation and maintenance. Scheduled and unscheduled maintenance. Correct parts available when and where required in the quantities necessary to support maintenance. Range and depth, or scale. Past experience or statistical projections. Repairable items. Nonrepairable items. Initial spares. Correct amount of spares in the appropriate locations to support maintenance. Inventory cycle. Economic Order Quantity.	Spares decisions: probability of failure, consequences of failure. Inventory: forms (material for production & spare and repair parts). Functions of inventory: geographic specialization, decoupling, balancing supply and demand, and safety stock. Inventory risk: manufacturing risk, wholesale risk, retail risk. Inventory cycle. Elements of inventory cost: transport, storage, obsolescence, opportunity, order. Production and inventory control: monitoring inventory levels, EOQ's, order point, discrete lot sizing. MRP. JIT. Kanban. Probability of failure & the consequences. Availability of replacement items. Decision to spare also influenced product location and operating environment. Spares from LSA. SMR (source, maintenance and recoverability) codes. Spares quantities determinants: LSA data, MTBD (demand), budget constraints.	Scheduled and unscheduled maintenance. LSA: Reliability predictions and modelling techniques. Maintenance concept: needs of the supply or spare parts requirements. Piece-part or modular replacement. Cost and feasibility of increased realiability versus reduced quantities of repair parts. Effect of human engineering design on maintainability. Corrective and preventive maintenance. Repairable and non-repairable items. Stock levels of spares compensate for repairable items undergoing maintenance. Added stock levels of spare and repair compensate for the pipeline and procurement lead time for item acquisition. An additional stock level of spares compensates for condemning or scrapping repairable items. Range or variety of spares. Optimum quantity for each line item. Evaluation of the impact of item selection and quantities on the effectiveness of the product. Demand prediction and identifying the consequences of not leaving the spare or repair part in stock. Criticality of an item. Identify replacements. Replacement and repair frequencies, repair and resupply cycle times, condemnation factors and unit cost. Stock-out promotes cannibalisation. Preparation of stock lists and procurement documentation. Component obsolescence and modifications. Initial supply of spares. Small number of items may represent a large percentage of the total inventory value EOQ.	Perform supply support trade-offs, establish supply support concepts, develop supply support requirements. Provisioning requirement criteria, evaluate provisioning and support proposals, approve provisioning plan, prepare provisioning documents. Procure spares, repair parts, and special supplies for testing, training, and to support operations. Verify suitability of spares and repair parts, validate/update provisioning plan, identify SS deficiencies, update provisioning plan. Procure spares and repair parts identified by change/modifications decisions.	On-hand stocks, safety stock, in-transit assets, speculative stocks, dead stocks. Inventory management under certainty and uncertainty. Inventory levels, make-or-buy decisions, LIFO/FIFO. Items with - high rates of sale, high values per unit, costly storage requirements, high strategic value to customers. Production inventory control - master schedules, production sequencing, production smoothing. Production resources planning - MRP I (Materials Requirements Planning), MRP II (Manufacturing Resources Planning), JIT (Just-In-Time), Kanban. Quantitative Applications to Inventory Management - Total inventory cost, Economic order quantity. Inventory costs - order placement or setup costs, inventory investment, warehousing costs, inventory risks, stock-out costs.

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PACKAGING, HANDLING, STORAGE AND TRANSPORTATION (PHS&T)	-	Procedures and resource requirements.	Identify actions and requirements necessary to establish capability. Functional requirements analysis & actions. How the PHS&T program shall be conduted. Description of how each specified PHS&T requirement shall be complied with and performed. Documentation defining all PHST. Environmental considerations and system/equipment impacts. Cost considertaions, location, duration of transport, and general PHST. LSA requirements.	Resources and procedures of short- and long-term requirements PHS&T resources, techniques, and methods for both short- and long-term storage. Planning and programming the details associated with movement of the system. Establishment of critical parameters and constraints. Special security requirements. Geographic and environmental restrictions. Special handling equipment and procedures. Impact on spare or repair parts and basic issue item storage requirements. PHS&T technologies and resource-intensive PHS&T procedures. Environmental impacts and constraints.	Special provisions. Transportation and handling requirements for both operational and maintenance functions. Transportation and handling environments. Modes of transportation. Requirements for re-usable containers. Packing requirements and procedures. Storage and shelf space requirements for spare/repair parts. Storage environments.	PHS&T not to reduce its effectiveness Plan, develop, and manage the activities necessary to ensure that equipment is serviceable when it reaches the ultimate user and when it is moved by the user during its operational life. Packaging Levels - level a (maximum), level B (intermediate), level C (minimum). Preservation. Packing-common, selective, and special. Reusable containers. Packaging data. Marking. Handling: Distance, weight, Dimensions, Material handling equipment. Storage. The short- or long-term storage of items. Temporary or permanent facilities. Warehouses, covered in open areas, uncovered in open areas, in a controlled environment, or in special facilities. Transportability - Physical limits, Dynamic limitations, Environmental limitations, Hazardous effects. Modes of Transportation.	Transportation - to & from firm. Transport may influence the location for a firm. Transportation logistics: the firm, suppliers, the market, the needs, transportation capabilities of available logistics channels. Storage: type of facility, stored quantity. Size of storage facility: quantity of product distributed, technological content of the product, product reliability, replacement time for additional spare and repair parts. Transport modes: road, rail, water, air, pipeline. Grouping of carriers: Common, contract, exempt, private carriers. Transportation rate structures.	Develop and support an effective transportation strategy. PHS&T complexities: carrier to choose, selecting optional modes, requirements within regulatory structure, best rates, objectives for profitability and sustainable growth against the requirements for quality, excellence and customer service. Transportation costs are the largest component of any commercial firm's total outlay. Nature of PHS&T. Information systems. PD&T managers issues: finished good inventory positioning (where to stock): forward or backward. Transportation mode selection. Scheduling, routing and selecting a carrier. Inventory control.	Transportation and handling concepts, provide transportation and handling input to support plan requirements.	Packaged to withstand most severe climatological conditions, and impacts and shock levels. Economic significance of packaging. Conditions of austere operational facilities, shelf-life constraints, climatic extremes. Packaging objectives - Protection, labeling and identification, sales promotion, consumer security, storability, transportability, environmental factors, communication to the consumer. Packaging design - Production, purchasing, engineering, materials handling, storage, marketing, traffic management, legal counsel. Packaging design interface with pallet configurations. Packaging design - Protection against rough handling and resulting shocks, dirt, dust, moisture, and other contaminants. Relationship to environment in terms of disposability and multipurpose use. Facilitation of production, marketing, and logistics functions. Packaging design - Prevention of pilferage and tampering. Safeguarding of hazardous materials. Simplification and more efficient piling, warehousing, and inventory control through use of standard shipping units. Packaging design - Definition of unit of sale. Provision of product identity and definition of quality, quantity, size, color, etc. Assistance to marketing by means of "miniature billboards" which are provided by attractive shipping containers. Building of customer goodwill through convenient, reusable containers.nMaterials handling - principles: minimum handling, short distances, material routes on same level to avoid lifting and lowering, once in motion materials should be kept moving, use mechanical and automatic means of materials handling, standardize materials handling equipment, gravity flow, maximum investment in movement rather than in stationary equipment, minimize ratio of dead weight to payload.nMaterial handling methods: Manual systems, mechanized systems, automated systems, combination systems. Principles of pallet utility.nWarehousing and storage - Legal status of warehouse: public or private warehouse. Field or bonded warehouse.nWarehousing operations: Role in logistics system, commodities handled, public vis-à-vis private warehousing. Warehouse design, economics of warehousing, functional warehouse cost standards - warehouse volume, warehouse dispersion. Transportation - Legal forms of transportation: common carriers, contract carriers, exempt carriers, private carriers. Operational modes of transportation - rail, highway, water, air and pipeline. Intermodal. Transfer facilities - packaged freight terminals, container terminals, bulk commodity terminals, carrier equipment transfer facilities. Transportation regulatory agencies and their jurisdiction. Transportation rate structure.

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DATA & DOCUMENTATION	Production, engineering data, prints and drawings. Standards, specifications, technical manuals. Changes and modifications. Inspection and testing procedures. Performance and failure data. Other forms of technical logistic data and information.	Technical data and the documentation planning.	Data requirements (software and firmware) plan & compile. Technical data planning, development & delivery. Technical publication plan and delivery. Establish recordable information required, generated by, planning performance cycles. Specific description of how the technical data program shall be conducted. A detailed description of how each specified technical data requirement shall be complied with and performed. Technical data support requirements, breadth of information required. LSA requirements. Identification of computer resource support requirements. Update requirements and operations, support and maintenance task requirements.	Scientific or technical information necessary to translate materiel system requirements into discrete engineering and logistic support documentation.	Operating and maintenance documentation requirements. Maintenance documentation compatible with the levels of activity performed at the location where these documents are used. Operating and maintenance documentation written to the skill levels of the individual accomplishing the functions covered by all procedures. Operating and maintenance documentation specifies the correct support and test equipment, spare / repair parts, transportation and handling equipment and facilities. Documentation includes special warning notices in areas where safety is a concern.	Technical publications. The technical manual: Operator's manual, maintenance manual, parts manual.	Well-documented library of technical publications. Technical publications department - all printed, & media (microfilm, video tape, computer displays & so forth). Technical writers need to write for the reader, not themselves. Writing (technical or nontechnical) is judged on two levels: level of literacy & level of competence. Intended audience: "evaluate" readers' educational level. Scope of the publication. Job analysis: facilitates the writing task, provides a task listing and task analysis. Identifying parts upon which maintenance can be performed. Identification of tools & test equipment, personnel requirements. Specific activity data.	All recorded information. Accurate determination of the requirements for the acquisition and timely utilisation of adequate technical data. Engineering technical data: design data, R&M, human factors, LSA. Verification & validation. Equipment publications, manuals, discs storage. Any mistakes or inaccuracies in the documentation could represent a major fault in the operation and use of the product.	Performtechnical data trade-offs. Establish technical data concepts. Establish technical data concepts. Identify technicall data deficiencies.	Specifications: research, development and engineering, product, functional, product fabrication (military application), process, material specifications. Engineering drawings: level 1 conceptual design drawings, level 2 developmental design drawings, level 3 production drawings, parts lists. Installation drawings. Technical manuals: equipment and component manuals, system-level manuals, consumer manuals.

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FACILITIES	Physical plants.	Facilities planning	Long lead time for military facility approval. Facility requirements on operational and maintenance analyses, system/equipment design, specifications. Facilities required: support system testing, training, operations, storage & maintenance. Facilities requirements for all levels of maintenance. Facility requirements and constraints. Specific description of how the facilities program shall be conducted, managed and implemented to meet all contract requirements. A detailed description of how each specified requirement shall be complied with and performed. Facilities planning based on operational, training, supply and maintenance analysis and planning, identification of new construction requirements, identification of rehabilitation requirements, identification of support and test requirements. Define types of facilities, locations, space needs, environmental factors, fixed and mobile requirements, existing facilities. Identification of appropriate LSA requirements.	Required permanent or semi-permanent operating and support facilities. Comprehensive planning. Studies to define & establish impacts on LCC, facility locations and improvements, space requirements, environmental impacts, duration or frequency of use, safety and health standards requirements, and security restrictions. Utility requirements, for both fixed and mobile facilities, with emphasis on limiting requirements of scarce or unique utilities. Human-factor engineering.	Performance of maintenance functions at each level. Facility requirements necessary to support the system. Facility requirements necessary for maintenance at each level. Operational and maintenance facility requirements minimized to the greatest extent. Equipment environmental requirements associated with operational and maintenance facilities.	Land and buildings, structures, or utilities built on or in the land. Fixed or mobile. Permanent facilities. Mobile facilities. Maintenance facilities. Supply facilities. Training facilities. Special facilities.	Warehousing, training, spare & repair parts, size & location. Maintenance facility: Size, expected repair actions, workload determinants, personnel requirements. Sizing maintenance facility, office space that may be required in meeting personnel needs, alternative functions such as training. Expected repair actions: O, I & D level. Operational scenario assumption, 6 hour per day 7days per week, etc. Number of times corrective action is expected considers the total number of all maintenance actions. Workload determinants. Personnel requirements: function of the tasks that must be performed and the time required for their performance. Warehouse facility.	Commercial & military. Overseas operations, facility acquisition takes much longer. Implemeting change to an existing facility will require a review of its present status. Then an analysis of new product requirements. Training facility - computer aided instruction.	Evaluate requirements and define facilities support capability. Perform facility trade-offs. Establish facilities concept. Provide facilities plan requirements, establish facility plan. Facilities constructions or modification, approval and start and completion thereof, activate operational support facilities, validate/update facilities plan, identify facilities deficiencies, initiate action to modify facilities. Identify facilities deficiencies, initiate action to modify facilities.	Facility decision considerations: Purpose, or mission, of the facility; principle of locational gravitation, economic factors, sociopolitical criteria. Purpose of facility: production facilities, distribution centers, service centers, inventory storage points. Principle of locational gravitation: Transfer-production trade-offs, (close to source of input or output). Effects of economic factors on location: costs of transfer of raw materials and working stocks from the sources to the production plant, costs of transfer of finished products from the plant to market centers, production cost (labor, taxes, utilities, facility costs, etc.) at the plant site. Economic factors: impact of logistics on commercial locations (quantitative and graphic analysis techniques) - isotims and isodapanes. Sociopolitical criteria: quality of life, workforce dynamics, community attitudes, political indicators, environment and ecology, absorptive capacity of local infrastructure.

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MANPOWER & PERSONNEL	Logistic Support Personnel - Manpower & Personnel & Training. Qualitative and quantitative skill, performance requirements, and standards. Training requirements, standards, curricula and devices. Human factors engineering requirements. Personnel protection.	Qualitative and quantitative information to identify maintenance personnel requirements by numbers, skills other qualifications and training requirements.	Qualitative & quantitative personnel requirements & constrictions. Manpower & training objectives. Number, type & skills of personnel (maintenance and operational). Task frequencies times & steps manhour planning & operating hours for all personnel specially skill & accuracy standards. Requirements, restrictions, constraints, parameters - manpower & personnel integration. Manpower & personnel goals, objectives & constraints to generate specific manning plans, establish design drivers & influence design of emerging system/equipment. Establish program defining requirements for fully trained operation & maintenance personnel. Constraints & requirements. Human dimensions. Specific description of how manpower and personnel program shall be conducted, managed and implemented to meet all contract requirements. A detailed description of how each specific requirement shall be complied with and performed. Identification of manning determination, restrictions and incentives, and their derivation from system/equipment design activities. Identification of specified manning criteria categories.Identification of variables of personnel performance factors or constraints affecting quality, psychological considerations, training, workload & environment. Identification of LSA requirements. Identification of specific constrictions, qualitative and quantitative personnel limitations and other requirements.	Identification and acquisition of military and civilian personnel with skills and grades. Manpower requirements are developed and personnel assignments are made to meet mission support demands throughout the life cycle. Manpower requirements are predicted on accomplishing the logistics support mission in the most efficient and economical way. Requirements to optimize numbers, skills, and grades.	Maintenance of the system (or product) and its associated test and support equipment. Operational & maintenance personnel requirement. Pre-requisites for personnel expertise levels. Operational and maintenance personnel requirements minimized to the greatest extent possible. Personnel skill levels defined at each location and compatability with the complexity of operational and maintenance tasks. Personnel effectiveness factors. Client personnel involvement in the various levels of maintenance.	Military and civilian personnel needed to support operations and maintenance and the skills they require. Personnel in the military services are classified in two ways, grade (rank) and skill specialty. Commercial skill specialty. By position title rather by an identification number. In some cases assignment to a position is based on experience, and in others it may be based on some combination of training and experience.	-	Appropriate skills to operate any new piece of equipment or product, which skill levels. Complexity of system. Replaceable or repairable and will a duly described, accepted or certified technician be capable of repairing the device as prescribed by the documentation. Skills & skill levels. How much additional training is needed? Determine the tools which could be designed into the equipment to simplify the work to be performed. Number and type of maintenance personnel. Skill levels of individuals. Type of new skills level requirements needed and how much additional training is required. Time they are alloted to work on problems, the more problems they experience, or the worse the reliability of the product becomes, the harder it is to ensure that the equipment will be properly maintained and kept in operation. The impetus for personnel and manpower becomes reliability, maintenance concept and designs of the diagnostic routines as part of the maintenance concept. Lower the skill level more complex device becomes. Train people properly, have the right skill levels at the right place, at the right time, doing the appropriate job, as this has a direct impact on the corporation.	Estimate of skill requirements. Establish personnel and training concept. Personnel and training requirements, personnel and training plans, determine personnel availability. Prepare training package, instructor training, operations and maintenance personnel training. Verify required skill levels, verify availability of trained personnel for operations and maintenance. Identify personnel & training deficiencies. Update training package, conduct additional operations and maintenance training.	Definition and understanding of the corporation's mission, its products, and its organization as a goal-oriented activity. Logistics mission: factors governing role of logistics - type of business transacted, importance of logistics costs, need for trade-offs among logistics cost categories, complexity of the logistics network, nature of corporate strategy, capabilities of logistics managers; Definition of logistics functions; organization of logistics - project organization, matrix organization, centralized/decentralized logistics management function, organization for logistics services. Development of Logistics Human Resources: Logistics HR qualifications - experience, education, professional certification, technical skills, human characteristics. Development of position descriptions; recruitment and training. Management of HR: employee motivation; optimizing HR productivity - productivity indicators, performance appraisal, rewards and recognition. Personnel performance profiles. Interrelationship of logistics disciplines and job categories.

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TRAINING AND TRAINING DEVICES	Logistic Support Personnel - Manpower & Personnel & Training. Qualitative and quantitative skill, performance requirements, and standards. Training requirements, standards, curricula and devices. Human factors engineering requirements. Personnel protection, including safety, survival, clothing, escape and rescue and sterss pertaining to the system or equipment.	Qualitative and quantitative information to identify maintenance personnel requirements by numbers, skills other qualifications and training requirements.	Qualitative & quantitative personnel requirements & constrictions. Manpower & training objectives. Contractor incentives. Develop & plan training and training devices & training requirements. Quantity, skill levels & all training requirements. Identify operator & maintenance training equipment locations, training devices. Requirement, constraints, & parameters. Training programs, training aids & devices & support, training equipment, aids or devices and its requisite support. Establish need for training & training devices to support instruction or support simulator settings. Formal training program. Specific description of how the training program shall be conducted, managed, implemented, and supported to meet all contract requirements. A detailed description of how each specific requirement or training tasks shall be complied with and performed. Determinations of training aids, devices or training equipment requirements and their logistic support. Determinations of training aids, devices or training equipment requirements and their logistic support. Identification of specifc training requirements Identification of specific aids or device or simulator requirement. Identification of training constraints for the program. Identification and scheduling of planned training, planning conferences and the generation of lesson plans and appropriate update. Identification of LSA requirements. Training package: Tasks-skill, learning levels and performance standards, cross training, training effectiveness,	Processes, procedures, techniques, training devices, and equipment used to train civilian and military personnel to operate and support a materiel system. Qualitative and quantitative requirements for the training of operating and support personnel throughout the life cycle of the system. The design, development, delivery, installation, and logistic support of required embedded training features, mockups, simulators, and training aids are also included. Assess the training burden associated with competing materiel designs Develop an effective training program. Design training devices that effectively replicate the end item and minimize the training burden.	Formal training includes both initial training for system/product familiarization and replenishment training to cover attrition and replacement personnel. Training requirements. Training programs. Training programs compatibility with the personnel skill level requirements and specified for the optimum performance of the operational and maintenance tasks. Training aid equipment requirements.	Trained and qualified operators and maintenance personnel. Necessary devices and equipment to support training are also developed by this group. Training objectives. Operator training. Maintenance training. Supervisor training. Instructor training. Initial training. Sustainment training. The overall concept of how training of personnel who will operate and maintain a new item of equipment will be conducted. The concept may consist of a curriculum. Training development. Training presentation. The training program: training plan, training requirements, training methods. Training methods. Lectures. Performance. On-the-job training. Self-study. Training materials: Instructor guide. Student guide. OJT handbook. Training aids. Testing. Training Support includes: Instructors. Facilities. Training equipment. Equipment types being as follows: Actual equipment. Audiovisual equipment. Mock-ups. Simulators.	Training must be specifically designed and developed to be consistent with the product that is being produced, the applicable technical publications, the maintenance instructions, and the test and support equipment. Scheduled to assure the availability of operators and repair technicians as needed to support the product. Prerequisites to training: Types of training (O, I, D), student population prior skills, knowledge & education. Training philosophy. Training requirements analysis. Training program. Supporting course materials.	Operator, maintenance and supervisory personnel. Levels of maintenance have been defined. Skill levels possessed by people already employed, matching the education requirements with the skill levels. If knowledge base is not known the depth and breadth of training will be very difficult to establish. Training devices. Levels of training. Interface between man and machine must be kept as simple as possible. Training will be required at all levels of maintenance. On the equipment and support equipment Training split between theory and practical. Determining how much training is required: type, depth & breadth, i.e. number of hours. Field service personnel also be training personnel. Training plan, course outline, instructors guide, technical manuals, other presentation material. Training consists of processes, procedures techniques, training devices and equipment. Crew training, new equipment training, initial, formal and OJT and logistics support training.		

AUTHOR / THEME	DODD 4100.35 IN CARPENTER	PALGUTA, BRADLEY AND STOCKTON	MIL-STD-1369-A	ARMY REGULATION 700-127	BLANCHARD	JONES	HUTCHINSON	FINKELSTEIN AND GUERTIN	NASA	LANGFORD
COMPUTER RESOURCES	-	Logistics Information System Plan.	Plan and develop computer requirements (firmware and software). Computer resource constraints, considerations or criteria & define associated support concepts to include Interim Contract Support (ICS), Contract Logistic Support (CLS), standardization & other such requirements. Computer data records required and equipment needed to support information & contract systems to meet technical support management needs. Document recordable information. Description of how the program shall be conducted, managed and implemented to meet all contract requirements. A detailed description of how each specified requirement shall be complied with and performed. Determination of data needs, equipment and resources and their requisite support. Identification of requirements for data formats, substance and methods of processing. Identification of validation requirements, verification and delivery of data on time to meet needs. Communications identification and points of contact for people involved in the management process. Identification of system/equipment computer resource criteria, restrictions and requirements. Identification of LSA requirements.	Facilities, hardware, software, documentation, manpower, and personnel needed to operate and support computer systems. Computer resources include both stand-alone and embedded systems. Planned, developed, implemented and monitored by a computer reources working group. Computer reources support is available where and when needed. Computer resource requirements do not exceed available or achievable manpower resources and personnel capabilities.	Computer resources. Computer equipment and accessories at each level. Document processes addressing computer and software resources. Computer software configuration management system. Computer software and data management security system. Software reliability.	Computer resources support (software and firmware).		Changes associated with computer programs are properly documented and maintained. Change properly coordinated and implemented. Audit trail is always maintained. Computer software being generated will be properly identified, annotated and documented. Specific diagnostic routines designed to help check all of the software applications being used in the product. Diagnostic programmes are fully evaluated and deficiencies are corrected prior to future deployment. Software configuration baseline exists. Know where all of the operating products are and what the configuration baseline of each product is. Periodic audits need to take place. Control over computer software. Plan highlighting documentation training, support equipment and facilities required for the software.		Computer facilities, equipment, software, firmware, associated documentation, skilled personnel, and supplies needed to operate an embedded computerized subsystem. Influences of computer resources on Logistics Engineering: Computer programs and software identified; computer language requirements; specifications; requirements for compatibility with other programs; software configuration management procedures and quality control provisions; Influences of computer resources on Logistics Engineering: System software requirements for operating and maintenance functions identified and developed; software complete in terms of scope and depth of coverage; supporting software compatibility with equipment interfacing with host system; Influences of computer resources on Logistics Engineering: operating software compatibility with maintenance software; computer language requirements compatibility for operating and maintenance software; software clearly described; software tested, validated, and verified with respect to reliability, maintainability, and performance. Organization of computer software: Hardware Configuration Item (HWCI), Software Configuration Item (CSCI) - Top Level Computer Software Component (TLCSC) - which consist of Lower-Level Computer Software Components (LLCSC) - consisting of other LLCSC or units. Software development cycle: Software life-cycle phases - software requirements analysis, preliminary design, detailed design, coding and unit testing, Computer Software Component (CSC) integration and testing, CSCI testing. Reliability of computer resources prospective of software reliability, software reliability considerations, software failure sources - specification faults, design faults, code generation, computer program errors. Hardware and software interaction.

AUTHOR / THEME	DODD 4100.35 IN CARPENTER	PALGUTA, BRADLEY AND STOCKTON	MIL-STD-1369-A	ARMY REGULATION 700-127	BLANCHARD	JONES	HUTCHINSON	FINKELSTEIN AND GUERTIN	NASA	LANGFORD
RELIABILITY, AVAILABILITY AND MAINTAINABILITY (RAM)	-	-	Reliability apportionment and predictions. Reliability - Redundancy used in design. Contribution of planned preventive maintenance procedures to increase reliability. Effects of PHS&T, shelf life, and maintenance on reliability. FMECA data . LRU's with a failure rate greater than a certain percentage. Components with a known useful operating life and their frequency of replacement. Maintainability - System Mean Time To Repair (MTTR). Maintainability - System Mean Active Maintenance Downtime (MAMDT). Maintainability - System Mean Time Between Maintenance Actions (MTBMA). Maintenance or turnaround tasks with a MAMDT greater than a certain period.	RAM are key design parameters that influence both the performance (mission effectiveness and system availability) and economics (support requirements and LCC) of the materiel system	R&M Interfaces. R&M factors. System R&M. R&M allocation. Reliability testing. R&M Plan. Maintainability demonstration. Reliability block diagram. RCM. System wear-out period. Failure modes and effects. Item failure rates. Parts with excessive failure rates. Mean life. Adequate derating factors. Minimize equipment design complexity. Protection against secondary failures. Minimal adjustable components. Avoidance of friction or pressure contacts in mechanical equipment. Elimination of critical-useful-life items. Component cooling provisions. Effectiveness factors.	R&M. Operate without failure and how long it will take to fix an item when it fails.. Reliability. The probability that an item of equipment will perform its intended mission without failing, assuming that the item is used within the conditions for which it was designed. Maintainability. The probability that a failed item can be repaired in a specified amount of time using a specified set of resources. (statistical prediction). MTBF, MTTR Availability, or the ability to use a system when required, Inherent, Achieved, Operational.	Reliability, probability, performance as expected, time, specified conditions. MTBF. Tools of reliability: redundancy, simplification of design, high reliable parts, derating of parts, environmental constraints. Failure rate curve, bathtub. MTTR.	Trade-off of reliability against other desired qualities. Reliability vs total system cost. MTBF = Reliability. Reliability activities: Selection and application of components, Reliability analysis, FMECA, Reliability prediction, Critical useful life analysis, design review, reliability test and evaluation. Maintainability: Maintainability analysis, Maintainability predictions, LSA, Design reviews.	R&M logistics support capability. R&M Trade-off study. Gross R&M Requirements. R&M Evaluation criteria. R&M evaluation. R&M design guidelines. R&M design goals. Demonstrate attainment of R&M goals.	Reliability: Operating cycle, average operating intervals, failure frequency. System Life-Cycle Reliability: Phases of system reliability, bathtub curve. Maintainability: mean corrective maintenance time, mean preventive maintenance time. Corrective maintenance: mean corrective maintenance time, MTBF, failure rate-lambda; preventive maintenance: mean preventive maintenance time, MTBM (preventive), preventive maintenance frequency. Logistics/admin dealy: mean logistics delay time, MTBL (logistics delays), logistics delay frequency. General maintenance: mean active maintenance time, MTBM, MDT (downtime). Availability: inherent, achieved, and operational
CONFIGURATION MANAGEMENT	-	-	MIL-STD-483. Configuration management policies, responsibilities, authority, relationship and interfacing activity with overall management organization. Integrated logistic support representation on CCB, integrated logistic support authority in design approval, ECP, trade-off studies. Configuration documentation.	ECP	Configuration management process where equipment, documentation, supply support, support and test equipment and facilities relate to each other in such a way that equipment/project performance goes ahead unhindered. Numbering system that addresses all aspects of the system. Business processes available, approved and audited. Engineering Change Proposal (ECP) process. Items, documents and support equipment traceability.	CCB &ECP	-	Elements of configuration man: configuration identification, configuration control, configuration status accounting, configuration auditing. Selection of prime and lower level configuration items (CI). Configuration control: CCB's, Class I, II or III, ECN's/ECP's, Configuration Control Process. Config status accounting is a MIS that provides traceability of configuration baselines and changes thereto and facilitates the effective implementations of changes. Configuration audits: Validate that the development requirements have been achieved and that the product's config is identified. FCA & PCA Physical nature of parts, assemblies, equipment or products, or any combination of these.	-	Configuration identification: Configuration items - functional configuration item, product configuration item; establishing configuration baselines - functional, product baselines. Configuration control: Engineering Change Proposals (ECP's) - Class I & II; Deviations and waivers; Specification Change Notes (SCN); Notes Of Revision (NOR). Configuration Status Accounting (CSA) - Engineering management information system: Configuration item drawings, CSA database, Configuration Identification Manual (CIM), Engineering release and correlation of manufactured products, Engineering release record. Configuration Audits: Functional Configuration Audit (FCA), Physical Configuration Audit (PCA). Configuration Management Process; Configuration Control Board.

AUTHOR / THEME	DODD 4100.35 IN CARPENTER	PALGUTA, BRADLEY AND STOCKTON	MIL-STD-1369-A	ARMY REGULATION 700-127	BLANCHARD	JONES	HUTCHINSON	FINKELSTEIN AND GUERTIN	NASA	LANGFORD
OBSOLESCENCE	-	-	-	-	System phase-out and disposal costs. System/equipment retirement and material phaseout plan.	Disposal costs: Inventory closeout, PHS&T, data management, refurbishment, demilitarization, waste management.	Obsolescence cost.	Designed-in Obsolescence. Obsolescence plan. Disposal categories: surplus material, scrap, obsolete material and equipment, waste, rejected products and services,safety stock. Disposal strategic options: Use as is, reclamation for intra-plant use, sale to anotherfirm, return to vendor, sale to dealer or through a broker, dumping.		
DISPOSAL	-	-	-	Minimum hazardous materials. Recycleability. Reuse of product. Environmentally preferable products. Waste prevention. Ultimate disposal Use of recovered materials Pollution prevention.	Environmental qualification	Disposal	-	-	-	Corporate safety policies and procedures. Design Safety. Hazards Analysis.

Source: Blanchard (1986; 1991; 1992; 1998; and 2004), Jones, J. (1995 and 2006), Finkelstein and Guertin (1988), United States Army Regulation AR-700-127 (1999 and 2005), Carpenter (1967), Palguta; Bradley and Stockton (1987), Hutchinson (1987), United States DoD MIL-STD-1369-A (1988), and NASA (1974).

'A man should look for what is, and not for what he thinks should be.'

– Albert Einstein.

'A world without nuclear weapons would be less stable and more dangerous for us all.'

– Margaret Thatcher.

'microprocessor to be used on aircraft, where it can be employed in navigation; digital flight control and weapons fire control systems; radar data processing; and airborne battle management systems.'

– Paul McNulty

CHAPTER 5 PHASE 2 RESEARCH: DECONSTRUCTION OF CASE STUDIES

5.1 Introduction

This chapter documents the deconstructed case studies used for the study. In chapter 3, section 3.3.2, the research design of phase 2 of the research is described, and entails the deconstruction of the case studies. Phase 2 of the research consisted of evaluating six case studies within the high technology industry (military and industry) in the South African context. The case studies included key areas requiring more focused research. This chapter focuses on the deconstruction of these case studies, and their evaluation for key areas requiring further focused research. The specific cases were selected based on the fact that integrated logistics support (ILS) originated in the military environment, hence the case studies on three military high technology systems. However, ILS has over the years also been applied to industrial systems, for example, petrochemical, power generation, and satellite earth stations. Case studies of specific industrial systems have been used to compare their integrated logistics support systems (ILSS) to case studies of similar systems within a military environment. The case studies are evaluated at system level and delve deeper into ILS related issues, which include:

1) Maintenance;
2) Support and test equipment (S&TE);
3) Supply support;
4) Packaging, handling, storage and transportation (PHS&T);
5) Technical data and documentation;

6) Facilities;
7) Manpower and personnel;
8) Training and training devices;
9) Computer resources;
10) Reliability, availability, and maintainability (RAM);
11) Configuration management;
12) Obsolescence; and
13) Disposal.

Six case studies of four different high technology systems were used for the study. Before presenting the actual case studies, it is important to provide some introductory technical background regarding the systems that were used for the case studies.

Two sets of two case studies are of similar systems, but used in different operational environments. Two case studies are of two military radar systems based in two different developing countries (South Africa and a South American country). A further two case studies are of radio navigation systems, that is, a military system and an industrial system, both based in South Africa. Another two case studies include one of a satellite earth station and one of a developing modular nuclear reactor, based in South Africa.

Only background general and technical information for the four types of systems is provided. The technical background information for the two sets of similar systems will be discussed together under one section each, but the case studies will be described separately as they each have separate supporting infrastructures. These four types of systems are:

1) Radar;
2) Radio navigation systems;
3) Satellite earth station; and
4) Modular nuclear reactor

Background general and technical information regarding the four systems is provided next.

5.2 Background general and technical information of systems used in case studies

In this section background general and technical information is provided on the four types of systems. It is necessary to provide this information so that the reader may grasp the information provided in the case studies and understand that the support required for these high technology systems is quite complex. A discussion follows regarding the background general and technical information of the first system, that is, radar.

5.2.1 ***<u>Radar – background general and technical information</u>***

Radar (*'Radio Detection and Ranging'*) uses radio signals to detect an object and to determine its position and distance from the transmitter. A basic radar system consists of:

1) An antenna, which is the mechanism (interface) used for transmitting the radio signal to the object and receiving the radio signal from the object, and sending the radio signal to the receiver and signal processing system;
2) A transmitter, which is used to generate and transmit the high frequency radio signal;
3) A receiver and signal processing system, which is used to receive the radio signal from the antenna and process the signal in a useable format for the display system; and
4) A display system, which represents the position of the object visually.

Collins (2004:1336) defines radar as follows:

> *'… the use of high frequency radio pulses transmitted towards an object and reflected back to the transmitter/receiver system, hence determining the position of the object.'*

According to Skolnik (2001:1–2), radar (*'radio detection and ranging'*) can be used for the location and detection of reflecting entities such as ships, aircraft, people, the natural environment, and vehicles. Radar can be used to determine the distance of an object in any weather.

Skolnik (2001:13) mentions various functions of radar, including:

1) Remote sensing radar (weather, planetary, short-range below-ground probing, and sea ice mapping);
2) Oil and gas exploration;
3) Air Traffic Control (ATC);
4) Law enforcement radar;
5) Weapon control tracking;
6) Space-astronomical radar;
7) Entomological and ornithological radar applications; and
8) Collision avoidance as used by ships and boats.

This was a brief presentation of background information to radar: radar is considered a high technology system with a high consequence of failure as it is used to detect aircraft in the air. Next, the background general and technical information of the second system is discussed. This system consists of navigational aids and guidance systems.

5.2.2 ***Radio navigation systems – background general and technical information***

Radio navigation systems use radio frequencies which aid aircraft in determining their position and speed, and assist them to land safely, especially in inclement weather. Navigation refers to the processes used to direct a vehicle in motion. Navigation and the complexities thereof is *'the determination of the position and velocity of a moving vehicle…. Navigation sensors may be located in the vehicle, in another vehicle, on the ground, or in space'* (Kayton and Fried, 1997:1). The United States Oceanographic Office (1956, cited in Kayton and Fried, 1969:1) provides a similar definition, and defines navigation as *'the process of directing the movements of a craft from one point to another'.*

The United States Department of Defense and Department of Transport (2001:2–2) define aircraft navigation as *'the process of piloting aircraft from one place to another and includes position determination, establishment of course and distance to the desired destination, and determination of deviation from the desired track'.'*

An aircraft moves through various phases between its departure point and its destination point; these flight phases are defined by Kayton and Fried (1997:7–9) as takeoff, terminal (departure and approach), en route, approach, and landing. The United States Department of Defense and Department of Transport (2001:2–5, 2–8 to 2–10) define the various phases between departure point of an aircraft and its destination point as takeoff, terminal (departure and arrival), en route, approach, and landing.

Some of the radio navigation systems as used in the study are provided below, that is, 'Terrestrial radio-navigation systems' and 'Point source systems' as defined by Bose, 1983; Henney, 1959; Hildebrand, 1989; Hurley, 1951; Anderson and Flint, 1959; Metz, 1959; and Colin and Dodington, 1956, in Kayton and Fried, 1997:116–133). The various systems are as follows (Kayton and Fried, 1997:116–138; Helfrick, 1984; and Middleton, 1989):

1) Very High Frequency (VHF) Omnidirectional Range (VOR). *'The ground station radiates a cardioid pattern that rotates at 30 revolutions per second (rps), generating a 30 Hz sine wave at the airborne receiver. The ground station also radiates an omnidirectional signal,*

which is frequency modulated with a fixed 30 Hz reference tone. The phase difference between the two 30 Hz tones varies directly with the bearing of the aircraft' (Kayton and Fried, 1997:122). VOR operation is *'based on the concept of phase differences between two alternating voltages'* (Middleton, 1989:155).

2) Doppler VOR (DVOR). Site error is reduced by using the principles of wide antenna aperture (Anderson and Flint, 1959, in Kayton and Fried, 1997:126). The roles of the array and central radiator are reversed. The reference phase is formed by a central Alford loop that radiates an amplitude modulated (at 30 Hz) omnidirectional continuous wave. The United States Department of Defense and Department of Transport (2001:3–25) mention that a VOR using the Doppler effect, that is, DVOR, is used at sites where normal VOR operation is difficult.

3) Distance Measuring Equipment (DME). DME is *'an internationally standardized pulse-ranging system for aircraft'* (Kayton and Fried, 1997:127). *'When the ground station is collocated with a VOR station, the resulting combination forms the standard* [International Civil Aviation Organisation] *ICAO rho-theta short-range navigation system'* (Metz, 1959, in Kayton and Fried, 1997:127). The aircraft interrogator compares the transmitted and received times, subtracts the fixed delay and displays the result on a calibrated meter. Middleton (1989:155) defines DME as accurately measuring *'slant range from an airborne transmitter/receiver to the ground station. (Slant range incorporates aircraft altitude as well as ground distance.)'.*

4) Tactical Air Navigation (Tacan) is a short-distance navigation system (Helfrick, 1984:192). Colin and Dodington (1956, in Kayton and Fried, 1997:133) define a Tacan as *'a military omnibearing and distance measurement system', while* Middleton (1989:156) defines a Tacan as a device used to determine range and bearing of an aircraft.

5) VOR-Tacan (VORTAC). *'each VOR station, instead of being collocated with a DME, is collocated with a Tacan Beacon'* (Kayton and Fried, 1997:138).

An instrument landing system guides aircraft to an airport runway, especially during periods of inclement weather and limited visibility. Kayton and Fried (1997:608) define an instrument landing system as a *'collection of radio transmitting stations used to guide aircraft to a specific airport runway, especially during times of limited visibility'.* Landing systems provide homing functions and information regarding heading. Futhermore, it indicates absolute altitude and controls the aircraft glide path (Helfrick, 1984:199). Middleton (1989:157) defines an instrument landing system as *'accurate guidance of an aircraft towards the touchdown point of a designated runway'.* The United States Department of Defense and Department of Transport (2001:3–32) define an instrument landing system as providing *'vertical and horizontal navigation (guidance) information during the approach to landing at an airport runway';* Kayton and Fried (1997:608) mention that an instrument landing system typically consists of a localizer antenna, glide slope, marker beacons, and radiation monitors.

Without the use of radio navigation systems to navigate and guide aircraft, there is a high occurrence of accidents with a high consequence of failure, which implies a loss of life. According to Kayton and Fried (1997:597), the approach and landing phases of flight are the riskiest; approximately fifty percent of all catastrophic accidents occur during the approach and landing phases, of which two-thirds are due to flight crew errors. Landings are normally conducted with visual cues, and inclement weather requires the pilot or autopilot to rely on electronic assistance.

Burin and Rozelle (2004:1) mention that between 1st January 2001 and 1st November 2004, *'eight of 12 hull-loss accidents involving large commercial jets … had no fatalities …'.* Approach and landing accidents (ALAs), including controlled flight into terrain (CFIT), accounted for one-third of the hull-loss accidents. *'… this is the first time in recent years that fewer than half of the hull-loss accidents were ALAs.'*

Definitions of hull-loss and CFIT are defined in the same news report as follows (Burin and Rozelle, 2004:1):

> *'Hull-loss means damage to a commercial airplane that is substantial and beyond economical repair; or an airplane that remains missing after search for wreckage has been terminated; or an airplane that is substantially damaged and inaccessible.'*
>
> *CFIT '… occurs when an airworthy aircraft under the control of the flight crew is flown unintentionally into terrain, obstacles or water, usually with no prior awareness by the crew.'*

Table 5–1 provides statistics recorded of selected years from 1945 to 2007, which lists fatal airliner hull-loss accidents, during the various flight phases of take-off, initial climb, en route, approach and landing, as well as training accidents (Aviation Safety News, 2007). The figures include corporate jet and military transport accidents, but exclude fatal airliner figures, including corporate jet, and military transport accidents.

Fatal civil airliner accidents per continent for selected years from 1945 to 2007 are provided in Table 5–2. Fatal civil airliner accidents per geographical region from 1945 to 2007 are shown in Table 5–3, where the first African country to make the list is at number 19, namely the Democratic Republic of Congo (DRC). South Africa is not among the top 25 geographical regions that show the highest number of fatal civil airliner accidents. Excluded from these figures are corporate jets, military accidents, hijackings, and other criminal occurrences.

Table 5–1: Hull-loss accidents – fatal airliner, various flight phases and training

YEAR	FATAL AIRLINER		TAKE OFF		INITIAL CLIMB		EN ROUTE		APPROACH		LANDING		TRAINING	
	ACC	C	ACC	C	ACC	C	ACC	C	ACC	C	ACC	C	ACC	C
1946	60	756	0	0	9	133	20	312	20	286	4	9	4	17
1958	56	1,063	5	37	4	45	23	634	13	290	1	1	1	1
1960	58	1,349	3	22	9	166	20	485	20	591	2	38	2	7
1970	72	1,520	8	78	15	291	25	731	24	412	4	130	5	20
1980	43	1,195	7	103	7	62	16	536	20	628	5	22	3	10
1990	39	693	6	20	9	155	17	204	20	405	2	10	0	0
2000	36	1,086	5	94	6	54	20	586	14	523	4	12	1	3
2001	28	768	5	147	9	53	17	482	18	261	1	1	1	3
2005	35	1,059	1	3	4	31	15	558	11	94	2	4	2	5
2006	27	888	Not available		Not available		Not available		Not available		Not available		Not available	
2007	2	134												

Legend: ACC: Accidents C: Casualties
Source: Aviation Safety News, (2007), 2007 data as per website on 31 August 2007.

Table 5–2: Fatal civil airliner accidents per continent from 1945 to 2007

NO.	CONTINENT	ACCIDENTS	FATALITIES	GROUND FATALITIES
1	North America	840	12646	174
2	Europe	760	20544	185
3	Asia	637	17107	316
4	South America	560	10183	370
5	Africa	323	6938	119
6	Central America	145	2123	76
7	Australasia	105	1309	1
8	International waters	66	2188	0
9	North and South Poles	4	271	0

Legend: No.: Number.
Source: Aviation Safety News, (2007), 2007 data as per website on 31 August 2007.

Table 5–3: Fatal civil airliner accidents per geographical region from 1945 to 2007.

NO.	COUNTRY	ACCIDENTS	FATALITIES	GROUND FATALITIES
1	USA	629	9850	119
2	Russia	195	5680	19
9	United Kingdom	80	1264	10
19	DRC	38	452	6
25	Ukraine	30	1141	0

Legend: DRC: Democratic Republic of Congo. No.: Number. USA: United States of America
Source: Aviation Safety News, (2007), 2007 data as per website on 31 August 2007.

This section provided an overview of the background general and technical information regarding radio navigation systems. It is clear that failure of these systems has catastrophic and fatal consequences. What follows next is an overview of the background general and technical information of a satellite earth station.

5.2.3 ***Satellite earth station – background general and technical information***

Satellite communication consists of a satellite spacecraft in orbit communication (receiving and transmitting) to one or more earth stations on the ground; these earth stations serve as both a transmitter and a receiver to the satellite spacecraft. Satellite earth stations communicate with satellites in space.

Elbert (1987:9) defines an earth station as *'an internationally accepted term, which includes satellite communication stations located on the ground, in the air (on airplanes), or on the sea (on ships)'.* Furthermore, Chetty (1991:18) explains that an earth station can be ground mobile, fixed, aeronautical, or maritime terminal and consists of *'an antenna, a power amplifier, a low-noise receiver, and ground communications equipment, and are equipped with power supplies, control, test and monitoring facilities or telemetry, tracking, and command systems'.* Communication satellites provide a great many services, including cable television (TV); mobile services; pay-TV; regular telephone, telex, and TV; business voice and data; satellite news-gathering; and private international satellite service (Chetty, 1991:417).

A satellite has an orbit in which it moves around the earth and is defined by Maral and Bousquet (1993:5) as *'the trajectory followed by the satellite in equilibrium between two opposing forces. These are the force of attraction, due to the earth's gravitation, directed towards the centre of the earth and the centrifugal force associated with the curvature of the satellite's trajectory'.*

Satellites can be classified depending on the service they provide and their geographical coverage. They fall into international, regional, domestic and experimental classifications as defined by Evans (1991:26–38). Only the international and regional classifications are listed and described. These classifications include background information for each organisation:

1) International:

   i) Intelsat (International Telecommunications Satellite Organisation). Intelsat was formed in 1964, they initiated the first international communication satellite system in 1965, and in 2006 they merged with Panamsat. Their customer base has access to entertainment, information and people (Intelsat, 2008).

   ii) Inmarsat (International Maritime Satellite Organisation). Inmarsat was formed in 1979. Their services include *'global mobile satellite services'*, which can be used in a diverse environment which includes the sea, air and land (Inmarsat, 2008).

iii) Intersputnik (International Space Telecommunication Organisation). Based in Moscow, Russia, it was founded in 1971. Intersputnik has 19 signatories and 25 member countries. Intersputnik leases satellite usage to broadcasters, enterprises, and telecommunications operators (Intersputnik, 2008).

2) Regional:

i) Eutelsat (European Telecommunications Satellite Organisation). Based in Paris, France, Eutelsat was established in 1977 (Eutelsat, 2008). Eutelsat's products and services include:

a) Broadcast services;
b) Broadband services;
c) Telecoms; and
d) Maritime and mobile communications (Eutelsat, 2008).

ii) Arabsat (Arab Satellite Communication Organisation). Arabsat was established in 1976 by the Arab league member states. Arabsat offers broadband, telecommunications, and broadcast services (Arabsat, 2008).

There are two primary resources which satellites need, namely, geostationary satellite orbit (GSO) and the radio frequency spectrum, which form the *'orbit/spectrum resource'*. A treaty has declared the GSO and radio frequency spectrum as *'limited natural resources'* (International Telecommunication Convention, 1982, in Smith, 1990:5). This limitation is briefly described below (Smith 1990:5–16):

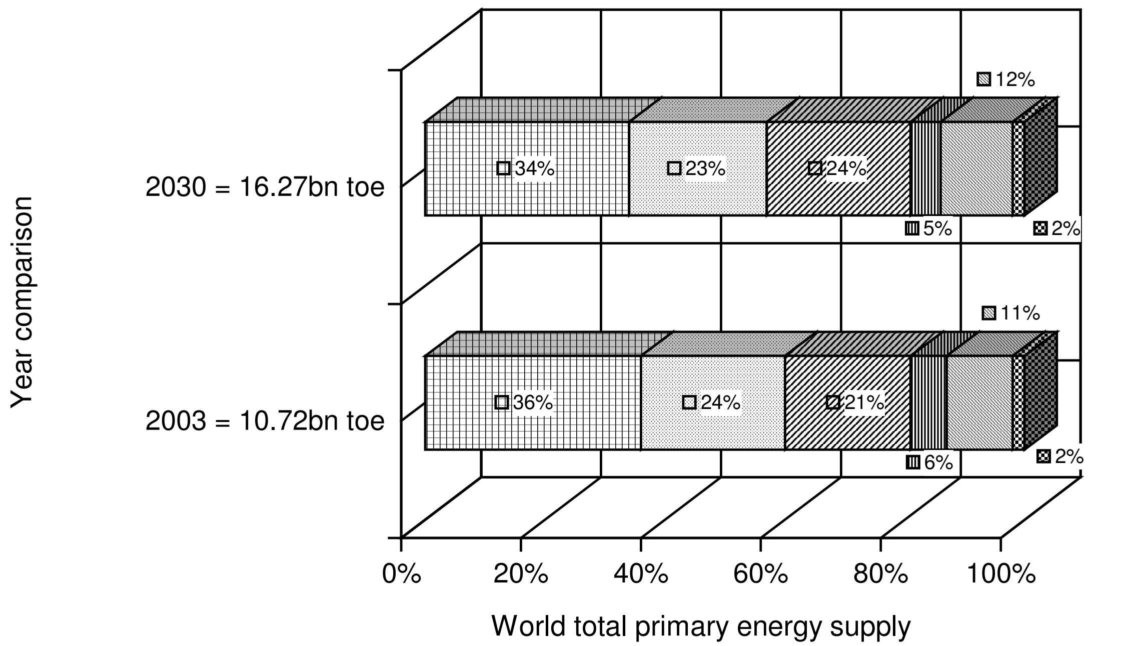
1) Geostationary satellite orbit. The altitude of a satellite in GSO is approximately 36,000km (Smith, 1990:5). Theoretically, 1,800 satellites can be in orbit in the GSO without any risk of collision. (United Nations {UN}, 1981, in Smith, 1990:6). As of 1988, the GSO had 110–130 operational satellites, and 400 at various planning stages (European Space Agency {ESA}, 1988 in Smith, 1990:16).
2) Radio frequency spectrum. Radio waves have certain physical characteristics, which limit the full use of the radio frequency spectrum for satellite communications (Smith, 1990:7).
3) Other limitations. To provide an area on Earth with a useful service, the satellite in GSO must be positioned in a specific area. *'These limitations involve the concepts of area of visibility, coverage area, service area, and service arc'* (Smith, 1990:9).

This section provided background general and technical information related to a satellite earth station. The high consequence of failure of this high technology system includes loss of communication. The next section provides background general and technical information regarding a modular nuclear reactor.

5.2.4 *Modular nuclear reactor – background general and technical information*

In this section background general and technical information regarding a modular nuclear reactor is provided and linked to the requirement of energy in developing countries. The International Energy Agency (IEA) (2006) estimates that there will be a 60% increase in energy demand from 2003 to 2030. Figure 5–1 provides the energy generating alternatives, which are supplied worldwide; it further indicates the comparison of these energy-supplying alternatives for 2003 and the estimate for 2030. Oil will still be the leading energy source in 2030; natural gas will overtake coal as the second energy source. Nuclear energy is expected to only contribute five percent of global energy demand in 2030 (IEA, 2006, cited in WEC, 2006:13). There are four risks *'associated with new generating investments';* these are technological, reliability, restructuring, and market risks (Harding, 2004:15–16).

Africa accounts for 12% of the global population, but only uses two percent of the world's energy (Tennenbaum, 2006). According to The Economist (2007a), Africa generates four percent of the world's electricity, of which three-quarters is consumed by Egypt, South Africa, and northern African coastal regions. Nuclear power accounted for 17% of global electricity generation and one fifth of the US power needs in 2002 (MIT, 2003:1). Global electricity consumption is expected to increase over the next few decades, *'especially in the developing world …'* (MIT, 2003:1). In addition, the World Bank believes that there are at least 500 million sub-Saharan Africans who do not have *'modern energy'* (World Bank, cited in The Economist, 2007a). In developing countries the 1600MWe reactors are not compatible with the electrical grids, and the future reactors do not need to be large in order to compete (Kadak, 2007). This results in new modular reactors meeting excessive energy demands, where these new reactors have extensive operational cycles, resulting in reduced maintenance outages (Kadak, 2007).



	2003 = 10.72bn toe	2030 = 16.27bn toe
Hydro	2%	2%
Renewables	11%	12%
Nuclear	6%	5%
Natural gas	21%	24%
Coal	24%	23%
Oil	36%	34%

Source – International Energy Agency, cited in World Energy Council: 2006:13, (adapted)

Figure 5–1: World total primary energy supply

According to Harding (2004:17), *'distribution system consolidation'* is designed for economies of scale advantages for large organisations, enabling them to *'provide important social services'*, (for example cost cross-subsidisation, electrification, and *'free electricity to the poor'*), and not for competition within markets. Restructuring the electricity in South Africa entails the privatisation of 30% of the generating capacity of its power utility, and consolidating its 400 electricity distributors into only six distributors (Harding, 2004:17).

Thelen Reid Brown Raysman and Steiner LLP (2005) define the difference between distributed generation and central generation is as follows:

1) Distributed generation is about *'installing and operating electric generating equipment at or near the site of where the power is used and sized for the facility's needs'.*
2) Central distribution *'consists of building and operating large power plants, transmitting the power over distances and then having it delivered through local utility distribution systems'.*

South Africa's electricity grid is *'more radial (power plants to loads) than networked (all plants to all loads). Such grids are inherently harder (because of local and global market power in both generation and transmission) to make "competitive."'* (Harding, 2004:17).

The African continent relies heavily on hydropower, and 13 of the countries in Africa are dependent on hydropower for at least 60% of their energy needs (The Economist, 2007a). Figure 5–2 provides a view of the earth at night, the 'light' areas indicate electricity availability; it is clear that developing countries, including those in Africa and South America, are amongst those parts of the world where electricity is lacking.

According to Williams and Feiveson (1990:543), nuclear power will need to be cost-effective, safe and *'highly diversion-resistant'* for it to have a major impact on global energy. Various designs exist – the small high-temperature gas cooled reactor (HTGR), however, offers notable safety benefits over the small light water reactor (LWR) (Williams and Feiveson, 1990:547).

Source: NASA (2000).

<u>Figure 5–2: The world at night</u>

Advantages of modular nuclear reactors as argued by Merrifield (2006:3–4) include:

1) *'… allow deployment at remote sites with most of the manufacturing conducted at an offsite facility using assembly line-like activities';*
2) *'… customers can specifically tailor the size of potential plants to meet the particular needs of a project or geographical area';*
3) *'… their fuel design, have a significantly greater amount of calculated temperature margin between the regulatory limit and the cladding capabilities. The potential inability to cause*

fuel melt during a design basis accident brings with it the suggestion that containment structures may be unnecessary';

4) *'… utilizing continuous refueling, do not share the refueling requirements of their light water counterparts. The low levels of excess reactivity in [modular nuclear reactors], in contrast to the large excess reactivity in light water reactors, would result in a meaningful decrease in total source term, and raise the possibility of reduced emergency planning zones surrounding these plants';* and

5) *'… high temperature gas reactors, which have exceedingly high outlet temperatures, allow for innovative uses such as hydrogen production, energy production for remote mining activities, and desalination efforts.'*

Wong (1994), provides more advantages of a modular system, these are:

1) Components can be fabricated in factories, transported to the site for installation, which in turn shortens the time of construction and lowers the capital cost outlay;
2) Economies of scale exploitation;
3) Operating and maintenance costs are reduced due to the numerous generic and standardised components;
4) Inherently safety features are built-in, and the number of active cooling components are reduced due to the passive nature of the heat removal system of the plant; and
5) Due to helium's neutron transparent properties, the primary coolant circuit's radioactivity level is decreased, thereby reducing worker doses and maintenance costs.

Power generation over the next several decades proves to be challenging, as it is anticipated that the world's consumption of electricity will double, and the power plants built in the earlier part of the twentieth century are approaching the end of their expected lifespan (The Economist, 2007b). A further concern is global warming, and the lack of imports of gas and oil from unstable and hostile countries by Western countries, and many governments view nuclear power as the only solution to these concerns (The Economist, 2007b). According to Fin24 (2005a), South African coal-fired power plants generate approximately 94% of its electricity, which every year pumps *'millions of tons of greenhouse gasses – a major cause of global warming – into the atmosphere …'* (Fin24, 2005a). The European Commission has set targets for 2020 to reduce its greenhouse gases by 20%, to increase renewable energy usage by 20%, and to increase energy efficiency by 20% (European Commission, 2008).

Globally, 31 nuclear reactors are constructed and more are planned, where *'some of the most ambitious programmes are under way in developing countries'*, including South Africa which plans to grow their exsiting programme (The Economist, 2007b). The first nuclear power plant in

Obninsk, (close to Moscow) started operating on 26 June 1954 (IAEA, 2004) and was in operation for 48 years (Down to Earth, 2008). According to the International Atomic Energy Agency (IAEA, 2006), nuclear plants are operating at *'higher safety levels'* than 20 years ago.

The average availability of nuclear power plants in the United States in 2001 was as high as 90%, however, many nuclear power plants have had low availability figures for a number of years; the '*life-cycle availability*' is lower than 90% (MIT, 2003:38). One concern regarding refuelling, repair and maintenance of nuclear plants in developed countries is the qualification and training of plant personnel to operate and manage these plants. This requires revitalising the workforce, whereas in developing countries the risk is greater as the skills shortage is apparent in the nuclear plant construction, maintenance, and operations (MIT, 2003:50).

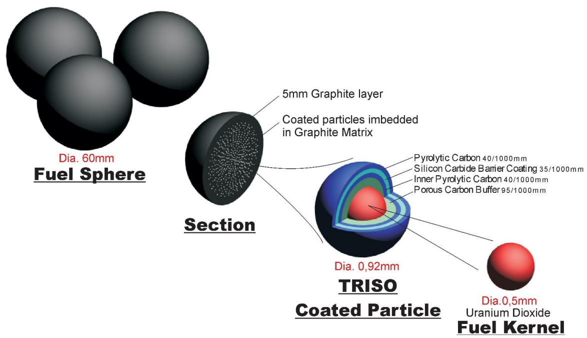
There are numerous forms of energy generating technologies; these are coal, nuclear, biomass, hydro, wind, solar, wave, and pumped storage (Eskom, 2008). According to Eskom (2007b:1–2), the cost to construct a power station which uses coal as its fuel costs approximately R80 billion (2007 figures), where the operational lifetime is expected to be around 50 years.

In South Africa, a demonstration nuclear power plant, a *'pebble-bed'* reactor based on German technology is due for construction in 2009, where the *'uranium fuel is encapsulated in rugged "pebbles", the size of tennis balls …'* (The Economist, 2007b). A MIT (Massachusetts Institute of Technology) professor, Andrew Kadak, along with his students, has been designing an *'alternative pebble-bed'*, and is confident that '*these reactors cannot melt down …'* (The Economist, 2007b). The South African *'pebble-bed'* reactor is *'the most advanced reactor design in the world at present … an inherently safe system …'* (PBMR; 2005, cited in Fin24; 2005b). The reactor has combined robustness, *'inherent safety'*, and simplicity to produce cheap electricity (Tennenbaum, 2006). The South African Minister of Public Enterprises labels this nuclear power source *'the perfect nuclear technology for Africa and the developing countries'* (Tennenbaum, 2006). According to Gcabashe (cited in Tennenbaum, 2006:37), Eskom produces 50% of the electricity consumed on the African continent, and 95% of the electricity in South Africa.

According to Massachusetts Institute of Technology (MIT) (2008), the characteristics of the pebbles and fuel handling system of the pebble bed reactor are:

1) 360,000 pebbles make up the core (an example of the structure of the pebbles is provided in Figure 5–3);
2) Approximately 350 pebbles are discarded daily;
3) Every 30 seconds a pebble is discharged;
4) On average, each pebble cycles 15 times through the core; and

5) The fuel handling system handles approximately 3,000 pebbles each day (MIT, 2008).



Source: PBMR (2006).

Source: PBMR (2008).

Figure 5–3: Pebble bed reactor ceramic-encapsulated uranium fuel and fuel spheres

Working in a nuclear reactor exposes personnel to the risk of radiation. Particularly vulnerable are operators and maintainers who are required to inspect and maintain areas within the plant at specific times, either during planned outages or during periods of unplanned maintenance. Strom (1996:389) identified ten principles of radiation protection. It is essential to know the conditions of the maintenance environment to ensure that these principles are applied adequately. These principles include:

1) Time;
2) Distance;
3) Dispersal;
4) Source reduction;
5) Source barrier;
6) Personal barrier;
7) '*Decorporation (internal and surface irradiation only)*';
8) Effect mitigation;
9) Optimal technology; and
10) '*Limitation of other exposures*'

This section provided an overview of the background general and technical information as it relates to a modular nuclear reactor. In the sections that follow, the case studies of a developing modular nuclear reactor, military radar systems, military and industrial radio navigation systems, and an industrial satellite earth station are deconstructed. In order to comply with the security and sensitivity requirements of these systems, they have been coded as Systems Alpha, Bravo, Charlie, Delta, Echo, and Foxtrot. The systems do not in anyway correspond to the order as previously provided in this section or chapter.

5.3 Deconstructed Case studies

This section discusses the deconstructed case studies; beginning with system Alpha which follows in paragraph 5.3.1.

5.3.1 *System Alpha*

For the purposes of this study, system Alpha has been used. System Alpha is a radar system that is more than five years old and originates from an overseas supplier. It has undergone (1998 to 2004) an extensive upgrade programme to improve its operational capability and performance. There were originally 10 systems procured, however, over the last few years, the systems have been cannibalised, leaving only four operational systems. The extended life cycle of the system, including the upgrade programmes, is expected to reach beyond 2014.

System Alpha is an early warning surveillance system fitted with a similar, but more compact sub-system on one of the primary systems equipment structures. System Alpha consists of numerous transportable sub-systems (modules), including:

1) Antenna (Primary and secondary);
2) Transmitter;
3) Power generator;
4) Stores/workshop;
5) Processing and control, processors and displays; and
6) Communications.

The cabins receive their primary power from the power generator by means of power cables. The cabins are interconnected with each other by means of signal cables. The cross-site signal cables are fitted with identification sleeves at each end, which correspond to the coloured disc mounted on the relevant cabin's signal termination panel. Each connector is also keyed to prevent accidental connection to an incorrect cabin connector.

System Alpha is fully transportable and can be deployed at any selected site in accordance with strategic and tactical requirements. Site selection is normally conducted three months before a planned deployment to secure permission to gain site access. Other aspects to consider in that three month period are the route to the site, accessibility of vehicles, radar site and domestic site planning, availability of water, food, and other logistic requirements. The actual deployment of the system is a tedious process entailing detailed work to set the system up.

The maintenance of system Alpha is split into two levels, which is performed by various personnel, units and contractors. These two levels are the Operational (O) level and Depot (D) level. These two maintenance levels are split into various technical disciplines or sub-systems, including embedded software, electrical, electro-mechanical, mechanical equipment, and electronic maintenance. The electronic maintenance is split further into different maintenance sub-systems, including a transmitter/antenna, receivers, displays, processors, communications, and secondary systems.

The O-level maintenance of the electronic equipment and embedded software is the responsibility of the end user. A private contractor performs the D-level electronic equipment maintenance.

Maintenance problems occur quite regularly at the sites of the semi-static systems due to electrical power outages. The National Electricity Regulator (NER) audited Johannesburg City Power and *'identified serious problems'*, furthermore, cited as one of the concerns was an insufficient maintenance standard, as well as not adhering to work procedures (Citizen, 2005).

The technical personnel undergo a three-year apprenticeship in their respective technical fields. They need to pass the theoretical modules and practical aspects of their apprenticeship to become qualified artisans. The qualified technical personnel required for each system are a technical officer, and technicians for the technical disciplines, as well as a mechanical technician, motor vehicle fitter, and material support clerk (technical).

Classroom-based training (theoretical and/or practical), and self-paced training is used to train personnel. On the job training is continuous. Training curricula are devised for the various courses. Students write theoretical and/or practical examinations for each course attended. The contractor supplies training documentation. Training venues are provided either by the contractor at their facility or at a facility provided by the end user.

The D-level maintenance contract between the end user's representative and the contractor is based on time-and-material philosophies. The majority of the maintenance contract personnel at the contractor are ex-military personnel and consist of eight technicians, one supply support co-ordinator, one systems manager and one contracts manager.

Original documentation for the system comprised technical manuals, test specifications and microfiches. When the unit moved to its current location, a large number of technical manuals were accidentally shredded as it was thought that these documents were kept by the end user's publications depot. During the subsequent five years the contractor managed to recover most of the handbooks from various sources, and scanned the documents to be available in digital electronic format. Storage space needed for documentation has decreased considerably as compact disc (CD) storage media is used. All documentation is under configuration management.

Support and test equipment is partly supplied by the military (O- and D-level) and partly by the Contractor (D-level). Built-in test equipment (BITE) forms a major part of the maintenance of the receivers and transmitter area of the system. All precision measuring equipment (multimeters, torque wrenches, oscilloscopes, spectrum analysers, etc.) is calibrated annually at an accredited calibration facility. The calibration certificates are kept for audit purposes.

Configuration management is applied to the system, including the use of a management information system (MIS) at each site. Each MIS system has a physical breakdown structure (PBS) or buildstate of the system and a failure reporting, analysis, and corrective action system (FRACAS). The MIS also contains personnel information, test equipment information, supporting documentation, and support and test equipment (S&TE) data. Full maintenance planning is performed on the MIS system.

Configuration management principles are further applied at the contractor using a database software programme for database management and control of the documentation; furthermore, an enterprise resource planning (ERP) system is used for storage of documentation and material information.

Strict guidelines are followed for compliance purposes concerning packaging, handling, storage and transportation (PHS&T) of the system and its supporting equipment. All equipment racks have to be securely fastened when the system is transported. All line replaceable units (LRUs) that are sensitive to vibration and shock are packed in a specially manufactured crate. All printed electronic circuits (PECs) are packed in bubble plastic bags. If they are static sensitive, they are packed in static sensitive bags and further protected by foam padded cardboard boxes. Handling of the static sensitive PECs complies with the International Organisation for Standardisation (ISO) electrostatic discharge (ESD) requirement. The handling of equipment is conducted by adhering to prescribed procedures and instructions. These procedures are located in the relevant technical manuals and operational documentation. The mode of transportation for the system is primarily by road, although rail and air transport may be used.

The D-level facility is a fully equipped repair centre consisting of trained technicians, an anti static repair facility, surface mount repair stations, and depot level test and support equipment. The D-level repair centre also keeps its own stock of spares for the repair of LRUs sent in by the end user. D-level maintenance facilities include electro-mechanical facilities, mechanical fitting facilities, motor transport facilities, radar mechanical facilities and paint workshop facilities. These workshops are housed in hangars and brick buildings.

Each system is provided with a full complement of O-level spares. The type and quantities of spares are calculated by means of a logistics support analysis (LSA).

System Alpha is self-contained during transportation as well as during deployment. Comprehensive O-level support is conducted from the first day of the deployment until after the demobilisation phase. The system is software driven. Each deployment requires site-specific data. It is only after the demobilisation phase that D-level maintenance is performed to ensure that the system is fully operational and maintained in standby mode for the next deployment.

Due to the fact that operational requirement levels of system Alpha are as high as 100% system availability during mission times, quality assurance is applied in the strictest manner possible. Quality assurance (QA) plays a major role in approving repairs and releasing the LRU for operational use, especially in the radar environment, where the risk must be reduced when controlling aircraft. A QA oversight in this context can cause a malfunction in the system resulting in an aviation/aircraft incident.

All sub-systems, assemblies, and LRUs repaired at D-level are subjected to test specifications, acceptance test procedures, and only officially approved setting up and calibration processes. Only once a certificate of conformance has been issued, is the repaired items released to the end user.

This section provided the case study for system Alpha. The radar system is currently suffering from component obsolescence; it has been used beyond its designed life span, undergoing numerous upgrade programmes. In the next section the deconstructed case study for system Bravo follows.

5.3.2 ***System Bravo (South American)***

System Bravo is a radar system, similar to system Alpha. It is deployed in South America at two sites, and has been operational for more than five years. These systems are similar to the South African systems in that they have been upgraded to improve some of the sub-systems. However, they have not upgraded the other sub-systems as apposed to system Alpha. The information in the following paragraphs are intended as *'information only'*: it provides the reader with some background information to the problems experienced in South America concerning the support of system Bravo. Furthermore, it provides some comparative statistics of South Africa and a South

American country relating to various aspects. It is important to note that the South American country was selected to be compared to South Africa, because of its status as a developing country, and not (necessarily) because it is the location of the Bravo system.

A list of the issues affecting transportation within Ecuador (as previously described is an example of a South American country):

1) Lack of transport when a system must be transported to a different site.
2) Shortage of prime movers.
3) Personnel use public (bus) transport to and from sites. (Distances are long and the roads wet and dangerous; in most cases delays are evident).
4) The following statistics concerning transportation in the country are from the CIA's World Factbook (2008):

   i) Railways total 966km (2006 estimate).
   ii) Length of roadways totals 43,197km of which 6,467km are paved and 36,730km are unpaved (2004 estimate).
   iii) Waterways total 1,500km of which most are inaccessible (2006 estimate).
   iv) Pipelines include 578km of crude oil (extra heavy), 1,386km of oil, 1,185km of refined products, and 71km of gas (2006 estimate).
   v) This country has 407 airports, of which 104 have paved runways and 302 have unpaved runways; there is only one heliport in this country (2007 estimate).

Supply support for system Bravo involves spares delivery by means of public transport. The administrative route followed during delivery of spares results in long lead times. There are many agents, buyers and departments involved. Spares frequently need to go through more than one country before final delivery on site, and each country has agents. When D-level personnel are required to travel to site from South Africa, they frequently carry the small critical spares with them to avoid customs and other delays.

The frequency of staff changeovers on site is too high. Before one personnel member can settle into the process, the relief arrives on site. Skill levels of personnel are low. Due to the language problem, personnel tend not to use the English manuals and the majority maintains the systems by trial and error principles (that is, swapping at O-level till the failure seems to have disappeared).

Good procedures are not in place to ensure proper maintenance of support equipment, for example, the power plants. Long distances, lack of expertise and the non-existence of scheduled servicing cause regular primary power surges and failures, which result in lengthy and expensive

Bravo failures. LRUs sent for repair show extensive rust, corrosion, non-professional workmanship and inappropriate use to such an extent that units are declared beyond economical repair.

Facilities on site require consistent maintenance, resulting in inadequate storage areas for spares, S&TE, and PHS&T. Documentation for the system is in English, resulting in a language barrier. This, in turn, results in inadequate maintenance on the system. At the time when the system was upgraded, the technical manuals were amended and shipped to site from South Africa. The technical manuals were damaged during shipping and transportation due to inadequate packaging. New manuals have subsequently, been delivered to site – these were shipped in crates and hence arrived undamaged. Configuration management is partly applied to the system and documentation.

Computer resources are a concern, because old technology disc drives and data discs are used. This sub-system was only partly upgraded during the recent upgrade. The data discs are bulky and susceptible to mishandling and damage. The software is developed and loaded onto the discs in South Africa and shipped to site. There is no official jobcard system in place – failures are recorded in a logbook system and limited analysis is conducted of this data. The overseas contractors manage obsolescence as the need arises. Disposal of the system is not currently a concern.

This section provided the case study for system Bravo; the radar system is currently suffering from a skills shortage and infrastructure limitations. In the next section the deconstructed case study for system Charlie follows.

5.3.3 ***System Charlie***

In the paragraphs that follow, the deconstructed case study for system Charlie is provided. This system is a modular nuclear reactor, which is currently under development; its sub-systems are in different life cycle phases. Maintenance on system Charlie requires a tedious process: A permit to work (PTW) is required by maintenance personnel to access the plant for maintenance purposes. Personnel accessing the plant have to be dressed appropriately in the relevant personal protective equipment (PPE), which not only requires wearing a hard hat, steel toed safety boots, gloves, and eye protective gear, but special clothing (for example a '*bubble suit*') and dosimeters as well. Apart from personnel, special tools and equipment (ST&E), and general maintenance equipment also have to reach the maintenance area, hence the exposure of personnel to a radiation and contaminated zone for longer periods.

There are four lines of maintenance envisaged for system Charlie, namely, lines 1, 2, 3, and 4. The operator will perform line 1 repairs, while line 2 will be conducted by the maintenance workshops, line 3 by a regional facility, and line 4 will be the responsibility of the original manufacturer. Refuelling is continuous, which in turn reduces the need for frequent shutdowns. It is expected that there will be a planned maintenance outage every six years. Only spares of the first and second lines will be stored on site.

Numerous personnel will be needed to operate and maintain system Charlie, including operators, radiation protection personnel, maintenance personnel, quality control personnel, safety personnel, engineering staff, and management staff. The personnel will require extensive training by means of simulators, classroom training, on-the-job training, and replenishment (replacement) training.

Facility requirements for system Charlie include, but are not limited to, a plant building, decontamination facilities, laboratories, and clean rooms. Specific support and test equipment is needed to sustain system Charlie, including commercial off the shelf (COTS) equipment, and ST&E; these require design and manufacturing. In addition, equipment, such as cranes, forklifts, and hoists are required to handle and transport equipment.

Stringent configuration management principles are applied during the design phase of system Charlie. PHS&T requirements include specialised transportation of sub-systems to site, handling of the sub-systems at the factory and on site, and storage and handling of sub-systems and critical components. Additional detailed ILS requirements will be known, once the logistics support analysis has been completed.

In this section a case study of system Charlie was discussed. In the next section the deconstructed case study for system Delta follows.

5.3.4 *System Delta*

System Delta is a radio navigation system and differs considerably from system Alpha: there are 20 systems at multiple sites, which are not transportable (except for the training system) and can be maintained at O-level by a remote system. Similar to system Alpha, system Delta does require a support structure, although its deployment has been permanent at various locations, and it has been operational for more than five years.

System Delta originates from Europe. The systems are deployed at various sites within South Africa, and one is deployed on a South African island. Maintenance on system Delta has been split into various areas of maintenance responsibilities, more specifically in the proximity of where military bases are situated. All the sub-systems of system Delta are operational 24 hours a day, 365 days a year. System Delta's maintenance concept is based on a five-tier definition, executed at three levels of repair (O-, I-, and D-level).

Due to unstable mains power, all the sites have an uninterruptible power supply (UPS) installed. Back-up batteries and a power generator have also been installed as additional back-up systems. The systems at the sites communicate with the specific workshop and the contractor depot by means of a global system for mobile communications (GSM) link.

When an LRU fails at an O-level operational site, the remote control maintenance software has the ability to rectify the fault remotely. Should this not be possible, the faulty LRU is removed by I-level maintenance personnel and sent for diagnostic testing, where, if a fault is found, the LRU is sent to the D-level contractor repair facility. Should a fault not be found, however, the LRU is kept at a central storage facility until needed by the O-level organisation. During the process of removing the LRU from one of the sub-systems of system Delta, a serviceable LRU is installed in its place.

Two full-time maintenance technicians are required at O- and I-level to support system Delta. Specific minimum educational qualifications are a prerequisite in order to maintain the systems. Experience required for O-level maintenance support is one year, and two years for I-level maintenance support. It is the D-level contractor's responsibility to ensure that competent, qualified personnel are available to support the systems for the duration of the contract.

All personnel are required to complete formal training on system Delta. Theoretical training is classroom-based, whereas practical training is conducted using the equipment. The contractor supplies training manuals. After successfully completing the specific training courses, the personnel are able to support the respective systems. Continuation training is also a requirement, should the system be upgraded. Practical training requires the use of test benches and test equipment; that is, standard test equipment instruments, software, and special to type test equipment (STTE).

Maintenance, training, storage, and calibration facilities are required for the support of system Delta. All maintenance conducted by O-level is performed using the remote controlled maintenance software. I-level maintenance requires the use of an electro-mechanical workshop, a general workshop and a system specific workshop. Designated contractors and depots conduct D-level maintenance. Calibration of test equipment is contracted out to a private firm; a calibration certificate is issued and kept on file. Serviceable LRUs are stored in containers on site, while test equipment has to be stored in a well-ventilated temperature controlled storage room. All related documentation is stored in a technical library, where a master copy of all documentation is kept at a central publications depot. Documentation for system Delta includes system specific technical manuals, standard operating procedures, and test equipment operating manuals.

Material supply acquisition for system Delta is divided into three categories, namely, consumables, repair parts (components), and LRUs. All spares arriving at the stores are placed in an area demarcated as *'goods received'* and are inspected against quality standards, as well as the specific purchasing specification. Should the items conform, they are placed within the stores system. If they do not conform, they are placed in quarantine where further action is awaited, for example, return to supplier, or further inspection by a higher authority or contract manager. Data are collected throughout the system's life cycle to continuously improve the supply chain. When damaged and/or beyond economical to repair, LRUs arrive at a repair facility, where a material review board (MRB) decides what action to take, that is, whether the LRU could be repaired by a D-level repair facility, or disposed of.

The respective maintenance organisations ensure that items requiring transportation leave their respective facilities in the prescribed packaging with the necessary supporting documentation, including the fault report and labels. Specific electrostatic discharge (ESD) practices are followed in accordance with recognised international standards. Industry specific best practices are not always followed with regards to transportation and handling, as some items are damaged during transportation and handling.

S&TE for the systems includes STTE, for example, flight calibration equipment. Other S&TE includes software and standard off-the-shelf equipment. The actual systems are also calibrated at regular intervals.

The reliability, availability and maintainability (RAM) process is used to improve the system performance of system Delta. This is performed by means of collection, processing and analysing maintenance and failure data, identification of cost drivers, and initiation of corrective action.

This section provided the deconstructed case study of system Delta. These high technology complex systems of system Delta are multi-systems at multiple sites and require complex ILS. In the next section a discussion of the deconstructed case study of system Echo follows.

5.3.5 *System Echo*

System Echo is a radio navigation system that has been operational for more than five years. This system was procured from Europe and installed at South African locations by a South African company. The end user of system Echo has been divided into specific regional maintenance responsibility areas. The maintenance responsibilities of the equipment are split between the end user and a contractor. The end user and contractor are both responsible for O-level and I-level maintenance, and the contractor is responsible for D-level maintenance. The expected life expectancy of the equipment is 15 years. All the systems operate 24 hours a day, throughout the year. The operational availability of system Echo is required to be above 99.9%. It is essential that the systems operate 24 hours a day throughout the year, hence the installation of batteries or generators at the sites as back-up power in the event of power failures.

O-level maintenance is performed using the Remote Control Monitoring & Maintenance System (RCMMS), and includes preventive maintenance of the systems, failure reporting, and fault diagnosis. I-level maintenance includes LRU fault diagnosis and LRU replacement, and realignment. D-level maintenance involves the component level replacement and repair of the LRUs, software maintenance, and preventive and corrective maintenance activities. All repairable or faulty LRUs received at the D-level repair facility are inspected for damage. Material review board (MRB) reports are generated for damaged LRUs, and submitted to the MRB, where a damage report is generated. A decision is made to determine whether the LRU can be repaired, which is done at D-level, or in the case where the LRU is irreparable, it is disposed of.

Maintenance on system Echo is split into preventive and unscheduled maintenance. Preventive maintenance includes all scheduled tasks at monthly, three monthly, and six monthly intervals. These tasks include, amongst others, inspections, calibration, and condition monitoring. Unscheduled or corrective maintenance includes all activities necessary to restore the systems to an operational level, for example, disassembly, replacement of an LRU or component, re-assembly, and verification.

Personnel required to support the systems include system specific technicians, data capturing clerks, logistics engineers, a configuration controller, a financial clerk, a contract administrator, and engineering personnel. The technical support personnel are required to have the desired minimum qualification and experience within their respective fields. Training consists of formal training in a classroom environment, on-the-job training, which happens during the installation of the equipment, and training at the respective sites. Practical training involves working on serviceable equipment. It also involves the use of the respective test benches and appropriate test equipment.

All documentation for system Echo is written in English. Configuration management principles are not fully implemented on the technical manuals. However, all documentation and amendments are reviewed and included in the master record index (MRI).

Spare parts for system Echo are categorised as standard items, peculiar items, long lead items, and items only available from a single source. Standard items are typically COTS items and have a lead-time of one week. Peculiar items have a lead-time of 12 weeks and require manufacturing to specific requirements. Long lead items are normally imported and require periods of more than 14 weeks for delivery.

Faulty LRUs are replaced with a spare LRU. The failed LRU is sent to the contractor with the necessary documentation for repair. Once the LRU is repaired, it is sent back to the specific end user site, where it replaces the spare LRU. The spare LRU is sent to the contractor for testing and evaluation. If necessary, the LRU is repaired. It is sent back to the end user's spare holding depot.

Several categories of S&TE are required for the different levels of maintenance of system Echo. These categories include support equipment, special tools typically only available from the system's original equipment manufacturer (OEM), commercial off the shelf (COTS) standard test equipment, special to type test equipment (STTTE) available from the system's OEM, and finally software. S&TE is calibrated at regular intervals, and the calibration certificates are kept on file.

All packaged equipment is transported either by road or air. The respective store departments ensure that all equipment leaves their premises in the required packing and packaging. Re-usable containers are used where necessary. Static sensitive items are marked as such with the necessary labelling. Serviceable labels are completed in duplicate; one copy is included in the package, while the second copy is attached on the outside of the packaging material. Should the packaging require special handling, it is labelled and/or marked as such. The OEM or the end user specification is used as guidelines for storage of the equipment.

Software system maintenance is performed on system Echo. Maintenance includes preventive maintenance, corrective maintenance, and system analysis. The remote maintenance system is used to remotely monitor and control the status of the equipment installed at a site. The O-Level maintenance for system Echo is also performed via the remote maintenance system.

The operational software is subdivided into top-level computer software components (TLCSCs), called suites. TLCSCs are divided into low-level computer software components (LLCSCs), called packages. LLCSCs contain one or more units, called modules.

The O-Level maintenance organisation (responsible for maintenance) is responsible for the Configuration Management (CM) Build State Information of system Echo at O-Level. The contractor is responsible at D-Level. The evaluation of equipment performance and the logistics system is conducted by means of the RAM programme.

In this section the deconstructed case study of system Echo was provided. In the next section the deconstructed case study of system Foxtrot is discussed.

5.3.6 *System Foxtrot*

System Foxtrot, a satellite earth station that originates from the United States of America, has been installed in South Africa. Numerous other systems exist at this site, including other systems similar to system Foxtrot. For the purposes of this study, however, only one specific satellite earth station has been used, which is a system that has been operational for more than five years.

System Foxtrot consists of various sub-systems. As part of the electronic acquisition contract, other sub-systems were procured including the construction of the building which houses the electronic assemblies, an access control system, a fire fighting system, an electrical installation, and an air conditioning system.

The maintenance system is split into three levels of maintenance, namely, user level, support level, and factory level. In academic literature terms, user level corresponds to O-level maintenance, support level corresponds to I-level maintenance, and factory level corresponds to D-level maintenance. User level maintenance is performed by the end user and includes troubleshooting, scheduled maintenance, and LRU replacement. Support level maintenance includes LRU repairs, preventive maintenance of shop repairable units, and those tasks that generally do not require factory level repair. Factory level repair consists of component level repair, software maintenance, and engineering support.

In the event of a system failure, troubleshooting is conducted to identify the failed LRU. The failed LRU is replaced with a serviceable LRU and sent to the support level repair facility, where it is either repaired or if classified beyond economical repair, disposed of in the appropriate manner.

Regular scheduled maintenance is performed on the system, and includes, but is not limited to setting up power supplies, cleaning air conditioner filters, and monitoring oil levels. Preventive maintenance is also conducted on the building structure, for example, waterproofing, cleaning of gutter pipes, and checking the serviceability of lights.

Technical support of the system at user level requires three maintenance technicians. At this level, the technicians work eight-hour shifts. At support level, two maintenance technicians are required. To support the system at both user and support level, technicians are required to have five years experience. Two maintenance technicians are required at factory level maintenance.

All support and test equipment used at all levels of maintenance are calibrated at regular intervals at an accredited calibration facility. At user level, an equipment register is kept of all support and test equipment requiring calibration; these records are maintained on a database.

User level supply support items include LRUs that were supplied as initial stock and have an immediate effect on system availability. Factory level supply support items include all repairs and spare parts not readily available from suppliers within seven days.

Technical documentation required to support the system was also procured with the system. The technical documentation includes, but is not limited to training manuals, operator handbooks, and maintenance manuals.

Practical and theoretical training was provided to the maintenance personnel during and after the installation of the equipment. The training was conducted on the various sub-systems.

Specific facility requirements are needed to support the system at all three levels of maintenance. These requirements include specific power source specifications, and climatic and environmental conditions.

Reusable containers and packaging are used to transport all equipment between the end user and contractor. Road transport is primarily used to transport equipment between the end user and contractor. All static sensitive equipment is marked as such and special electrostatic discharge (ESD) handling procedures are followed.

Configuration management practices are followed with respect to the system, which include, amongst others, conducting periodic audits, implementing a configuration management plan, and compiling a master record index (MRI).

A data management system is used to capture all failure, repair, receipt and dispatch information for the system. Failure reports are used to capture failure data and are analysed at periodic intervals.

In section 5.3 a high level summary of the case studies was given, in table 5-4 the cases are deconstructed and presented in the framework developed for the deconstruction of the literature review. More specific observations and learning (per aspect) will ground the process of deciding where reality differs from theory, especially in a developing world context. In the next section a summary of chapter 5 is provided.

5.4 Summary of deconstructed case studies

In table 5-4, the deconstructed cases per ILS element are shown, as developed during the deconstruction of the literature. These systems are complex and have a high consequence of failure – hence the importance of reliability. These systems vary from single system and single site to multiple-system and multiple-site, which complicates the ILS required to support these systems. Maintenance with regards to the deconstructed case studies is dealt with in the next section.

5.4.1 *Maintenance*

When considering maintenance of the respective case studies, it becomes clear that all the systems have a logistics support or maintenance concept in place, which specifies the maintenance responsibilities at the different maintenance levels. One distinguishing factor is that the systems have different maintenance levels, ranging from two levels to four levels to five levels with three tiers. The important aspect is that despite the different maintenance levels, the management of the system is specified and all parties involved are aware of their specific maintenance responsibilities regarding preventive and corrective maintenance. The systems currently in use have a maintenance plan implemented; it is envisaged that the system under development will imminently have a developed maintenance plan implemented. In the next section support and test equipment with regards to the deconstructed case studies is dealt with.

5.4.2 *Support and test equipment*

Reviewing support and test equipment (S&TE) provides some differences between the systems due to the different nature and operational environments of the systems. System Charlie is currently under development and it is envisaged that it will require specific standard tools and equipment, which is available off-the-shelf, special to type tools, which will require design, an equipment handling system, cranes, trolleys, and so forth. Two systems require specialised, scarce S&TE. Two other systems not only require the S&TE to be calibrated, but require the actual systems to be calibrated as well. In addition, the five systems (excluding system Charlie, which is under development) calibrate their S&TE at regular intervals; the calibration certificates are kept for audit purpose. The availability of S&TE and personnel is a concern at present and includes a shortage of the required skills to operate the S&TE adequately – a case in point is a system where a deficient makeshift trolley is used to transport LRUs between the repair depot and stores. In the same system, a cathode ray tube (CRT) display calibration mechanism is no longer available (damaged and lost), resulting in an obsolete calibration mechanism that cannot be sourced from the supplier, because it is not cost effective to manufacture. The technicians are required to develop a similar (but not necessarily accurate) device in order to calibrate the devices. Fortunately, these CRT displays are being phased out and replaced with current technology displays. Another form of S&TE is safety equipment, which is also not readily available from stores (due to various reasons). The priority (or willingness) of task requires the technician to climb structures without a harness and a hard hat, which contributes to the possibility of injury, and the consequences of an injury. The risk factor is therefore increased that personnel may not be readily available due to injury and negligence regarding safety equipment. The systems currently in use each have an S&TE plan implemented. Supply support with regards to the deconstructed case studies is dealt with in the next section.

5.4.3 ***Supply support***

Supply support of the different systems also provides similarities and differences. System Charlie is currently under development and more detailed supply support information will be available after the logistics support analysis (LSA). The system uses large mechanical components, which require long lead times, and have to be ordered from the manufacturers well in advance to meet the construction deadlines. In addition, some of the components are created for a specific operating environment and require longer lead times to design and manufacture. Similarities between the five systems (excluding system Charlie) include a supply support plan and a theoretical inventory management cycle, which, in reality is not practical in the developing world context. These systems differ from each other in that maintenance levels are not the same for all of them: each system has its own repair policies and different local and international suppliers, resulting in lead times and delays. Although critical spares and repair parts are sometimes kept in stock, these and other spares and repair parts are mostly only procured once the need arises, thus leaving the system unserviceable for a longer period due to these delays. In the next section packaging, handling, storage and transportation with regards to the deconstructed case studies is dealt with.

5.4.4 ***Packaging, handling, storage and transportation***

Packaging, handling, storage and transportation (PHS&T) is different for each system, which is unique in terms of operating environment and components. Although under development, system Charlie has conceptual aspects identified, such as trolleys, which are required to move heavy bulky equipment, and cranes, which are needed to move the equipment for their operational position to trolleys or laydown areas. One system has specific storage requirements for contaminated waste (for example, oil, and consumables), and packaging requirements to dispose of the failed components. Customs approvals is an important component of system Bravo, given its international transportation requirements. Furthermore, transported items are susceptible to damage if the item is not packed correctly. Storage requirements of the systems are specified in the PHS&T plan of the respective systems. Successful storage is dependent on specific environmental controls, such as temperature, humidity, protection from dust and moisture, and so forth. Packing, packaging, preservation, and marking (PPPM) of the items is in accordance with set procedures of the OEM. Such specialised PPPM, however, is not always procured with the main system, but has to be procured by the end user in their specific country. In an emergency, a makeshift option is used if the specific PPPM is not readily available, which increases the risk of damage to the transported items. Technical data and documentation with regards to the deconstructed case studies is dealt with in the next section.

5.4.5 ***Technical data and documentation***

There is a considerable difference between the systems with regards to technical data and documentation. Although in a developmental stage, system Charlie has identified preliminary documentation to include, amongst others, support concepts for various critical components, technical and training manuals, parts catalogues, and operator manuals. System Alpha is the oldest of the systems used for the case studies, but also the most comprehensive. Prior to the late 1990s the documentation of system Alpha was only available in printed format and microfiche, but has subsequently become available in software media, following upgrades to the system. Similarly, only some of system Bravo’s documentation was converted to software media during the course of their system upgrade. Systems Delta, Echo, and Foxtrot were procured with printed documentation and software media. The documentation on the systems currently in use are under configuration control, however, not all the systems follow strict configuration management principles with regards to their documentation. In the past, personnel supporting one of the systems failed to fully incorporate amendments into their technical manuals, which resulted in them removing non-faulty LRUs, and sending it off to be repaired. Similar errors in handbooks result in personnel incorrectly diagnosing failures, and in so doing, inducing failures even further. In the next section facilities with regards to the deconstructed case studies is dealt with.

5.4.6 ***Facilities***

The facilities element differs considerably for each system. System Charlie is housed in a building with the supporting infrastructure within, or in close proximity of the main building. The majority of system Alpha is housed inside cabins, which are located either under a roof or in an open area. The S&TE and documentation are located in a building in close proximity of the system. The main stores facility for system Alpha is located within a hanger. Between the stores and the system is an open area with no roof, exposing LRUs to the environment. In rainy weather, the LRUs are left unprotected from moisture. Similar to system Alpha, system Bravo is partly housed in cabins, and its S&TE and documentation are housed in a building on site. Systems Delta and Echo are partly located in containers and partly in a secured open area. The documentation is stored in containers at each site. The S&TE is located off-site at the workshop facilities. System Foxtrot is housed within and on top of a building. The main storage facility, located in the main building of the site, is in close proximity of the equipment building, where some critical spares, S&TE and documentation are stored. All the systems currently in use have a workshop where minor repairs are performed and where the higher-level S&TE, spare and repair parts, and technical manuals are stored. However, there are delays in the repair process as S&TE and personnel are not always readily available. Training facilities for the systems currently in use are well equipped and located either at the end user or at the contractor facility. Manpower and personnel with regards to the deconstructed case studies is dealt with in the next section.

5.4.7 ***Manpower and personnel***

Similarities between the systems currently in use with regards to the manpower and personnel element include specified manpower requirements and profiles for the various personnel supporting the system. In addition, technical personnel are required to be qualified in their respective trades, and to have a specific knowledge and experience base. System Alpha focuses on cross training between sub-systems to secure increased skills and a reduction of risk when some personnel are not readily available, therefore ensuring that backup personnel are skilled to assist with repairs. System Bravo has skilled qualified personnel on site, however, maintenance-induced errors occur due to the lack of English proficiency in understanding the technical manuals. The systems currently in use differ in the number of personnel it requires for support. The number depends on the type of support required from the end user and contractor, and the number and locations of the various systems. Although system Charlie is still under development, preliminary manpower and personnel requirements have been identified to include operators, maintainers, engineers, management personnel, and administrative personnel. The exact quantities required for system Charlie will be identified in due course following the LSA. In the next section training and training devices with regards to the deconstructed case studies is dealt with.

5.4.8 *Training and training devices*

With regards to training and training devices there are similarities between the systems currently in use, namely, all have training requirements specified and all use their system specific training devices, and in particular, training facilities, training manuals, and a training system to perform practical training on. The systems employ a theoretical and practical training approach during courses; followed by on-the-job training. The systems also have qualified instructors who provide the training courses, and while the language barrier may complicate communication and facilitation skills may be lacking, the technical know-how is extensive. Systems differ in their training; for example, system Alpha employs a self-paced module approach to training and evaluating apprentices. Qualified artisans who join the support team are subjected to training courses and on-the-job training. System Alpha has a training station that is used for training, however, due to failures on the operational systems, the training stations are sometimes used for spares, so that the trainees have to use the contractors workshop system for practical training purposes. Both systems Bravo and Alpha utilise a theoretical and practical component for their respective training courses. Systems Delta and Echo make use of a training system to conduct practical training of the systems – should the training system, however, be unserviceable, the contractors workshop system is used for training. Although system Charlie is currently under development, conceptual training and training devices have been identified, and will be more detailed once the training needs analysis has been conducted. Computer resources with regards to the deconstructed case studies is dealt with in the next section.

5.4.9 *Computer resources*

Computer resource management used by the systems include aspects such as software development, software configuration management, and audits. However, the configuration management principles have not been enforced stringently, leading to a situation where one system's operational software was loaded onto another system by accident. The operational software of one of the aforementioned systems is not strictly secured and controlled, resulting in unauthorised versions being used. System Charlie is in the process of developing its computer resources element and cannot be divulged further in this document. In the next section reliability, availability, and maintainability with regards to the deconstructed case studies is dealt with.

5.4.10 *Reliability, availability and maintainability*

The reliability, availability and maintainability (RAM) element of ILS is similar in systems Alpha, Delta, Echo, and Foxtrot. These systems all have a theoretical RAM plan implemented with statistical projections of RAM figures – the reality, however, provides different actual figures. Systems Alpha, Delta and Echo currently use a failure reporting, analysis, and corrective action system (FRACAS), yet, the data provided on the jobcard are not always detailed and correct, leading to false analysis results. System Foxtrot originally used a similar system, but has subsequently stopped, as it didn't yield the correct analysis. System Charlie is currently investigating RAM tools, and a RAM system will be implemented in due course. System Bravo currently employs a logbook system on site, where failures are recorded on paper. These failures are not captured in a database system. Configuration management with regards to the deconstructed case studies is dealt with in the next section.

5.4.11 *Configuration management*

All the systems make use of configuration management principles and have a configuration management plan implemented. System Charlie is the most stringent, subjecting engineering documentation to a formal review process, and conducting regular audits. System Alpha has gone through an 'inverse distribution' type of configuration management control, where a configuration management process was implemented. Due to budget cuts, however, configuration management was removed from the maintenance contract, resulting in maintenance-induced failures when different versions of the documentation went into circulation. Subsequently, configuration management has been re-contracted. Systems Delta, Echo, and Foxtrot utilise configuration management principles. Although a theoretical configuration management plan is in place, these systems do not necessarily adhere to the procedures within the configuration management plan, due to new personnel who are unaware of such processes and procedures. System Bravo has a limited configuration management process in place, where the documentation amendments are controlled and implemented. However, no audits are conducted with respect to the system configuration. In the next section obsolescence with regards to the deconstructed case studies is dealt with.

5.4.12 *Obsolescence*

There are many differences between the systems regarding obsolescence. System Alpha is currently suffering from component obsolescence and isn't assisted by the original manufacturer for many LRUs or components, given the manufacturer's support for new systems in the market. In addition, many of the suppliers of components simply no longer manufacture their previous product lines. These suppliers have improved components that are procured and the LRUs are modified so that improved components can be fitted to them. Subsequently, the system users are managing obsolescence more effectively. Obsolescence, other than component obsolescence, is also a concern regarding system Alpha, where skills are limited, because of personnel who have either retired or left the organisation. Their knowledge has not necessarily been transferred to the junior personnel, hence the loss of critical skills. This fact negatively affects the support of system Alpha. Similarly, system Bravo is also suffering from component obsolescence, and manages it in the same way as system Alpha. System Charlie, on the other hand, is under development and has not considered obsolescence as a concern. Systems Delta, Echo, and Foxtrot are not suffering from component obsolescence and will manage it as the need arises. Disposal with regards to the deconstructed case studies is dealt with in the next section.

5.4.13 ***Disposal***

The disposal element of ILS is not of great concern to the systems in the case studies, except for one system that needs to consider disposal and long-term storage of solid and liquid nuclear waste. Three of the systems have a procedure to dispose of equipment in accordance with set regulations. System Alpha originally had 10 systems of which four are still operational. The six non-operational stations have not been upgraded and have either been mothballed or cannibalised. The users of system Alpha are disposing of these non-operational systems, either by means of selling them to other organisations or by writing them off as most of the LRUs are obsolete and cannot be used in the upgraded system. In the next section the aspects requiring further research are dealt with.

5.5 Aspects requiring further research

A number of aspects from phase 1 and phase 2 of the study required further clarity and a research instrument was set out in questionnaires and distributed to numerous organisations; the questionnaires and analysis thereof are provided in chapter 6. These identified aspects were characteristics of the ILS elements where information was lacking. The aspects that required further research are described below.

It was clear that basic training of the respondents was required to determine their basic knowledge of engineering, finance, and management. The respondents were asked about their respective job orientations, namely, engineering, maintenance or management, and this question along with the question regarding their experience and knowledge were analysed against all the relevant ILS questions.

Concerns about maintenance were scrutinised with questions related to defining the maintenance and operational personnel requirements, maintenance issues, common maintenance problems, system operational requirements (beyond life cycle), use of a maintenance plan, possible causes of maintenance personnel errors, possible causes of logistics delay time, RAM issues, and types of failures/defects.

Questions related to S&TE were asked in the form of S&TE factors used on their systems that required improvement. The S&TE factors that were available for the respondent to select included availability of S&TE and personnel, S&TE standardisation, and S&TE support/maintenance. Supply support issues included economic decisions as they relate to supply support, and possible causes of logistics delay time. Questions related to PHS&T focused on issues, such as material handling principles, storage facility requirements, and packaging requirements. Technical data and documentation questions included writing operator and maintenance manuals in such a manner that operating and maintenance personnel would be capable of understanding the contents thereof, qualities that make information valuable to an organisation, conduct periodic audits, and apply configuration management principles to documentation. Questions asked in relation to facilities included material handling principles, typical disposal costs, and storage facility requirements.

Manpower and personnel concerns have been dealt with in questions related to defining the maintenance and operational personnel requirements. Concerns about training and training devices were probed with questions related to writing operator and maintenance documentation in such a manner that operating and maintenance personnel would be capable of understanding the contents thereof. Furthermore, questions were asked related to basic training, training factors, possible causes of maintenance personnel error, possible causes of logistics delay time, and types of failures/defects. Aspects related to both manpower and personnel, and training and training devices were dealt with in questions relating to factors which could improve an organisation's efficiency (delivery system), attracting and retaining the applicable skilled personnel to maintain and operate the system, job orientation, experience and knowledge base, and use of a manpower and personnel (including training) plan.

Computer resources related questions included conducting periodic audits, and applying configuration management. RAM concerns have been investigated in questions related to RAM issues, which included conducting RAM analyses, defining the operational availability, and identifying parts with excessive failure rates. Configuration management issues have been covered in questions examining the necessity to conduct periodic audits, apply configuration management, and apply configuration management principles with respect to documentation.

Obsolescence related concerns were investigated in questions focused on determinants of obsolescence, experience and knowledge base, system operational requirements (beyond life cycle), use of an obsolescence plan, effectively managed obsolescence, and the use of a risk plan. Disposal matters were examined in questions related to experience and knowledge base, system operational requirements (beyond life cycle), use of a disposal or system retirement plan, and typical disposal costs. The next chapter (chapter 6) discusses phase 3 research.

Table 5–4: Deconstructed case studies

CASE STUDY THEME	SYSTEM ALPHA	SYSTEM BRAVO	SYSTEM CHARLIE	SYSTEM DELTA	SYSTEM ECHO	SYSTEM FOXTROT
MAINTENANCE	Logistic support concept. Maintenance contract with end user's representative. Time-and-material contract. Maintenance concept: O- and D-level on various technical areas of system. Maintenance responsibility: O-level performed by end user. D-level performed by contractor. Engineering support: design expertise, product/system expertise provided by contractor to customer. Procurement responsibilities for spares. Electro-mechanical and mechanical end user responsibility. System specific and electronic spares via maintenance contract. Delivery from suppliers, and to and from contractor. Safety hazard information. Maintenance schedules (maintenance tasks & frequency). Major assemblies have periodic maintenance/ servicing tasks. Maintenance plan. Data analysis and reporting.	Logistic support concept. Maintenance levels: O-, I-, and D-level. D-Level performed by overseas contractor. -	Maintenance concept. Maintenance philosophy. Four lines of maintenance. Predictive, preventive, and corrective maintenance. -	System mission requirements. Support concept. Repair policy. Maintenance organisations and environment. Support organisation. Maintenance plan. Maintenance matrix, O-, I-, and D-level per week. Failed unit at O-level site is repaired remotely, if not repairable then I-level responsibility for removal of faulty LRUs, Maintenance concept five tiers split into three levels. Physical breakdown structure of system including software breakdown is documented. -	Maintenance matrix (Customer/contractor), for five areas of maintenance responsibility. Maintenance volumes requirements, operating hours, systems, life expectancy. Maintenance concept: O-, I- and D level. Support organisation, maintenance process flow, data flow and responsibilities, data analysis and reports, corrective action. -	Levels of repair, User, Support & Factory level. Maintenance activities, and responsibilities. Support Structure. Maintenance process flow. Data flow and responsibilities. Data analysis and reports. Preventive maintenance schedules -
SUPPORT AND TEST EQUIPMENT (S&TE)	S&TE requirements for levels of maintenance. Standard test equipment. Special to type test equipment. Automatic test equipment. S&TE compatibility with main equipment. Calibration. All items that require calibration are sent periodically for calibration, calibration certificates are held on file indefinitely, calibration at D-level has single point of responsibility. Firmware. Archived on CDs, under configuration management, baselines kept and audited. Embedded special test equipment. Notebooks for each system, under configuration control. Ground support equipment. Cabin ladders, platforms, hydraulic jacks, chairs, first aid kits, and fire extinguishers checked for completeness and serviceability before system is transported as well as on regular periodic time intervals.	Requirements for support and test equipment. Commercial off the shelf, special support equipment. S&TE periodic calibration. S&TE compatibility with main equipment. -	Special tools and equipment. Equipment handling system. Commercial off the shelf equipment. Periodic calibration of S&TE. -	Support equipment. Test equipment (asset) register. Special tools. Standard test equipment. Special test equipment. Special to type test equipment. (Flight calibration). Software. Calibration of system and S&TE. - -	Support equipment, special tools, standard test equipment, special to type test equipment, software. Support equipment list per system O-, I- and D- level. Test equipment evaluation. Asset register, audited annually. Test equipment calibration, periodically, test equipment register, calibration procedures, records, and calibration status identification. -	Support equipment, special tools, standard tools, standard test equipment, and software. Support equipment list per system maintenance level. Test equipment evaluation. Test equipment calibration, periodically, test equipment register, calibration procedures, records, calibration status identification, asset register. -

CASE STUDY THEME	SYSTEM ALPHA	SYSTEM BRAVO	SYSTEM CHARLIE	SYSTEM DELTA	SYSTEM ECHO	SYSTEM FOXTROT
SUPPLY SUPPORT	System support at levels of maintenance. Depending on the system configuration, deployment, and utilisation. O-level dependent on operational requirement/mission. Special storage requirements. Items that require power up, recharge, or service while not in operational use, while stored in a special storage area and have a limited shelf life. Long lead & high cost spares. Items requiring long manufacturing times from local or international suppliers (lead time of three months), items with a high unit cost, due to design, research and development. System critical spares. LRUs and/or items of equipment which when they fail, render the whole system unserviceable. Risk of stock-out. Provisioning cycle Inventory safety stock levels. Stores management. End user stores in a storeroom in building, controlled by an MIS. Larger store area for incoming inspection, non-conformance, work in progress.	System support at all levels of maintenance. Spare and repair parts are partly in stock. Obtain spares from suppliers when needed. Repairable LRUs sent to contractor for repair, spares used are invoiced. -	System under development, supply support requirements will be determined after logistic support analysis has been conducted. -	Spares list for systems and per site. Recommended spares for O-, I- and D-level. Spares (LRUs) and repair parts (components). O-, I- and D-level spares storage area. End user stores instructions and package system. Labels identification, non-conformance, disposal, and selling. Acquisition procedure for LRUs and repair parts and consumables. Reprovisioning strategy. Inventory management procedure. Material review board. Beyond economical repair. -	Types, replacement policy, and period of supply: Standard items, peculiar supply support items, long lead items, and single source items. Spares flow diagram, sites maintained by customer and contractor. Supply support for sites. Contact list for spares. Acquisition of supply support items, I-, D-level and ad-hoc. Recommended spares for each maintenance responsibility area. Turn around times of LRUs. Items installed under project and D-level maintenance Container consumables. Preventative maintenance material and equipment requirements per system per I-, and D-level. Reprovisioning strategy, reorder cycle, order point, safety stock, safety level. Inventory management procedure, Material Review Board (MRB). Stock control. -	Types: Standard items, peculiar supply support items, long lead items, single source items. Acquisition of standard supply support items, user, factory level and ad-hoc. Stock items for user, support and factory levels. Recommended spares list. Acquisition of peculiar supply support items. Reprovisioning strategy, (order point, reorder cycle, safety stock), Inventory management procedure. -
PACKAGING, HANDLING, STORAGE AND TRANSPORTATION (PHS&T)	Transportation and handling requirements for operational and maintenance functions. Transportation and handling environments (rail, air, sea, and road). Transportation responsibilities, modes of transport, personnel, equipment, frequency of transportation. Requirements for re-usable containers, bubble plastic bags, antistatic bags, cardboard boxes, wooden crates. Packing requirements and procedures, condition of packaging, materials and item types , environmental factors, identification on packaging. PHS&T procedures and responsibilities. Handling requirements and identification (static sensitive devices, mechanical damage).	Transportation from end user to contractor is per air. From airport to end user site is per vehicle or public transport. Cardboard boxes and wooden crates used as packaging for equipment. Re-usable boxes and crates are used. -	System under development, PHS&T requirements will be determined after logistic support analysis has been conducted. Special containers are used to package and store equipment. Equipment requires cranes, forklifts, trolleys, etc. to transport the equipment. -	End user stores instructions and package system. Labels identification, non-conformance, and handling of static sensitive equipment. Transportation - Modes (Road - prime, air). Frequency when required, urgency. Packaging - Responsibilities, correct packaging, supporting documentation and labels. Equipment or packaging not damaged, if damaged investigate. Test documentation, failure forms, and applicable labels. Handling/storage - static sensitive, special storage areas. -	PHS&T requirements and system modules for each system. Spares flow, for sites maintained by customer and sites maintained by contractor. Transportation: responsibilities, modes of transport, frequency, and delivery address. Packaging: responsibilities, condition of packaging, material and item types, identification of packaging, OEM instructions. Handling: Responsibilities, handling requirements for identified item types, handling requirement identification. Storage: Protection from rain, excessive dust, temperature range, humidity considerations. -	PHS&T requirements. Transportation: responsibilities, frequency, delivery addresses. Packaging: responsibilities, condition of packaging, materials and item types, environmental factors, identification of packaging. Handling: responsibilities, handling requirements for identified item types, handling requirement identification. Storage: Requirements, Protection from rain, excessive dust, temperature range, humidity considerations.

CASE STUDY THEME	SYSTEM ALPHA	SYSTEM BRAVO	SYSTEM CHARLIE	SYSTEM DELTA	SYSTEM ECHO	SYSTEM FOXTROT
DATA & DOCUMENTATION	Technical and technical training documentation. Software documentation. List Of Applicable Publications (LOAP). Automatic and special to type test equipment documentation. Configuration of documentation using ERP system. Documentation audits. Maintenance documentation. Correct technical and maintenance information. Documentation written at skill level of person using the manual. Documentation inventories. Correct issue levels, configuration management.	Technical and technical training documentation. Documentation written at skill level of person using the manual. -	System under development, data and documentation requirements will be determined after logistic support analysis has been conducted. Operator and maintenance manuals. Illustrated parts breakdown, spare parts lists, procedures, and processes. -	Technical documentation, standard operating procedures, Inspection/test/repair standards and procedures. General standards and specifications, technical manuals, test equipment documentation. Acceptance of documents - reviewed internally, under configuration control following acceptance of documentation, forms part of system MRI. -	Documentation requirements and list of documentation. Acceptance of documents. Updating process. Distribution process. Document format and layout. Document numbering. Language. -	Documentation requirements and list of proposed documentation. Acceptance of documents, updating, distribution. -
FACILITIES	Facility requirements for maintenance levels (O- and D-level). Equipment environmental requirements. Operational cabins radio frequency (RF) screened, antistatic precautions. Storage environments: technical stores, library, transito, other stores under roof, well ventilated, cement floor, access control, fire protection. Test equipment store. Tool stores. Software storage. Site for system. Parking space for vehicles, equipment, offices for staff, logistic support area. -	Facility requirements for maintenance levels. Operational cabins RF screened. -	System under development, data and documentation requirements will be determined after logistic support analysis has been conducted. Decontamination facilities. Laboratories. Clean rooms. Containment building. -	Existing facilities and new facilities used, maintenance, storage, calibration, and training. O- and I-level are end-user responsibility. D-level facilities are contractor responsibility. O level maintenance activities performed by remote maintenance software, O-level facilities are not required, except that in which the equipment is situated. I- and D-level maintenance requirements for Electro-mechanical, general, radionavigation workshops. Calibration - No facilities are required at O-, I- or D-level as test equipment calibration is outsourced under contract. Training facility - classroom and furniture for students and lecturer, power outlets, temperature limits, lighting. Equipment for practical aspects of course. Software - controlled store, issued on demand, fire proof safe. Storage - Holding areas for documentation, spares, test equipment. Containers on site for storage of LRUs and hardware items. Technical library in a container at the base workshop, end user documentation depot holds one complete set. Transito - receive & dispatch areas, secure area, admin, packaging facilities, racks, and secure. Test equipment store - access control, racks, ventilated, under roof, cement floor, temperature limits, racks, and fire protection. Tools stores - easily accessible, special tools and jigs, ventilated, under roof, cement floor, and adequate lighting.	Existing sites for O-, I- and D level. Contractor facilities. Containers. Training facilities. -	Facility requirement for user level: storage, maintenance support, and site facilities. Facility requirements for support level: storage, maintenance support, engineering support, administration, and training. Facility requirements for factory level: storage (work in progress, incoming goods receiving & inspection, dispatch, quarantine storage area, computerised stores control), maintenance support, engineering support, administration, and training. Security: access control for customer and contractor facilities. Facility requirements. -

CASE STUDY THEME	SYSTEM ALPHA	SYSTEM BRAVO	SYSTEM CHARLIE	SYSTEM DELTA	SYSTEM ECHO	SYSTEM FOXTROT
MANPOWER AND PERSONNEL	Operational and maintenance personnel requirement. Deploy service and maintain the system. D-level is outsourced to a contractor, O-level performed by end user. Pre-requisites for personnel expertise levels. Qualified in relevant trades, apprentices undergo training as per apprentice training curriculum. Advanced systems training, cross training, retention of trained personnel and expertise is of prime importance. Personnel competencies for each level of maintenance. O-level competence is application, while D level competence is application/analysis. Depending per system, site, allocated per rank, discipline needed. Personnel skill levels. Competencies per level depend per technical discipline. Technical assistance at O-level by contractor. Ad-hoc basis, sub-system repairs, setting up & calibration of sub-systems, software changes, maintenance tasks that are not O-level related, training of O-level personnel. Apprentices follow a three-year apprenticeship; qualified personnel need one to three years experience in specific discipline before attending other training courses/cross training on other disciplines.	Operational and maintenance personnel requirement. Deploy service and maintain the system. D-level is outsourced to a contractor, O-level performed by end user. I- level is split between end user and contractor. Pre-requisites for personnel expertise levels. Personnel competencies for each level of maintenance. Personnel skill levels. Competencies per level depend per technical discipline -	System under development, manpower and personnel requirements will be determined after logistic support analysis has been conducted. Requirement for operators, maintainers, management personnel. Prerequisites to be ascertained after logistic support analysis. -	Manpower profiles for O-, I- and D-level, qualifications and experience. Engineering support personnel – quality assurance (QA), configuration management, logistic engineering. Personnel requirements - number of personnel per discipline. Personnel certification - new personnel required to undergo training on system. -	Manpower profiles: O-, I- and D-level, administrative and engineering support personnel. Qualifications, experience, specific training prerequisites. Personnel requirements for O-, I- and D level. Personnel utilisation for support level, job title, location, minimum quantity, utilisation (full or part time). Personnel certification. -	Manpower profiles including quantity, qualification and experience per level of maintenance, administrative, engineering personnel (QA, configuration management, logistics engineering). Personnel requirements: Job title, quantity, and utilisation. Personnel certification: new personnel, certified for competency. -

CASE STUDY THEME	SYSTEM ALPHA	SYSTEM BRAVO	SYSTEM CHARLIE	SYSTEM DELTA	SYSTEM ECHO	SYSTEM FOXTROT
TRAINING AND TRAINING DEVICES	Training requirements for each artisan trade and level. Qualified in specific trade, practical qualification on system, high level of analytical capability with respect to technical field. Training programs: classroom based training and self paced training. Qualification of competency: required elements for technical training. Theoretical and practical training, per discipline. Training aids. Overhead projector/Transparencies, Digital projector, stationery, exam papers and answer sheets, course progress reports, student course feedback, facility well ventilated which sits required number of students. Training course pre-requisites. Background knowledge of technical field. Training curricula. Discipline, duration, venue, pass mark, pre-requisites of qualified students. - -	Training requirements for each artisan trade and level. Qualified in specific trade, practical qualification on system, and high level of analytical capability with respect to technical field. Training courses provided by a contractor who is responsible for D-level repairs. - -	System under development, training and training devices requirements will be determined after logistic support analysis has been conducted. Training needs analysis. -	Personnel certification - new personnel required to undergo training on system. Training resources - manpower, facilities, hardware, support and test equipment required to successfully train technician to be capable of performing all the maintenance activities of the system at specific levels of maintenance. Training philosophy - classroom and practical training followed by a period of on-the-job training under supervision of a qualified mentor. Instructors & mentors – D-level system engineer or field engineer. In-depth knowledge of system, test equipment and fault finding techniques. Facilities – end user or contractor responsibility depending whose premises, training facilities - air conditioned, overhead projector, stationery. Hardware - Test benches, test equipment. Training documentation - Student training manuals, instructor handbook, also placed under configuration control. Technical training course descriptions - Aspects covered during course, duration. Continuation training - unsatisfactory work results, major system upgrades or modifications. -	Training resources: manpower, facilities, and hardware. Training philosophy: Classroom, On the job (OJT) training. System engineer is instructor. Facilities: formal training- furniture, tools, stationery, hardware for practical- functional units, test benches, test equipment. Number of students, lecture hours, length of courses. Technical training: training manuals for students, instructor manual. Also placed under configuration control. Manpower prerequisites: maintenance technician, qualification, experience and additional experience. Technical training course descriptions (theory, practical), and duration, test and evaluation, competency. Student performance. Course evaluation. On the job training: after course at site under mentor. Re-training: new personnel, existing - unsatisfactory work results, system upgrades or modifications. Informal training at sites.	Candidate requirements: existing customer personnel. Training strategy for theoretical, practical and hands on training: operation and maintenance of equipment, number of students, student requirements. Training courses: in depth training, training manuals, course curriculum and schedule. -
COMPUTER RESOURCES	Procedure for operational software control (configuration control). All version baselines of operational software archived in fireproof safe, placed under configuration control. Auditing and verification processes for all operational software management. Software changes per engineering change proposal (ECP). Six monthly audits performed on operational software Interfaceability to other systems. System software deployment preparation, transportation and storage procedures. System operational software change procedures, using ECP and configuration control board (CCB).	Procedure for operational software control (configuration control). Auditing and verification processes for all operational software management. -	System under development, computer resources requirements will be determined after logistic support analysis has been conducted. Failure reporting and recording system. Continuous control and instrumentation measurement capturing. -	Computer resources and software support. Auditing and verification processes for all operational software management. -	Management organisation and software team and responsibilities. System and hardware description and configuration per FIR. System software and description and functionality. Standards and procedures: documentation, magnetic media, configuration, test procedures, software change requests, system trouble reports, corrective action, testing/acceptance testing. Software: Source items, software support items, buildstate. Quality activity, audit reviews and inspections, supplier control.	Computer resources and software support. Auditing and verification processes for all operational software management. -

CASE STUDY THEME	SYSTEM ALPHA	SYSTEM BRAVO	SYSTEM CHARLIE	SYSTEM DELTA	SYSTEM ECHO	SYSTEM FOXTROT
RELIABILITY, AVAILABILITY AND MAINTAINABILITY (RAM)	Effectiveness factors. Reliability growth programme. Other contractor involvement in product. Sub systems within main system are not main contractor responsibility. Other products/systems attached to main product. External agencies affecting the system. Evaluation process and corrective action formats for R&M.	Other contractor involvement in product. Sub systems within main system are not main contractor responsibility. Other products/systems attached to main product. External agencies affecting the system. -	System under development RAM requirements will be determined after logistic support analysis has been conducted. FRACAS implementation. -	Collection and processing of failure/maintenance data. Evaluation of logistic system and equipment performance. Measuring model. Data analysis. Failure reporting. RAM analysis. Corrective Action Board. FRACAS process. Maintenance requirements per system.	Inherent availability objectives per system. Measuring model reports, failure reporting, RAM analysis outputs. Fracas process. Maintainability: characteristics, requirements, hardware responsibility matrix, support requirements, levels of repair -	Evaluation of logistic system and equipment performance. Reliability programme. Failure data, build states, shipping & dispatch information, engineering change proposals, cost drivers, FMECA, failure reporting, Maintenance analysis and reports. Availability: Inherent, achieved, operational. FRACAS process, measuring model, RAM process. -
CONFIGURATION	Configuration management. Evaluation, coordination and approval of all changes to equipment configuration, Information database, status accounting, responsibilities, technical configuration of system, and documentation. Functional, mechanical, electrical and software requirements. Item identification and codification of system. Engineering change proposals (ECPs). Configuration Control Board (CCB). Master Record Index (MRI). Physical Breakdown Structure (PBS) of system. Audits. System technical configurations. Build history record. Baseline/product configuration and record on information system. History of configuration changes. Audits, hardware configuration & PBS, software version record, technical documentation, ECP records, MIS. Configuration items archived. Control of non-conforming products. Database. Control of purchased material and consumption.	Configuration management. -	Configuration management. Evaluation, coordination and approval of all changes to equipment configuration, Information database, status accounting, responsibilities, technical configuration of system, and documentation. Item identification and codification of system. History of configuration changes. Audits, hardware configuration & PBS, software version record, technical documentation, ECP records, MIS. -	Configuration identification. Control (CCB, ECP), status accounting & audits. Documentation management. Configuration responsibilities of system. Configuration management organisation. Deviations/concessions. Functional Configuration Baseline (FCB) to Allocated Configuration Baseline (ACB) to Product Configuration Baseline (PCB). Modification Information. Configuration Management Data System. Build State Record and build history. Subcontractor/vendor control. Configuration audits. Physical Configuration Audit, PCA procedure and requirements, Post audit action.	Configuration identification, control, status accounting and audits. Configuration management responsibilities and organisation. Configuration management data system. CCB, configuration control, documentation management, Design Change Proposal (DCP), classification of changes. Configuration baselines - FCB, ACB, PCB. Build State Record and build history. Deviations/Concessions. Configuration Status Accounting (CSA). Modification information. Configuration audits (Physical Configuration Audit), responsibilities, records kept. Post audit action. MRI.	Configuration identification, control, status accounting and audits. Configuration management responsibilities. Configuration management data system. CCB, ECP, DCP, classification of changes. Configuration baselines - FCB, ACB, PCB. Build State Record and build history. Documentation management. Modification information. Change procedure. Configuration Status Accounting (CSA). Configuration audits (Physical Configuration Audit), responsibilities, records kept. Post audit action. MRI.
OBSOLESCENCE	Suffering from obsolescence. Obsolescence plan.	Suffering from obsolescence.	System under development, obsolescence not considered as yet.	No obsolescence plan in place, not suffering from obsolescence.	No obsolescence plan in place, not suffering from obsolescence.	No obsolescence plan in place, not suffering from obsolescence.
DISPOSAL	Disposal plan for system. Disposal of hardware, software media and firmware. Disposal of documentation.	Disposal of hardware, software media and firmware. Disposal of documentation.	Disposal plan for LRU's must still be developed. Radioactive waste disposal.	Procedure for disposal of LRU's -	Procedure for disposal of LRU's -	Procedure for disposal of LRU's -

'I can prove anything by statistics except the truth.'

– George Canning

'There is nothing that is a more certain sign of insanity than to do the same thing over and over and expect the results to be different.'

– Albert Einstein

CHAPTER 6 PHASE 3 RESEARCH – QUANTITATIVE

6.1 Introduction

The literature review described in chapter 2 and deconstructed in chapter 4, and the deconstructed case studies to be found in chapter 5, resulted in identifying aspects for further research as mentioned in section 5.5. These aspects were areas within each of the ILS elements that were found to be lacking information. The questionnaire research instrument was set out as described in chapter 3.

The data collection process was complex since two data collection mechanisms were used. The paper-based questionnaires were captured manually. The web-based questionnaires were captured direct into a database. The two sets were combined and a statistical software program was used to conduct the analysis.

Descriptive statistics was used as a first order analysis to determine frequencies of responses and to determine whether there were significant trends in the responses. According to Keller and Warrack (2003:25) such statistics can be used to arrange, summarise and present data, in order to interpret meaningful results. The descriptive statistics tables are depicted in Appendix H. As a second mechanism 2-way tables were used and inferential tests performed to determine dependencies and measures of association between variables.

6.2 Questionnaire Focus

The questionnaire focus was based on collated findings from phase 1 and phase 2 that indicate that future research was required. Industries selected were based on the literature and the deconstruction of phases 1 and 2. Ethical and security concerns were dealt with by requesting permission to distribute the questionnaire from the military authorities.

A population of 40 organisations within the high technology industry in South Africa who use or profess to use ILS was identified. 11 participating organisations were selected (which utilised electronic and mechanical systems). The sample of 11 organisations included 566 respondents.

Companies involved with mature systems as well as new designs, high-technology systems, and systems still being used beyond their designed life cycles were chosen. Three levels or job orientation levels were selected for the study; engineering, maintenance, and management, and the experience and knowledge bases of the respondents were distinguished as follows:

1) Design of new system;
2) Maintenance (relatively new system, less than five years old); and
3) Maintenance (system older than five years).

In this section the focus of the questionnaire was described. It was based on collated findings from phase 1 and phase 2 requiring further research. The sample and respondents were also discussed.

6.3 Pilot study questionnaire

The pilot study questionnaire originally consisted of 141 questions and was refined to a final set of 45 questions; this questionnaire is contained in appendix E and a 90% response rate (25 responses) was recorded. A preliminary analysis was conducted on the responses in order to determine the relevance, understanding and accuracy of the questions, and the completeness of responses on paper-based questionnaires. In the next section the structured questionnaire is dealt with.

6.4 Structured questionnaire

Two final study questionnaires were used. This was due to the sensitivity of questions in specific environments that were taken into account, particularly the military environment. The specific ILS elements for the two environments (industrial and military) are contained in Table 6–1, and the two questionnaires were distributed as follows:

1) One for the military (25 questions), due to sensitivity issues regarding current capabilities.
2) One for industrial organisations (34 questions, including 25 questions mentioned previously for the military questionnaire).

Table 6–1: Questions asked relating to integrated logistic support themes for military and industrial organisations

ILS ELEMENT	MILITARY	INDUSTRIAL
Maintenance	Yes	Yes
Maintenance errors	No	Yes
Support and test equipment (S&TE)	Yes	Yes
Supply support	Yes	Yes
Packaging, handling, storage, and transportation (PHS&T)	No	Yes
Technical data and documentation	Yes	Yes
Facilities	No	Yes
Manpower and personnel	Yes	Yes
Training and training devices	No	Yes
Computer resources	Yes	Yes
Reliability, availability, and maintainability (RAM) – dependability	Yes	Yes
Configuration management	Yes	Yes
System/product operational requirement	Yes	Yes
Obsolescence	Yes	Yes
Disposal	No	Yes

Table 6–2 below lists the ILS themes and the concerns raised regarding discrepancies between the literature review and the case studies. The areas for further study are also listed.

Table 6–2: Integrated logistics support concerns between reviewed literature and case studies, and additional further study required

THEME	CONCERNS	FURTHER STUDY
Maintenance	Testing & evaluation criteria, Effectiveness factors, Actions and support required for material fielding, Testing categories: no testing, internal testing, external testing, automated testing, semi-automated testing, manual testing, maintenance activity indicators: System supportability indicators (MTBM, MTBR, etc.) and facility effectiveness indicators (TAT, Logistics pipeline time, etc.)	Analysis, cost, strategic. Faulty maintenance work, Poorly defined & implemented maintenance practices, Strategic guidelines, philosophy & objectives. Maintenance plan. Risk management Plan. Maintenance induced failures, Operator-induced failures Wear-out (predictable) failures
Support and test equipment (S&TE)	Availability of S&TE across projects by same organisation, Planning and acquisition of logistic support for equipment, Support and test equipment items compatibility with the main equipment, Capabilities of operating and maintenance personnel, Selection process of S&TE, State-of-the-art technology, Special test equipment requires support.	Availability of S&TE, & personnel, S&TE standardization, S&TE support/maintenance

THEME	CONCERNS	FURTHER STUDY
Supply support	Life cycle support, Impact of human-factor engineering, Inventory safety stock levels, Provisioning cycle, Order frequency, Correct parts available when and where required in the quantities necessary to support maintenance, Range and depth, or scale, Past experience or statistical projections, Economic order quantity, Probability of failure & the consequences, Stock-out promotes cannibalisation.	Economical decisions: Consequence of failure, Cost to repair, Distance to support, Failure probability, Lead-time to repair, Operational environment
Packaging, handling, storage and transportation (PHS&T)	Procedures and resource requirements, Special security requirements, Geographic and environmental restrictions, Special handling equipment and procedures, Modes of transportation, Storage: The short- or long-term storage of items, Temporary or permanent facilities, Warehouses, covered in open areas, uncovered in open areas, in a controlled environment, or in special facilities, scheduling, routing and selecting a carrier.	Minimum handling, Size & dimensions of handled material, Standardize handling equipment. Additional repair & spare parts lead time, Impact on reliability of product, Product quantity distributed. Labelling & identification, Protection of equipment during transportation, Transportation constraints, Inventory cycle.
Technical data and documentation	Specific description of how the technical data program must be conducted, Identification of computer resource support requirements, Operating and maintenance documentation written to the skill levels of the individual accomplishing the functions covered by all procedures, Well-documented library of technical publications.	Understandable documentation
Facilities	Facility requirements for operational and maintenance analyses, system/equipment design, specifications, Human-factor engineering.	Storage facility: Additional repair & spare parts lead time, Impact on reliability of product, Product quantity distributed
Manpower and personnel	Personnel protection, personnel requirements, Identification of variables of personnel performance factors or constraints affecting quality, psychological considerations, training, workload & environment., Human factors engineering requirements.	Maintenance & operational personnel requirements, attracting & retaining personnel. Manpower & personnel (including training) plan
Training and training devices	Human factors engineering requirements, Personnel protection, including safety, survival, clothing, escape and rescue and stress pertaining to the system or equipment, Training programs, Training aid equipment requirements.	Manpower & personnel (including training) plan. Ability of training instructors Adequacy of training material Personnel skill level related training programs
Reliability, availability and maintainability (RAM)	Reliability apportionment and predictions, Effects of PHS&T, shelf life, and maintenance on reliability, Reliability centred maintenance, Failure modes effects and criticality analysis, Effectiveness factors, Logistics/admin delay: mean logistics delay time, MTBL (logistics delays), logistics delay frequency.	Conducting RAM analyses, Defining the operational availability, Identifying parts with excessive failure rates, Administrative & approval activities, Ordering & shipping time (lead time),
Configuration management	Configuration documentation, Business processes available, approved and audited, Configuration management audits	Applying configuration management principles, conduct audits

THEME	CONCERNS	FURTHER STUDY
System/ product operational requirement	System life cycle, System operational utilization. This includes hours of system operation and frequency of use, Supportability characteristics.	Expected life cycle, Operational condition of deployments, Utilization requirements. Administrative & approval activities, Ordering & shipping time (lead time), Technical knowledge & specification
Obsolescence	System phase-out and disposal costs, System/equipment retirement and material phase-out plan, Obsolescence cost, Designed-in Obsolescence, Obsolescence plan.	Cost to support, New technology, Reliability, Supplier (Original Equipment Manufacturer – OEM) . Obsolescence Plan. Manage obsolescence under risk Redesign complete or part of system Replace complete system
Disposal	System phase-out and disposal costs, Disposal costs: Inventory closeout, PHS&T, data management, refurbishment, demilitarization, waste management, System/equipment retirement and material phaseout plan, Disposal categories: surplus material, scrap, obsolete material and equipment, waste, rejected products and services, safety stock, Disposal strategic options: Use as is, reclamation for intra-plant use, sale to another firm, return to vendor, sale to dealer or through a broker, dumping.	Disposal/System Retirement Plan, Dismantling/ disassembly costs, Environmental & safety concerns, Redesign for alternative use (e.g. demilitarization)
Maintenance errors	Maintenance personnel errors due to work space & layout, poor training, poor supervision, inadequate serviceable equipment, inadequate or incorrect tools and support equipment, poor procedures.	Inadequate work space or work layout, Poor supervision, Poor training & procedures. Maintenance induced failures Operator-induced failures Wear-out (predictable) failures

In this section the rationale for the two questionnaires and their respective breakdown was provided. The aspects requiring further research were also provided. In the next section the target group of high technology systems is provided.

6.5 High technology systems

Numerous organisations were approached requesting them to participate in the completion of the questionnaire. Some organisations were reluctant to participate, some were willing only to provide a sample of their relevant staff complement, while certain organisations were willing to provide a list of their entire staff complement. The respondents from the following high technology systems were used for the final questionnaire:

1) Military radar system;

2) Military radionavigation systems;
3) Industrial radionavigation systems;
4) Military aircraft;
5) Aircraft industry;
6) Industrial satellite earth station;
7) The Council for Scientific and Industrial Research (CSIR).
8) Engineering department at an academic institution;
9) Industry/study specific engineering organisations; and
10) Modular nuclear reactor development.

Structured and unstructured focus groups and discussions: took place with personnel from:

1) The military,
2) Military end-user contract organisation,
3) Aviation, and
4) Nuclear industry.

In this section the numerous organisations that were approached requesting completion of the questionnaire were listed. In the next section the questionnaire response is dealt with.

6.6 Questionnaire response

An overall response rate of 33% (187 responses) was achieved from 566 respondents for the final questionnaire. The response rates for the two separate questionnaires are:

1) Military response rate of 75% (122 responses) for the paper-based questionnaire (25 questions) from 162 respondents; and
2) Industrial response rate of 16% (65 responses) for web-based questionnaire (34 questions) from 404 respondents.

This section provided the breakdown of the overall response rate of 33%. The next section deals with the results of the descriptive statistical analysis.

6.7 Descriptive statistics – results

The respondents who answered the questionnaire were demographically a representative sample from the population of the organisations participating in the study. Within the high-technology industry, including the activities of engineering, management and maintenance, the staff are predominantly white males.

The descriptive statistics are explained within this section by means of figures. A brief summary of the categorisation used to group questions per exhibit is provided; thereafter each question is discussed in detail. 122 military and 65 industrial respondents participated, and this is represented graphically in Figure H–1 in Appendix H. In addition to the demographics presented, the following was observed from these statistics:

1) A very clear difference between the military and industrial response rate. (This may be cultural, but a subsequent study on the effects of organisational culture in this regard could be very interesting);
2) There is a marked improvement with respect to missing responses on the web-based questionnaire. However, the response rate is definitely lower. (This may be due to organisational cultural effects, comfort with web-based questionnaires, or merely a more realistic response rate);
3) There are several questions where the distribution is an inverted normal distribution. An inverted normal distribution is when the responses for both most important and least important are high and in relation the responses for neutral is low. It is necessary to establish whether this difference in strongly held opinions has any significant relation to demographic variables, or if it is generally true for all responses. These inverted normal distributions will be discussed in more detail with the relevant questions.

Question 6 asked the respondents their organisation's or institution's name; 131 of the respondents are involved with military or associated organisations (bearing in mind that although they completed a military organisation questionnaire, they might be involved with military systems as a contractor). 21 of the respondents are involved with existing industrial organisations, 34 respondents are involved with planned industrial systems, while 1 respondent did not complete the question. The graphical representation is provided in Figure H–1, in Appendix H.

In question 7 the respondents were asked about the current main system or project with which they are involved. Only 154 responses were received for this question. This is due to the sensitivity of the industry, where the systems are either of a military nature or the organisation is involved with military projects of a sensitive nature or the information is seen as confidential to the company. From the responses received four categories were decided upon. 52 of the respondents are involved with high-technology electronic systems that are grouped as ground systems, where ground systems are systems currently in use and remain on the ground (i.e. are not airborne). 42 of the respondents are working with aircraft high-technology systems, 33 with support functions (e.g. stores), where support systems are non-technical management or maintenance functions. 27 of the respondents are concerned with purely mechanical systems, i.e. a new modular power station. 33 of the respondents did not answer the question, for the reasons mentioned above. The graphical breakdown is to be found in Figure H–1, in Appendix H.

The respondents' classification per gender (question 1), race (question 2), and home language (question 3) is depicted in Figure 6–1. 170 males and 17 females completed the questionnaire. 143 are white, and 44 respondents are not, consisting of Black (31 respondents), Coloured (four respondents), Indian (three respondents), and other (six respondents). 115 of the respondents speak Afrikaans as a home language, and whereas 37 of the respondents use English at home, the remaining 35 respondents speak neither English or Afrikaans as a home language, but Northern Sotho (seven respondents), Southern Sotho (three respondents), Tsonga (one respondent), Tswana (10 respondents), Venda (one respondent), Xhosa (seven respondents), Zulu (two respondents), German (one respondent), Kiswahili (one respondent), and two respondents who answered "other", but did not complete the "other" field. 99 (52.94%) of the respondents are white, male and use Afrikaans as a home language while 126 (67.38%) of the respondents are white, male and speak either Afrikaans or English as a home language.

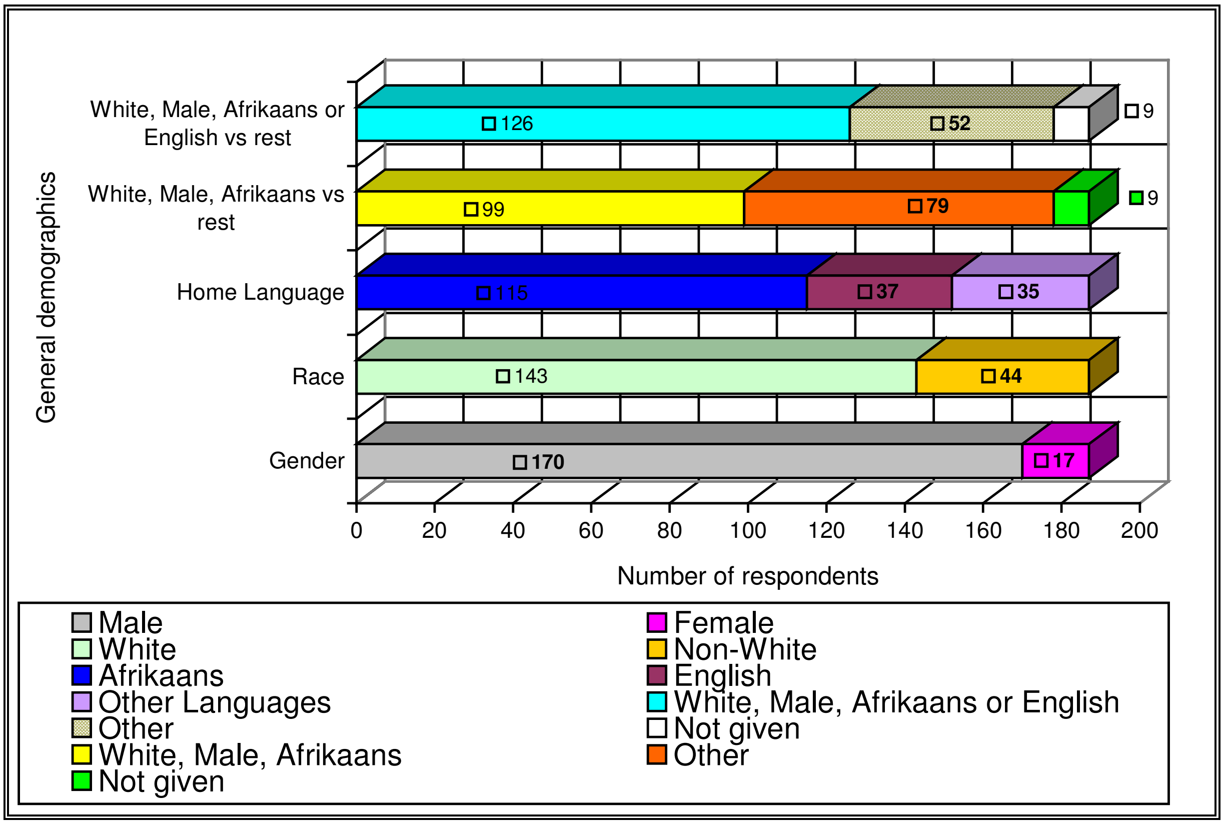


Figure 6–1: Respondents' general demographics (gender, race, and home language)

Question 5 enquired the age of the respondents. This ranged between 22 and 67; with 13 respondents aged 38. The average age of the respondents is 40 (40.45) years old. The distribution of ages is illustrated in Figure H–2, in Appendix H. Two age categories are provided: one age distribution is classified per decade (five groups, excluding the "age not given" group), while the second is classified per the revised Wechsler adult intelligence scale (WAIS-R) (Wechsler; 1981, in Louw, van Ede, and Louw; 1998:500-501). Participants were grouped, according to this scale, into six age groups, i.e. 20 to 24, 25 to 34, 35 to 44, 45 to 54, 55 to 64, and 65 to 74. The WAIS-R age categories are to be found in Figure H–2, in Appendix H. According to Hermann (2007) the average age in South Africa of an artisan is 54 years. Within the first category 33.70% were between the ages of 31 and 40, while 17.39% were between the ages of 51 and 67. Within the revised WAIS-R category 34.78% were in the 35 to 44 age group, and 27.17% were within the 45 to 54 age group (remaining percentages are available in Appendix H).

Question 4 asked the respondents the direction of their basic training, and the results are indicated in Figure H–3 in Appendix H. 145 (78.8%) of the respondents were trained in engineering, 37 respondents in management, 2 respondents in finance while 3 respondents did not furnish an answer.

In Question 8 the respondents were asked their job orientation. 68 of the respondents are involved with engineering, 44 with maintenance, 71 with management, while four respondents did not complete the question. See Figure 6–2 for the results.

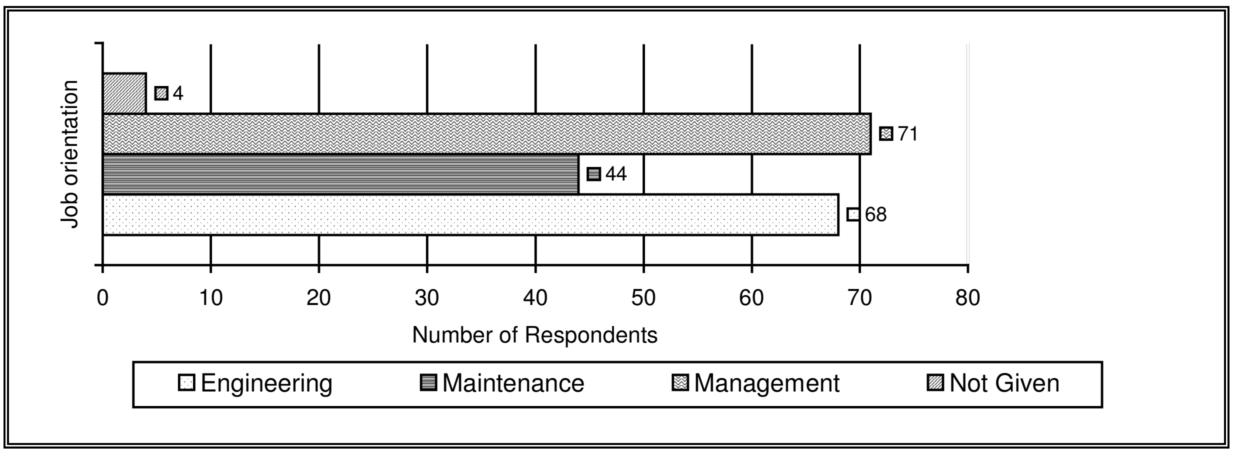


Figure 6–2: Question 8 – Job orientation

In question 9 the respondents were asked to rank the statements provided regarding factors that could be used to improve the efficiency of their organisations delivery system, the results are provided in Figure H–4 in Appendix H. 41.34% of the respondents rated question 9A (best practices) as least important, and 38.55% rated question 9A as most important. 37.64% of the respondents rated question 9B (knowledge) as important, and 24.72% rated question 9B as least important. With regards to question 9C 39.33% of the respondents rated the question as neutral (rated a 2), and 37.64% rated question 9C as most important. (Additional percentages are available in Appendix H). Question 9A (best practices) produced an inverted normal distribution, when analysing the data it was established that the majority of engineering and management personnel rated this question either most or least important, and that the majority of maintenance personnel rated this question as neutral (i.e. most respondents have a strong opinion regarding the question).

Question 10 asked the respondents to rank the question with regards to the qualities that make information valuable to an organisation, the results are provided in Figure H–5 in Appendix H. 55.31% of the respondents rated question 10B (accuracy) as the most important. 40.45% of the respondents rated question 10C (timely) as least important. (Additional percentages are available in Appendix H).

The respondents were asked about their knowledge and experience base in Question 11; the results are illustrated in Figure 6–3. 59 of the respondents possess knowledge and experience in designing a new system, 43 reported knowledge and experience in maintenance of systems that are less than five years old, while 85 have experience with systems that are more than five years old. The majority of the respondents are involved with systems which do not necessarily employ the latest technology, i.e. systems older than five years, and these could suffer from obsolescence.

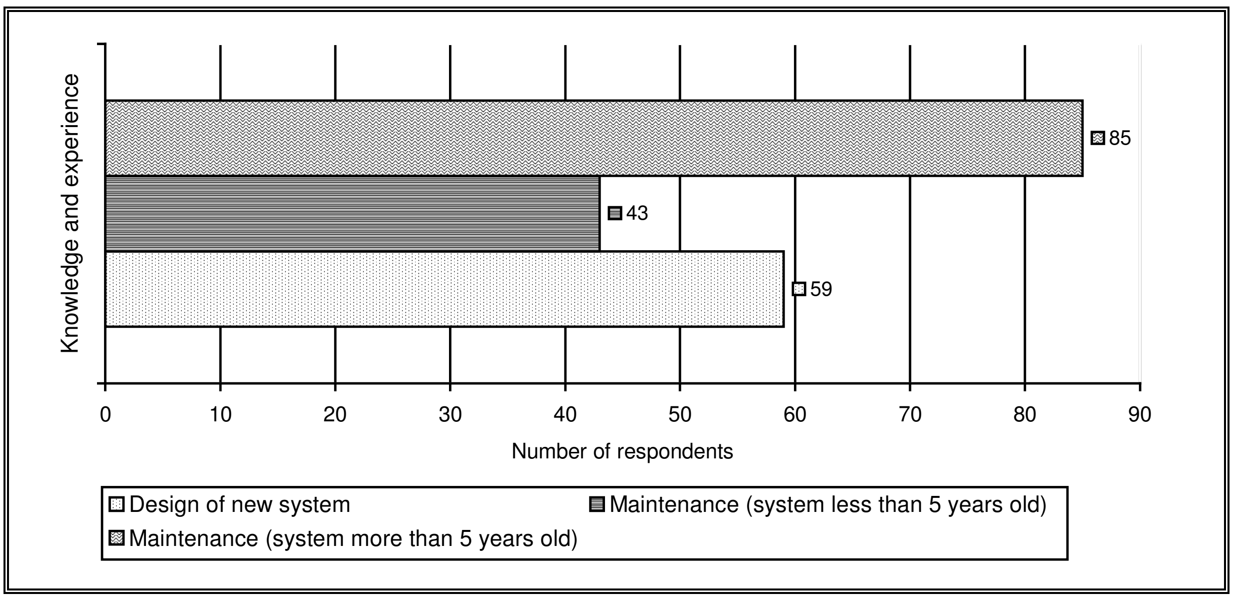


Figure 6–3: Question 11 – Knowledge and experience

In question 12 the respondents were asked to rate the necessity of writing operator and maintenance documentation in such a manner that operating and maintenance personnel are capable of understanding the contents thereof; the results are contained in Figure 6–4. All the respondents answered this question. The majority of the respondents (68.45%) answered as most necessary. In fact, 87.70% of the respondents rated this question as either a 1 (most necessary) or 2 (necessary). (See Appendix H for additional percentages.)

Question 13 asked the respondents to rate the necessity of defining the maintenance and operational personnel requirements, the results are provided in Figure H–6 in Appendix H. All the respondents answered this question. 75.40% of the respondents rated this question a 1 (32.62%, most necessary) or a 2 (42.78%, necessary). (Additional percentages are available in Appendix H).

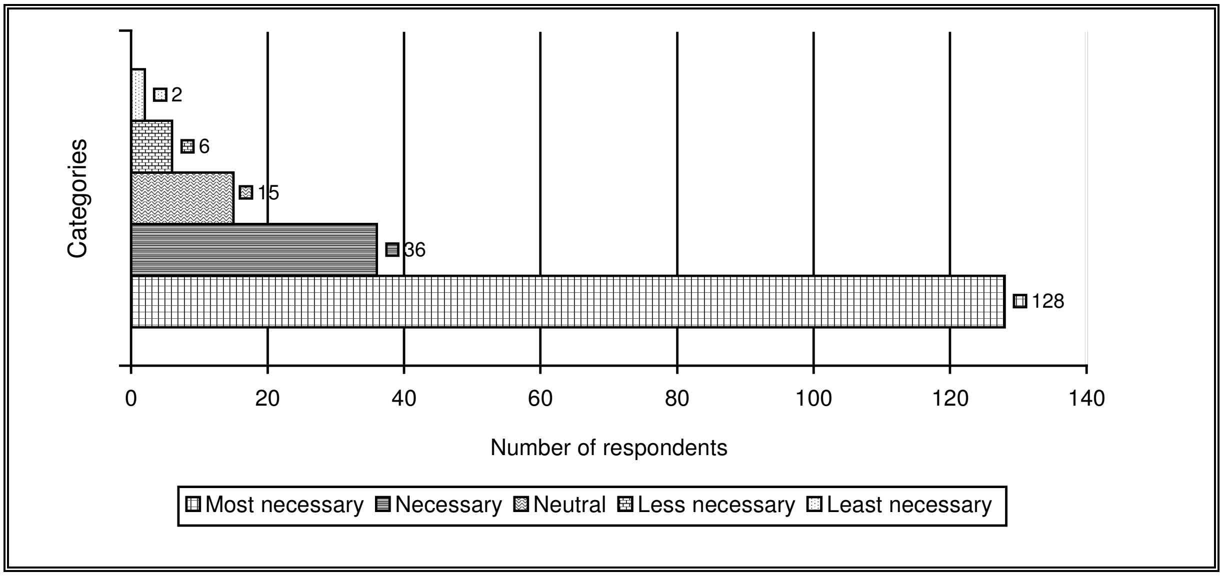


Figure 6–4: Question 12 – Writing operator and maintenance documentation in such a manner that operating and maintenance personnel are capable of understanding the contents thereof

In question 14 the respondents were asked to rate the necessity of conducting periodic audits, the results are provided in Figure H–7 in Appendix H. All but one of the respondents answered this question. More than half (54.30%) of the respondents rated this question a 1 (20.97%, most necessary) or a 2 (33.33%, necessary). 17.20% of the respondents rated this question either a 4 (less necessary) or a 5 (least necessary). (Additional percentages are available in Appendix H).

Question 15 asked the respondents to rate the necessity of applying configuration management, the results are provided in Figure H–8 in Appendix H. All the respondents answered this question. Almost half of the respondents rated this question a 1 (47.06% of the respondents), only one respondent rated this question a 5 (least necessary). 75.94% rated this question either as most necessary or necessary. (Additional percentages are available in Appendix H).

The importance of applying configuration management principles with respect to documentation was asked in question 16, the results are provided in Figure H–9 in Appendix H. 186 respondents answered the question. 50.00% of the respondents rated this question as most important (rated a 1), a further 35.48% rated the question as important (rated a 2). 2.69% each rated the question as less important (rated a 4) and least important (rated a 5). (Additional percentages are available in Appendix H).

Question 17 asked the respondents regarding the importance of attracting and retaining the applicable skilled personnel to maintain and operate the system, the results are provided in Figure H–10 in Appendix H. All the respondents answered the question. 59.36% of the respondents rated the question as most important (rated a 1), and a further 25.67% rated the question as important (rated a 2). 5.88% of the respondents rated the question either a 4 (less important) or a 5 (least important). (Additional percentages are available in Appendix H).

In question 18 the respondents were asked to rate the support and test equipment factors used on their system that required improvement; the results are provided in Figure 6–5. 68.68% rated question 18A (availability of support and test equipment, and personnel) as the most important statement. 49.17% rated question 18B (support and test equipment standardisation) as least important, and 49.45% rated question 18C (support and test equipment support/maintenance) as neutral. The most important factor, in their opinion, was the availability of support and test equipment, and personnel. (Additional percentages are to be found in Appendix H.)

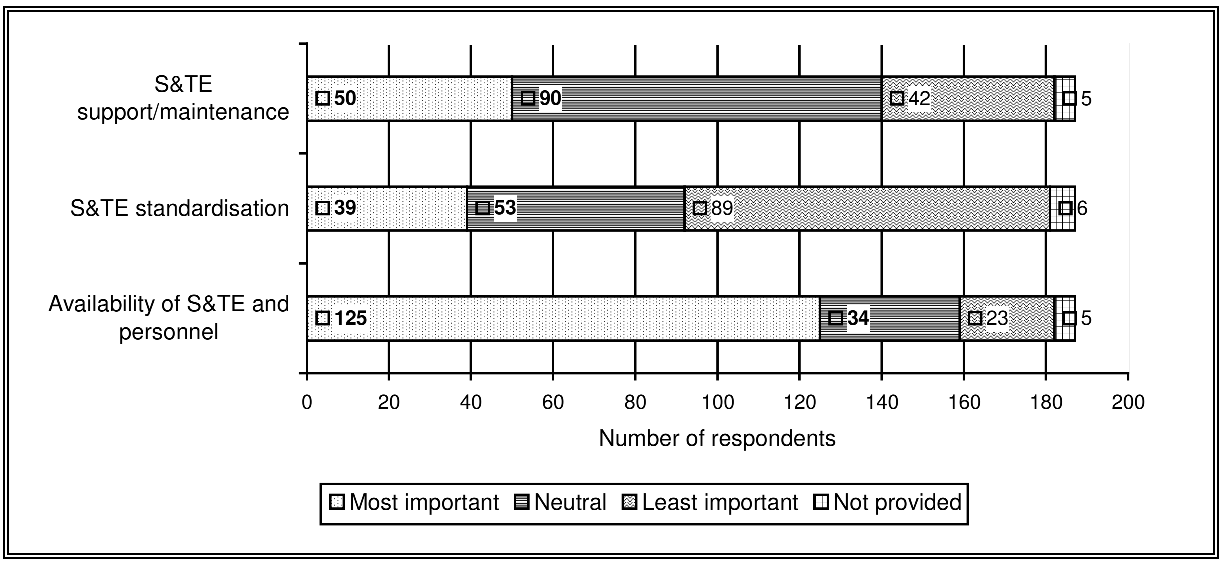


Figure 6–5: Question 18 – Support and test equipment factors used on your system that require improvement

In question 19 the respondents were asked to sort the statements regarding maintenance issues with regards to their high-technology system, the results are provided in Figure H–11 in Appendix H. Question 19A (analysis) was rated as most important (50.00%), question 19B (cost) was rated as least important (38.67%), and question 19C (Strategic) was rated as neutral (43.72%). (Additional percentages are available in Appendix H).

Question 20 enquired about reliability, availability, and maintainability issues with respect to respondents' high-technology systems, and Figure 6–6 illustrates the results. 50.55% of the respondents perceived question 20C (identifying parts with excessive failure rates) as most important. (Additional percentages are to be found in Appendix H.)

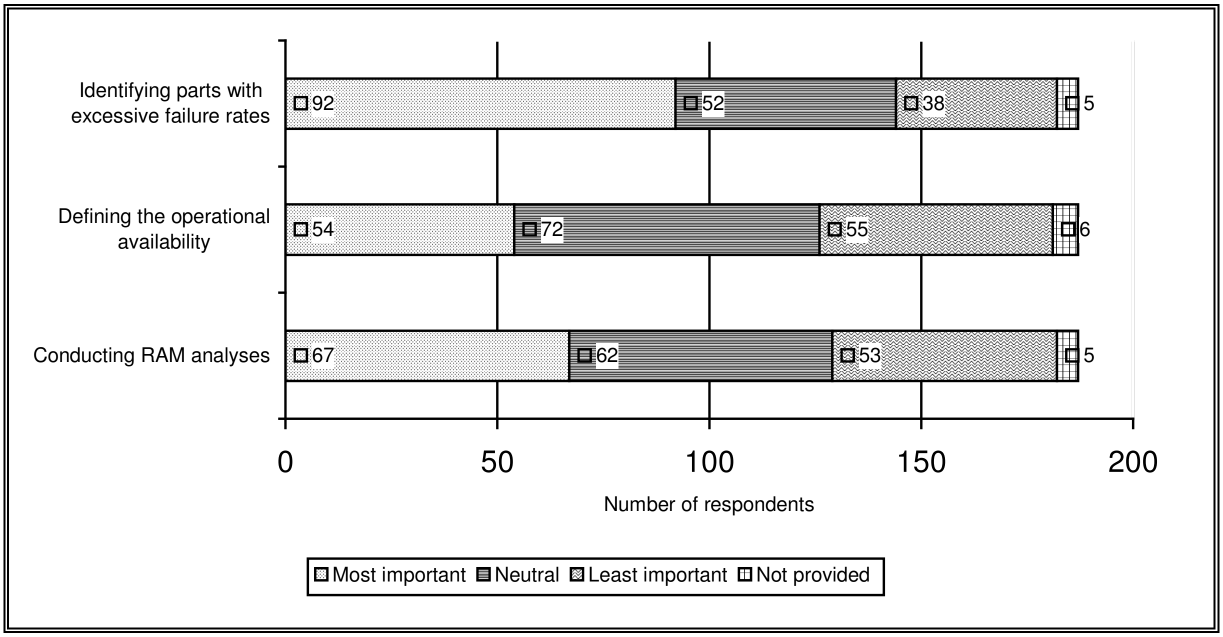


Figure 6–6: Question 20 – Reliability, availability and maintainability (RAM) - (dependability) issues

Question 21 asked the respondents regarding common maintenance problems as they relate to their high-technology system, the results are provided in Figure H–12 in Appendix H. Question 21A (faulty maintenance work) was rated as most important, question 21C was rated as least important, and question 21B was rated neutral. (Additional percentages are available in Appendix H). Question 21C (strategic guidelines, philosophy and objectives) produced an inverted normal distribution where the respondents had strong opinions regarding the question asked.

In question 22 the respondents were asked to rate the material handling principles of their high-technology system according to three statements, the results are provided in Figure H–13 in Appendix H. Question 22A (minimum handling) was rated as most important, question 22B (size and dimensions of handled material) as least important, and question 22C (standardise handling equipment) as neutral. (Additional percentages are available in Appendix H).

Question 23 asked the respondents to rate statements regarding the system operational requirements (beyond life cycle) with respect to their high-technology systems, the results are provided in Figure H–14 in Appendix H. Question 23A (expected life cycle) was rated as least important, question 23B (operational conditions of deployment) as most important and question

23C (utilisation requirements) as neutral. (Additional percentages are available in Appendix H). Question 23A (expected life cycle) produced an inverted normal distribution, where the respondents had strong opinions (most or least important) regarding the question asked.

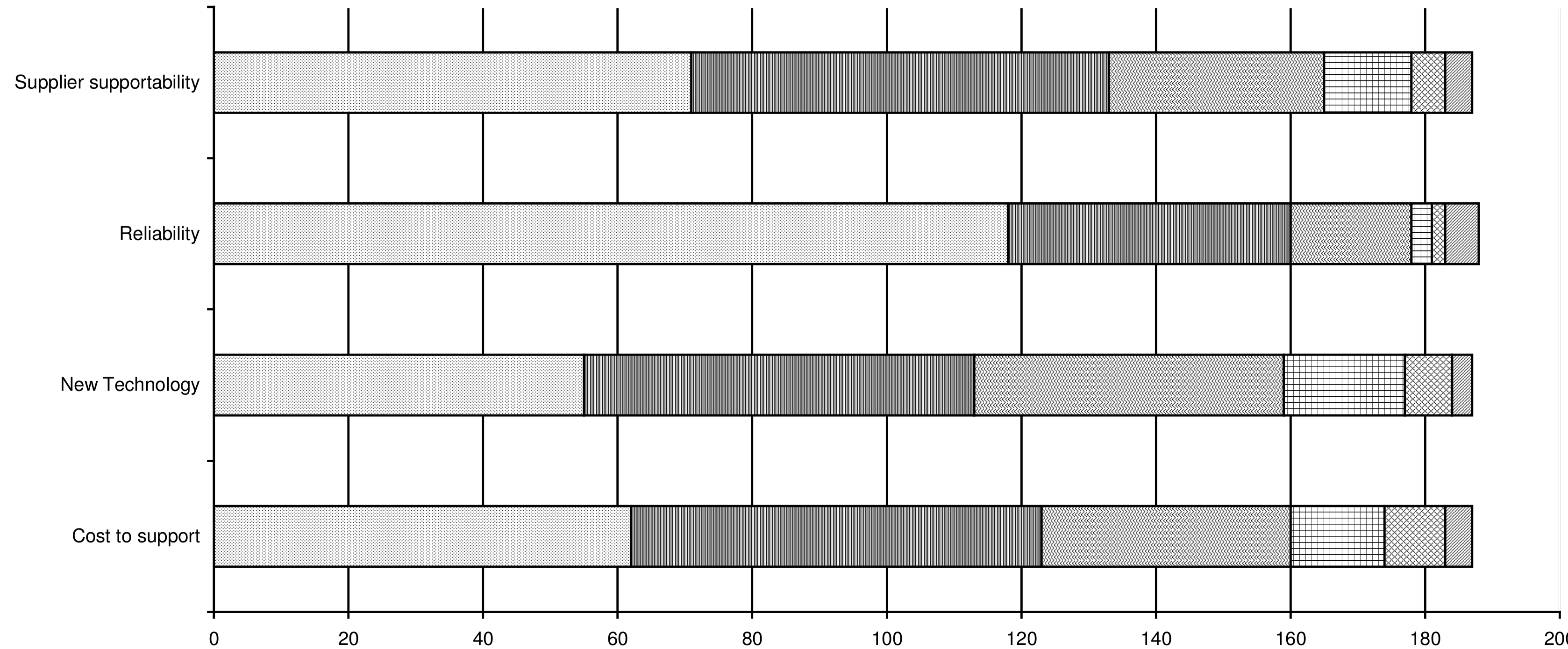
Question 24 asked about the determinants of obsolescence in the respondent's views, and the results are to be seen in Figure 6–7. Four statements were provided, to be rated on a Likert scale of 1 to 5, where 1 was most important and 5 was least important. Question 24C (reliability) was rated as the most important determinant of obsolescence (with 64.48% of the respondents selecting question 24C as most important). Question 24D (supplier supportability) was rated as the next important determinant of obsolescence, followed by question 24A (cost of support) and finally question 24B (new technology) was seen as the least important determinant of obsolescence. (Consult Appendix H for additional percentages.)

Question 25 asked the respondents to rate economical decisions as they relate to supply support with respect to their high-technology system; the results are illustrated in Figure 6–8. Question 25G (reliability of repaired system) was rated as most important, with 55.38% of the respondents rating this statement as a 1. (Additional percentages are available in Appendix H.)

Questions 26 to 34 were only completed by the industrial organisations and not by the military organisation as they felt that the questions were of too sensitive a nature.

Question 26 asked the respondents to rate on a scale of 1 to 3 the use of certain plans to improve the performance of their high-technology system; the results are contained in Figure 6–9. Question 26B (maintenance plan) was perceived to be the most important plan; 66.15% of the respondents rated question 26B as a one. The risk management plan was perceived to be the next most important plan with 47.69% of the respondents rating this as one. The disposal plan (question 26A) is perceived to be the least important plan. (Additional percentages are recorded in Appendix H.)

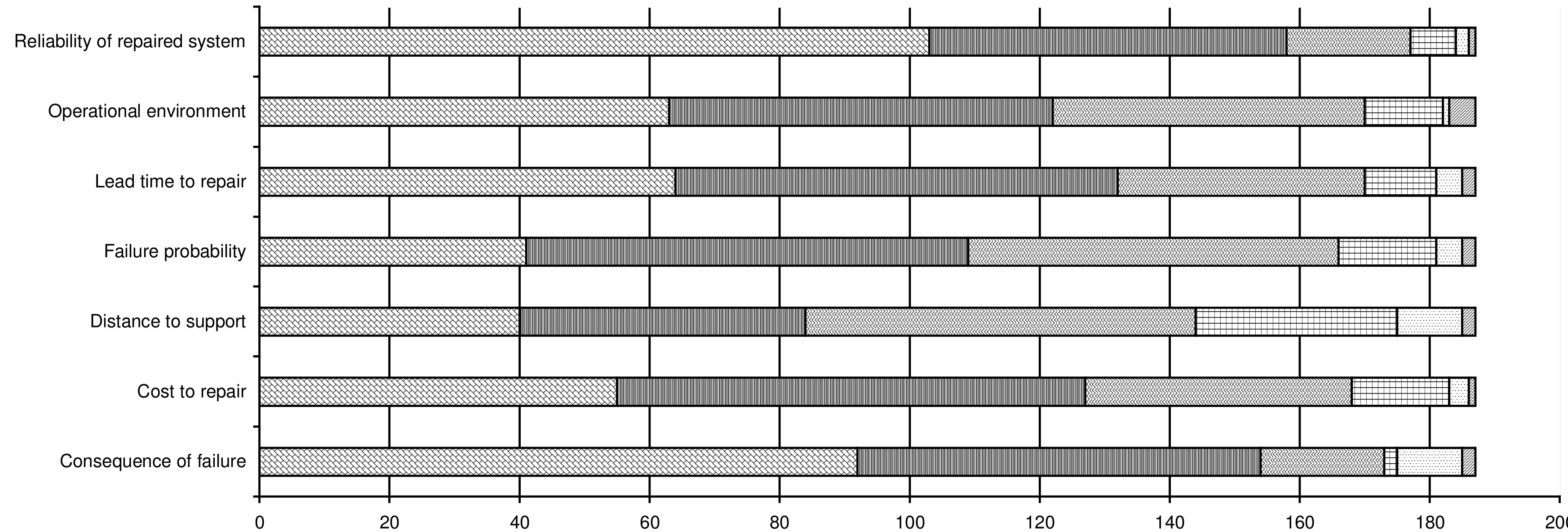
In Question 27 the respondents were asked about typical disposal costs as they relate to their high-technology system; see Figure 6–10 for the results. They were asked to classify the three statements from 1 to 3, where 1 is most important and 3 is least important. Question 27B (environmental and safety concerns) was rated as most important with 58.46% of the respondents rating it as a 1. Question 27C (redesign for alternative use, e.g. demilitarisation) was rated as least important with 46.15% rating the question as a 3. Question 27A (dismantling/disassembly costs) was rated as neutral with 43.08% of the respondents giving it a score of 2. (Consult Appendix H for additional percentages.)



	Cost to support	New Technology	Reliability	Supplier supportability
Not provided	4	3	5	4
Least important	9	7	2	5
Less important	14	18	3	13
Neutral	37	46	18	32
Important	61	58	42	62
Most important	62	55	118	71

Number of respondents

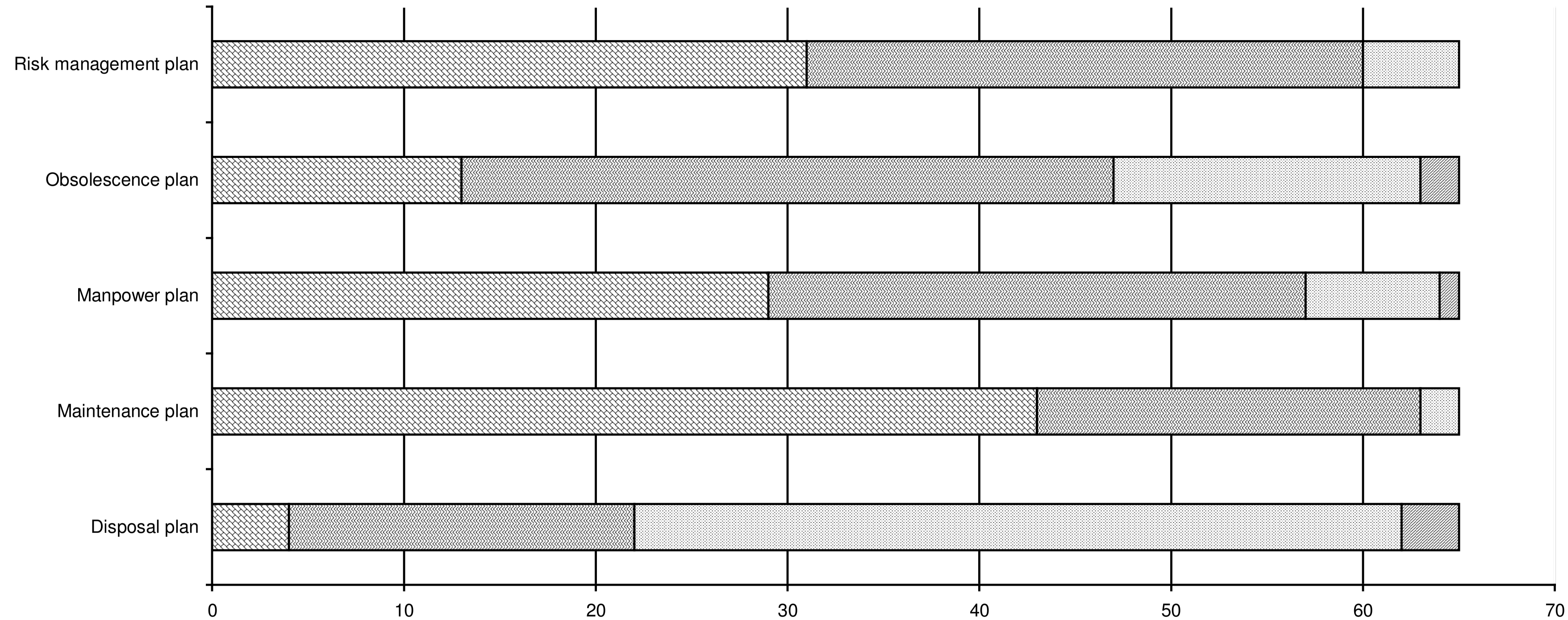
Figure 6–7: Question 24 – Determinants of obsolescence



	Consequence of failure	Cost to repair	Distance to support	Failure probability	Lead time to repair	Operational environment	Reliability of repaired system
Not provided	2	1	2	2	2	4	1
Least important	10	3	10	4	4	1	2
Less important	2	15	31	15	11	12	7
Neutral	19	41	60	57	38	48	19
Important	62	72	44	68	68	59	55
Most important	92	55	40	41	64	63	103

Number of respondents

Figure 6–8: Question 25 – Economical decisions as they relate to supply support



	Disposal plan	Maintenance plan	Manpower plan	Obsolescence plan	Risk management plan
Not provided	3	-	1	2	-
Least important	40	2	7	16	5
Neutral	18	20	28	34	29
Most important	4	43	29	13	31

Number of respondents

Figure 6–9: Question 26 – Using the following plans to improve your system's performance

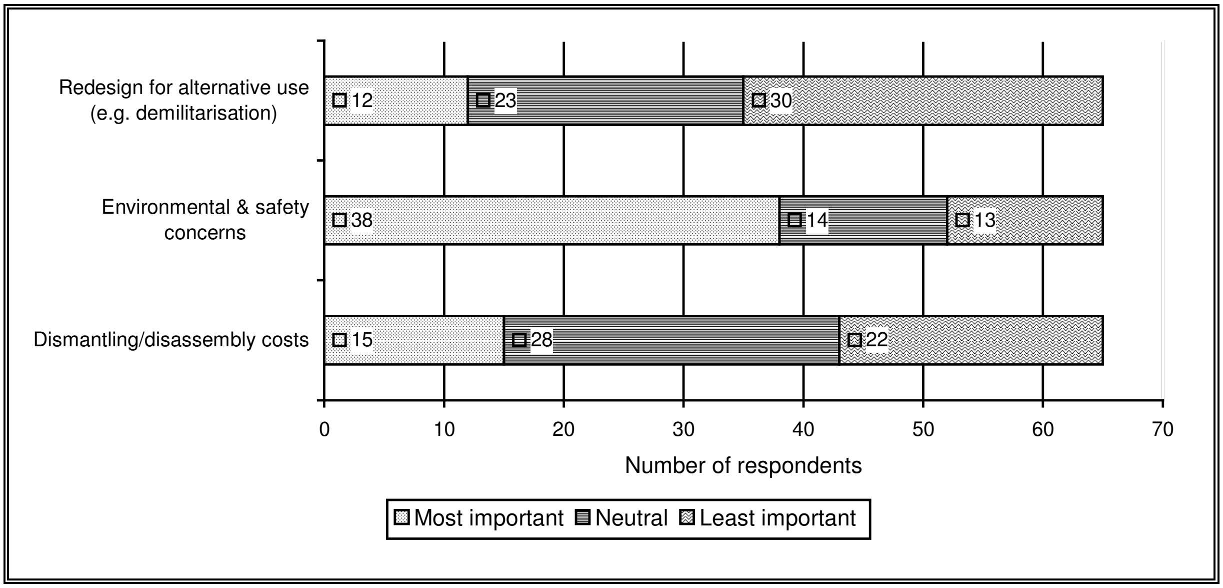


Figure 6–10: Question 27 – Typical disposal costs

Question 28 asked the respondents regarding storage facility requirements, results are provided in Figure H–15 in Appendix H. The respondents were required to sort three statements from one to three, where one is most important, and three is least important. The respondents rated question 28B (impact on reliability of product) as most important, with 52.31% of them rating the statement a one. Question 28C (product quantity distributed) was rated as least important with 58.46% of the respondents rating the question a three. Question 28A (additional repair and spare parts lead-time) was rated as neutral with 41.54% of the respondents rating the question a 2. (Additional percentages are available in Appendix H).

Question 29 asked the respondents to sort the statements related to packaging requirements from one to three, where one is most important and three is least important, results provided in Figure H–16 in Appendix H. The respondents rated question 29B (protection of equipment during transportation) as most important, with 52.31% of them rating the statement a one. Question 29C (transportation constraints) was rated as least important with 53.85% of the respondents rating the question a three. 63.08% of the respondents rated question 29A (labelling and identification) a 1 or a 2. (Additional percentages are available in Appendix H). Question 29A (labelling and identification) produced an inverse negative distribution, where the respondents had a strong opinion regarding the question.

Question 30 asked the respondents regarding training factors, results provided in Figure H–17 in Appendix H. The respondents rated question 30A (ability of training instructors) as most important, with 44.62% of them rating the statement a one. Question 30C (personnel skill level related training programs) was rated as least important with 40.00% of the respondents rating the question a three. Question 30B (adequacy of training material) was rated as neutral with 43.08% of the respondents rating the question a 2. (Additional percentages are available in Appendix H). Question 30C (personnel skill level related training programs) produced an inverse negative distribution, where the respondents had a strong opinion regarding the question.

Question 31 asked the respondents their opinion on effectively managing obsolescence, results provided in Figure H–18 in Appendix H. Question 31A (manage obsolescence under risk) was rated as the most important aspect to effectively manage obsolescence with 58.46% of the respondents rating this question a one. Question 31C (replace complete system) was rated as the least important aspect, with 56.92% rating the question a three. Question 31B (redesign complete or part of system) was rated neutral with 50.77% of the respondents rating this question a two. (Additional percentages are available in Appendix H).

Question 32 probed the respondents for possible causes of maintenance personnel error, with the results being recorded in Figure 6–11. Question 32C (poor training and procedures) was perceived to be the most important aspect, with 78.46% of the respondents rating this question as 1. The respondents perceived question 32A (inadequate work space or work layout) as least important since 55.38% of them rated this question a 3. Question 32B (poor supervision) was viewed as neutral because 49.23% of the respondents rated this question a 2. (Additional percentages are recorded in Appendix H.)

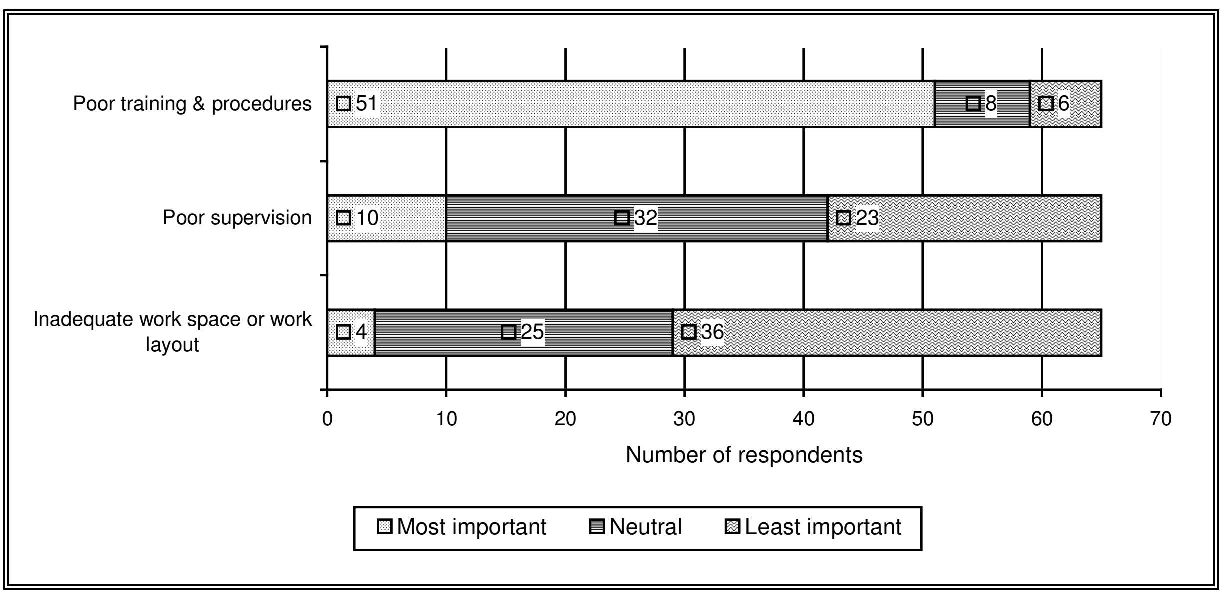


Figure 6–11: Question 32 – Possible causes of maintenance personnel error

Possible causes of logistics delay time was asked in question 33, results provided in Figure H–19 in Appendix H. Statement 33A (administrative and approval activities) is rated the most important aspect, with 40% of the respondents rating this statement as a one, and 38.46% rating the statement a two. Statement 33B (ordering and shipping time – lead time) is rated neutral as 40% of the respondents rated this statement a one, and 36.92% rated the statement a two. Statement 33C (technical knowledge and specification) is rated as least important as 55.38% of the respondents rated the statement a three. (Additional percentages are available in Appendix H).

Question 34 enquired regarding types of failures/defects, with the answers being provided in Figure 6–12. Question 34A (maintenance induced failures) is regarded as the least important aspect; only 23.08% of the respondents rated this statement as a 1. Question 23B (operator induced failures) is regarded as the most important aspect due to the cumulative frequency of 72.31% of the respondents selecting a one or a two. (Additional percentages are to be found in Appendix H.) Question 34C (wear-out {predictable} failures) produced an inverse negative distribution, where the respondents had a strong opinion (most or least important) regarding the question asked.

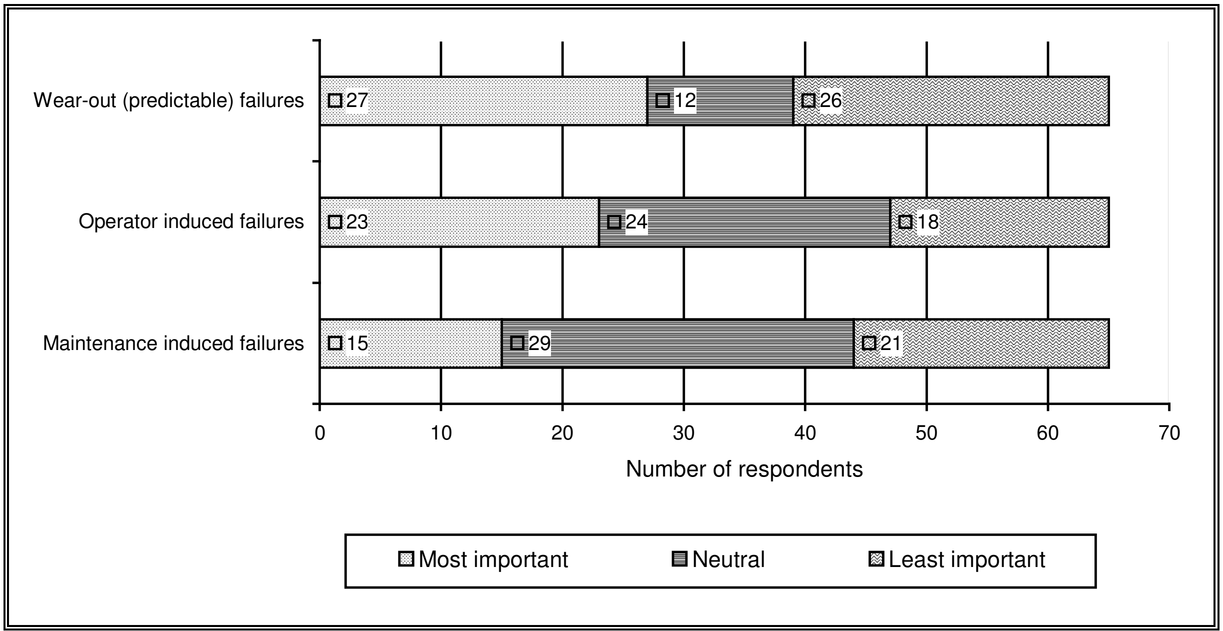


Figure 6–12: Question 34 – Types of failures/defects

In this section the descriptive statistical analysis of the questionnaire results was presented. In the next section the inferential statistical analysis is dealt with.

6.8 Inferential Statistical analysis

Contingency tables are used to determine whether two or more variables are dependent on each other. According to Howell (1995:363) such a table is a *'… two-dimensional table in which each observation is classified on the basis of two variables simultaneously'.*

Keller and Warrack (2003:538) argue that the *'… chi-squared test of a contingency table is used to determine whether there is enough evidence to infer that two nominal variables are related and to infer that differences exist among two or more populations of nominal variables'.* In other words, the chi-square test determines if two variables are dependent on one another.

Inferential statistics were used to determine whether significant differences between certain variables existed (Howell, 1995). Questions 8 (job orientation) and 11 (knowledge and experience) were compared to the questions below in Table 6–3 using a contingency table Chi-square test.

Table 6–3: Contingency table statistical analysis classified by questions 4, 8 and 11

Q NO.	QUESTION DESCRIPTION
4	Basic training
8	Job orientation
9	Factors which could improve your organisation's efficiency (delivery system)
10	Qualities that make information valuable to an organisation
11	Knowledge & experience
12	Writing operator & maintenance documentation in such a manner that operating & maintenance personnel are capable of understanding the contents thereof
13	Defining the maintenance & operational personnel requirements
14	Conduct periodic audits?
15	Applying configuration management?
16	Applying configuration management principles with respect to documentation?
17	Attracting & retaining the applicable skilled personnel to maintain & operate the system
18	Support and Test Equipment (S&TE) factors used on your system that require improvement
19	Maintenance issues
20	Reliability, availability & maintainability (RAM) - (dependability) issues
21	Common maintenance problems
22	Material handling principles
23	System operational requirements (beyond life cycle)
24	Determinants of obsolescence
25	Economical decisions as they relate to supply support
26	Using the following plans to improve your systems performance
27	Typical disposal costs
28	Storage facility requirements
29	Packaging requirements
30	Training factors
31	Effectively manage obsolescence
32	Possible causes of maintenance personnel error
33	Possible causes of logistics delay time
34	Types of failures/ defects

Legend: Q = Question, No. = Number

Inferential statistics are used to determine whether a criterion within populations differs by using sample data. According to Howell (1995:7) these statistics are utilised to:

> *'… estimate parameters of two or more populations, mainly for the purpose of finding if those parameters are different'.*

Miller and Freund (1985:2) state that statistical inference *'… concerns generalizations based on sample data.'* Keller and Warrack (2003:3) similarly mention that inferential statistics are used to *'… draw conclusions or inferences about characteristics of populations based on sample data'.*

The null hypothesis states that there is *'… no relationship between the two variables.'* (Keller and Warrack, 2003:538) The alternative hypothesis states that *'one variable affects the other,…'* (Keller and Warrack, 2003:538). In a true null hypothesis the two variables are not dependent on each other (Keller and Warrack, 2003:539).

Cramer's V is used to measure the strength of association of categorical variables, which can be represented in a contingency table (Unisa, 1992:256). According to PlanetMath (2008) Cramer's V is *'…a statistic measuring the strength of association or dependency between two (nominal) categorical variables in a contingency table'.* The strength of the association is determined by the value of the calculated statistic: if V is close to 1 the association is strong, and when V is close to zero the association is weak (PlanetMath, 2008). In the next section the cross tabulation analysis is furnished.

6.8.1 ***Cross tabulation analysis***

In this section the following cross tabulation is discussed; the variable question 8 (job orientation) versus question 4, and question 9 to question 34. The cross tabulation of question 11 (knowledge and experience) versus question 4, question 8 to question 10, and question 12 to question 34 is also discussed. In Table 6–4 below the cross tabulation Chi-Square statistic (P Value) and the Cramer's V value are provided. Only those cross tabulations with a Chi-Square P value of less than 5% will be discussed in detail in the paragraphs that follow.

Table 6–4: Chi-Square and Cramer's V statistics of cross tabulation of specific questions

QUESTION NO.	QUESTION 8 (JOB ORIENTATION)		QUESTION 11 (KNOWLEDGE AND EXPERIENCE)	
	CHI-SQUARE	CRAMER'S V	CHI-SQUARE	CRAMER'S V
4	***<0.0001***	0.5354	***0.0461***	0.1829
8	-	-	***<0.0001***	0.3767

QUESTION NO.	QUESTION 8 (JOB ORIENTATION)		QUESTION 11 (KNOWLEDGE AND EXPERIENCE)	
	CHI-SQUARE	CRAMER'S V	CHI-SQUARE	CRAMER'S V
9A	0.0650	0.1590	0.4197	0.1044
9B	0.2575	0.1235	0.4692	0.1000
9C	0.5327	0.0952	0.9337	0.0484
10A	***0.0348***	0.1715	0.2490	0.1224
10B	0.4324	0.1043	0.0668	0.1566
10C	0.4028	0.1072	0.8192	0.0658
11	***<0.0001***	0.3767	-	-
12	*0.0316*	0.1701	0.1026	0.1436
13	0.0669	0.1549	0.1454	0.1351
14	0.4868	0.0972	0.0551	0.1577
15	0.8320	0.0634	0.2364	0.1217
16	0.7910	0.0683	0.6576	0.0808
17	0.0857	0.1494	0.1110	0.1418
18A	***0.0121***	0.1899	***0.0339***	0.1692
18B	0.8762	0.0585	0.5378	0.0928
18C	***0.0156***	0.1855	***0.0132***	0.1863
19A	0.3796	0.1086	0.8261	0.0643
19B	0.8440	0.0629	0.6996	0.0779
19C	0.7192	0.0764	0.2032	0.1275
20A	***0.0030***	0.2121	0.3601	0.1094
20B	0.3103	0.1162	0.1247	0.1412
20C	***0.0029***	0.2128	0.7134	0.0763
21A	0.8905	0.0560	0.0835	0.1500
21B	0.5723	0.0902	0.8744	0.0578
21C	0.2290	0.1253	0.9747	0.0365
22A	0.1975	0.1297	0.2745	0.1184
22B	0.0568	0.1601	0.1833	0.1304
22C	0.2842	0.1185	0.7499	0.0725
23A	0.9268	0.0502	0.2164	0.1263
23B	0.1696	0.1347	0.1373	0.1388
23C	0.3310	0.1140	0.1357	0.1391
24A	***0.0123***	0.1891	0.7087	0.0766
24B	0.4367	0.1025	0.2237	0.1243
24C	0.2167	0.1270	0.1232	0.1407
24D	0.8118	0.0665	0.2849	0.1171
25A	0.7735	0.0704	0.2482	0.1209
25B	0.5021	0.0958	***0.0401***	0.1641
25C	0.2707	0.1195	0.0567	0.1575
25D	0.4227	0.1035	***0.0308***	0.1696
25E	***0.0091***	0.1931	***0.0487***	0.1607
25F	0.1922	0.1305	0.2187	0.1253
25G	0.2224	0.1252	***0.0049***	0.2003
26A	0.2227	0.2144	0.3452	0.1900
26B	0.3356	0.1873	0.0793	0.2535
26C	0.4911	0.1633	0.2713	0.2008
26D	0.9532	0.0737	0.5843	0.1502
26E	0.4217	0.1729	0.7487	0.1218
27A	0.4050	0.1756	0.3000	0.1937
27B	0.0698	0.2583	0.1432	0.2298
27C	***0.0048***	0.3392	0.5917	0.1468

QUESTION NO.	QUESTION 8 (JOB ORIENTATION)		QUESTION 11 (KNOWLEDGE AND EXPERIENCE)	
	CHI-SQUARE	CRAMER'S V	CHI-SQUARE	CRAMER'S V
28A	0.8282	0.1071	0.6750	0.1339
28B	0.9712	0.0634	0.4080	0.1751
28C	0.7796	0.1164	0.0735	0.2564
29A	0.3930	0.1775	0.5439	0.1540
29B	0.6030	0.1451	0.2816	0.1972
29C	0.4987	0.1609	0.5636	0.1510
30A	0.6278	0.1413	0.6779	0.1335
30B	0.3466	0.1854	0.6381	0.1397
30C	0.6699	0.1347	0.3854	0.1788
31A	0.3017	0.1934	0.4718	0.1650
31B	0.4154	0.1739	0.8042	0.1118
31C	0.3116	0.1916	0.5976	0.1459
32A	0.6408	0.1393	0.2272	0.2084
32B	0.6560	0.1369	***0.0209***	0.2983
32C	0.8612	0.1000	0.6518	0.1376
33A	0.9594	0.0697	0.0932	0.2474
33B	0.5423	0.1543	0.2822	0.1971
33C	0.6904	0.1315	0.8915	0.0927
34A	***0.0298***	0.2874	0.8874	0.0938
34B	***0.0330***	0.2840	0.5126	0.1588
34C	0.1961	0.2156	0.5345	0.1554

Regarding question 8 (job orientation) versus question 4 (basic training), this result is depicted in Figure 6–13. 67 respondents who have a basic training in engineering are currently involved with engineering responsibilities, whereas 41 of the respondents with basic training in engineering are currently involved with maintenance activities, and 36 of the respondents with engineering training are involved with management activities. There is one respondent with basic training in finance and management who is involved with engineering tasks, while 3 of the respondents with finance and management training are involved with maintenance and 33 of the respondents with training in finance and management are involved with management activities. Between question 8 (job orientation) and question 4 (basic training), there are six blank fields, which have been regarded as missing frequencies. The Chi-Square has a P value of <0.0001, meaning that the conclusion can be drawn that question 8 (job orientation) and question 4 (basic training) are dependent on each other. The Cramer's V statistic has a value of 0.5354, meaning that a conclusion can be drawn that there is a strong association between question 8 (job orientation) and question 4 (basic training). The reason for the dependence and strong association between the two variables is that 35.83% of the respondents have engineering as basic training and their job orientation is engineering. In addition 19.25% of the respondents have engineering qualifications and are in a management job orientation.

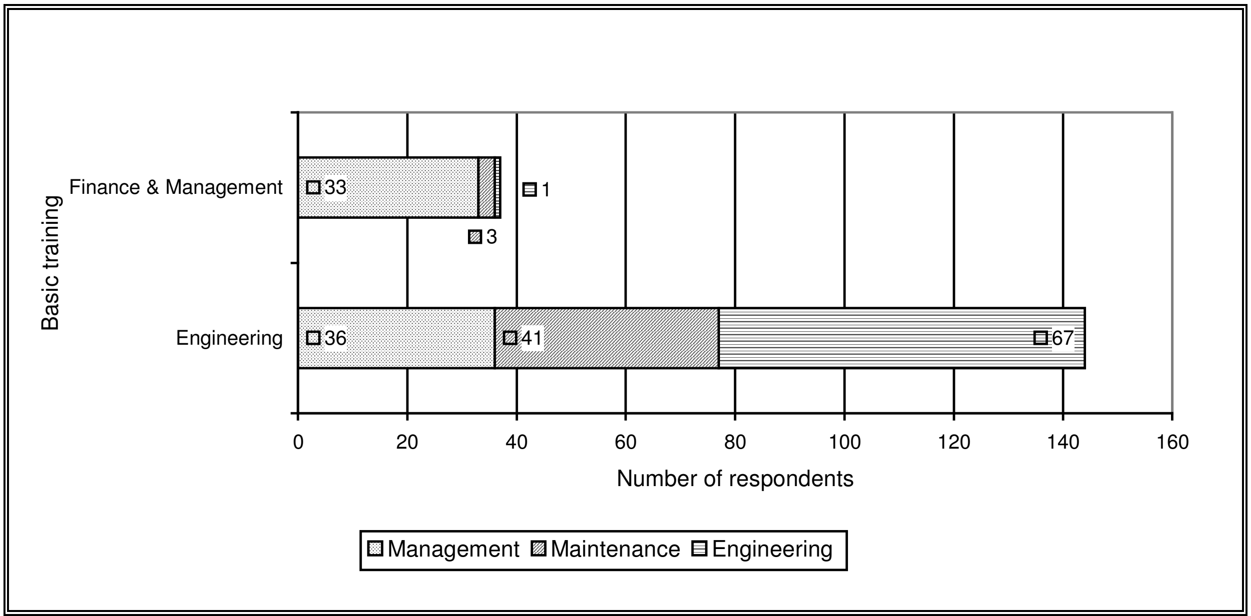


Figure 6–13: Cross tabulation of question 8 (job orientation) by question 4 (basic training)

The cross tabulation of question 8 (job orientation) versus question 9A (best practices) is depicted in Figure 6–14. Between question 8 (job orientation) and question 9A (best practices), there are 12 blank fields, which have been regarded as missing frequencies. The Chi-Square has a P value of 0.0650, meaning that the conclusion can be drawn that question 8 (job orientation) and question 9A (best practices) are not dependent on each other. The Cramer's V statistic possesses a value of 0.1590, meaning that one can draw the conclusion that there is a weak association between question 8 (job orientation) and question 9A (best practices).

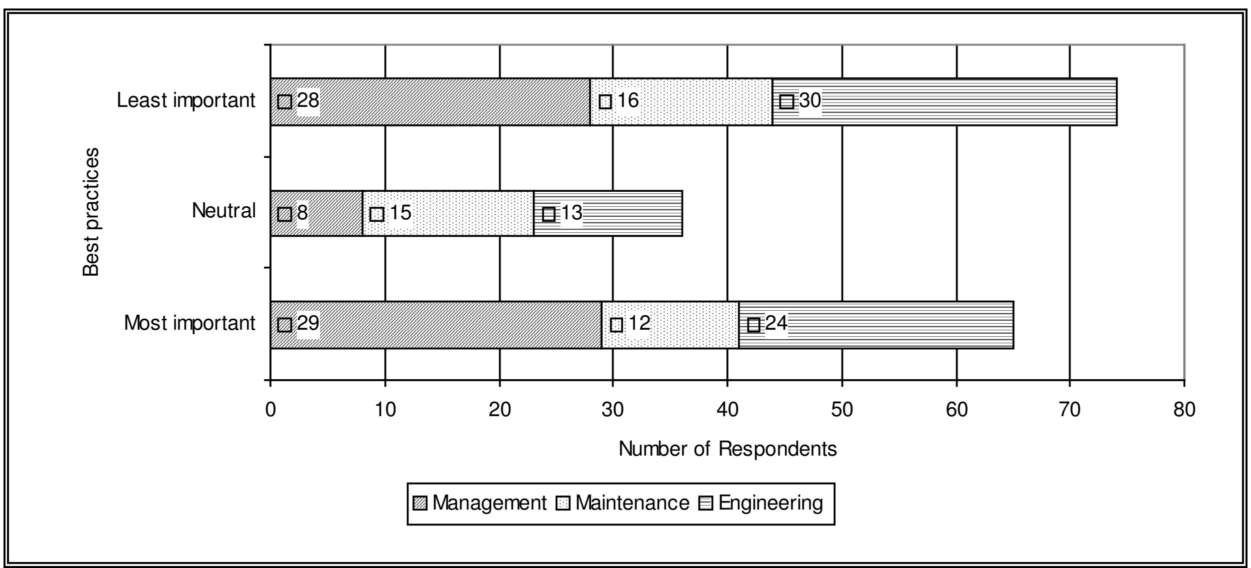


Figure 6–14: Cross tabulation of question 8 (job orientation) by question 9A (best practices)

The cross tabulation of question 8 (job orientation) versus question 10A (accessibility) is depicted in Figure 6–15. Between question 8 (job orientation) and question 10A (accessibility), there are 11 blank fields, regarded as missing frequencies. The Chi-Square has a P value of 0.0348, meaning that the conclusion can be drawn that question 8 (job orientation) and question 10A (accessibility) are dependent on each other. This dependency is due to 71.12% of the respondents being either in an engineering or management job orientation. Cramer's V statistic has a value of 0.1715; meaning that the conclusion can be reached that there is a weak association between question 8 (job orientation) and question 10A (accessibility).

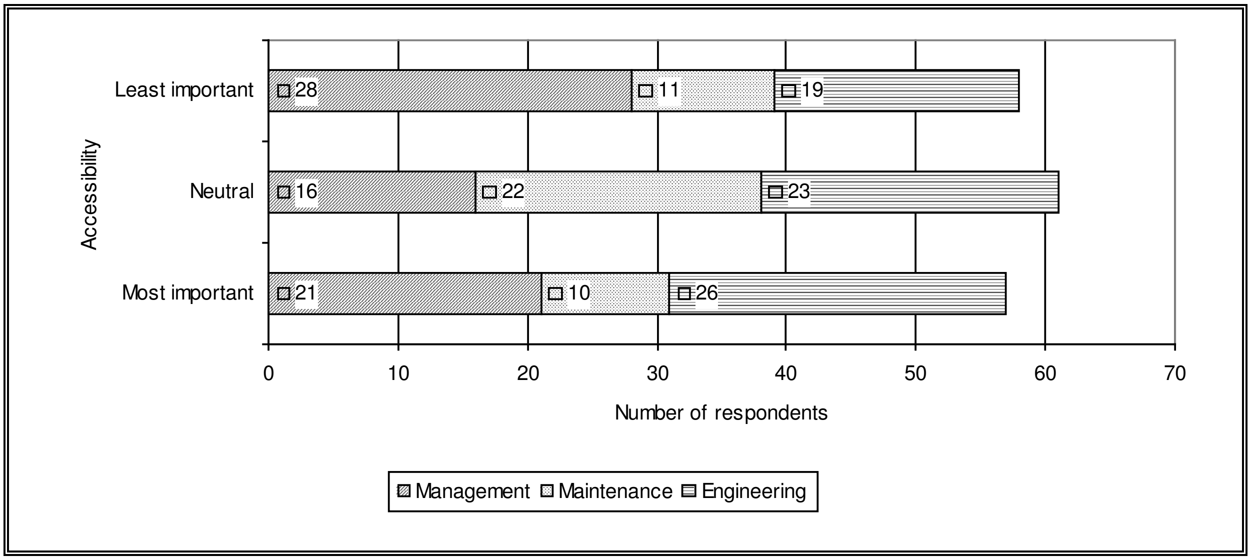


Figure 6–15: Cross tabulation of question 8 (job orientation) by question 10A(Accessibility)

The cross tabulation of question 8 (job orientation) versus question 11 (experience and knowledge base) is depicted in Figure 6–16. Between question 8 (job orientation) and question 11 (experience and knowledge base), there are 4 blank fields, which have been regarded as missing frequencies. The Chi-Square possesses a P value of < 0.0001, meaning that the conclusion can be drawn that question 8 (job orientation) and question 11 (experience and knowledge base) are dependent on each other. The Cramer's V statistic has a value of 0.3767, meaning that one can conclude that there is a moderate association between question 8 (job orientation) and question 11 (experience and knowledge base). This dependency and moderate association was related to 44.39% of the respondents having more than five years experience, and 74.33% of the respondents are either in an engineering or management role. 42 of the respondents who have an engineering job orientation possess experience and knowledge in the design of a new system. 83 of the respondents report experience and knowledge in systems that are older than five years old, of which 42 are involved in management, 24 in maintenance and 17 in engineering.

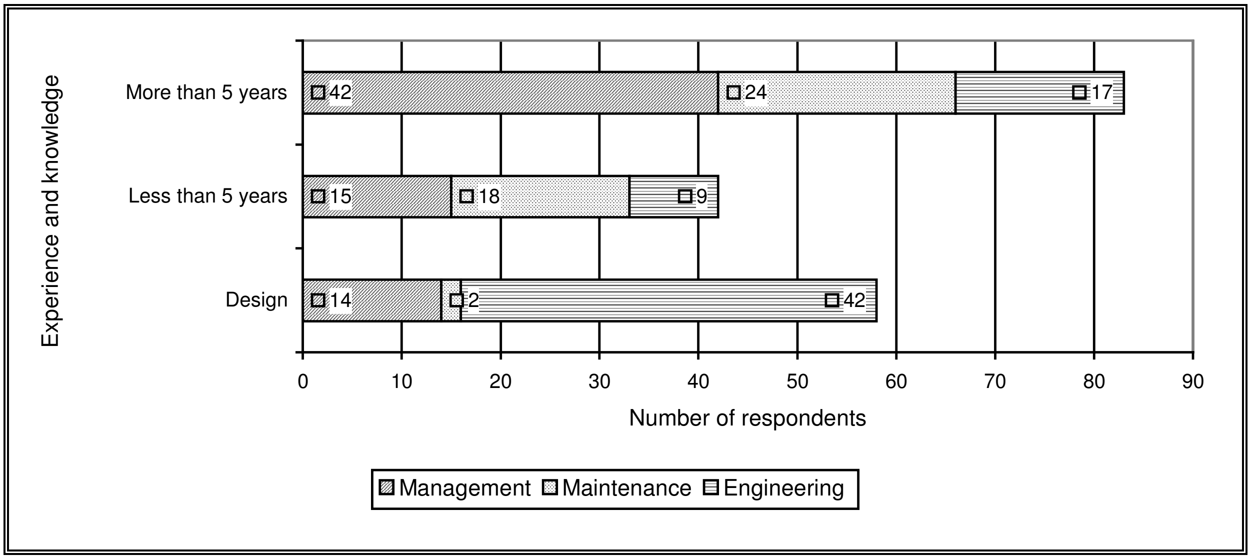


Figure 6–16: Cross tabulation of question 8 (job orientation) by question 11 (experience and knowledge)

The cross tabulation of question 8 (job orientation) versus question 12 (writing operator and maintenance documentation in such a manner that operating and maintenance personnel are capable of understanding the contents thereof) is depicted in Figure 6–17. Between question 8 and question 12, there are 4 blank fields, regarded as missing frequencies. The Chi-Square has a P value of < 0.0316, meaning that a conclusion can be drawn that question 8 and question 12 are dependent on each other. This dependence of question 8 (job orientation) and question 12 (writing operator and maintenance documentation in such a manner that operating and maintenance personnel are capable of understanding the contents thereof) is a result of 85.56% of the respondents selecting important or most important for question 12 (writing operator and maintenance documentation in such a manner that operating and maintenance personnel are capable of understanding the contents thereof). In addition none of the respondents in a maintenance role selected either less important or not important, compared to 90.91% of the respondents involved with maintenance whom selected important or most important for question 12 (writing operator and maintenance documentation in such a manner that operating and maintenance personnel are capable of understanding the contents thereof). The Cramer's V statistic records a value of 0.1701, meaning that the conclusion can be reached that there is a weak association between question 8 and question 12.

The cross tabulation of question 8 (job orientation) versus question 18A (availability of S&TE, and personnel) is depicted in Figure 6–18. Between question 8 (job orientation) and question 18A (availability of S&TE, and personnel), there are 9 blank fields; these have been regarded as missing frequencies. The Chi-Square has a P value of 0.0121, meaning that one can draw the conclusion that question 8 (job orientation) and question 18A (availability of S&TE, and personnel) are dependent on each other. The Cramer's V statistic records a value of 0.1899; meaning that the conclusion can be reached that there is a weak association between question 8 (job orientation) and question 18A (availability of S&TE, and personnel). The reason for the dependence and weak association is that 72.19% of the respondents are in an engineering or management role and they have strong opinions regarding the question. 53 of the respondents whose job is management orientated rated this question as most important, while seven rated the question as least important. 121 respondents rated this question as most important, and 23 rated this question as least important.

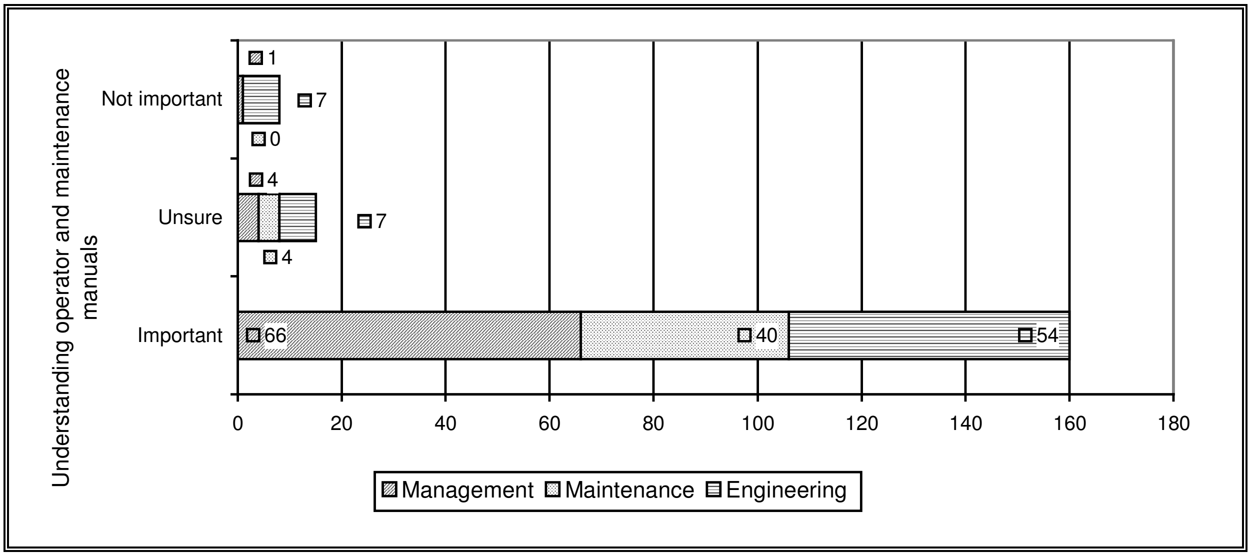


Figure 6–17: Cross tabulation of question 8 (job orientation) by question 12 (understanding operator and maintenance manuals)

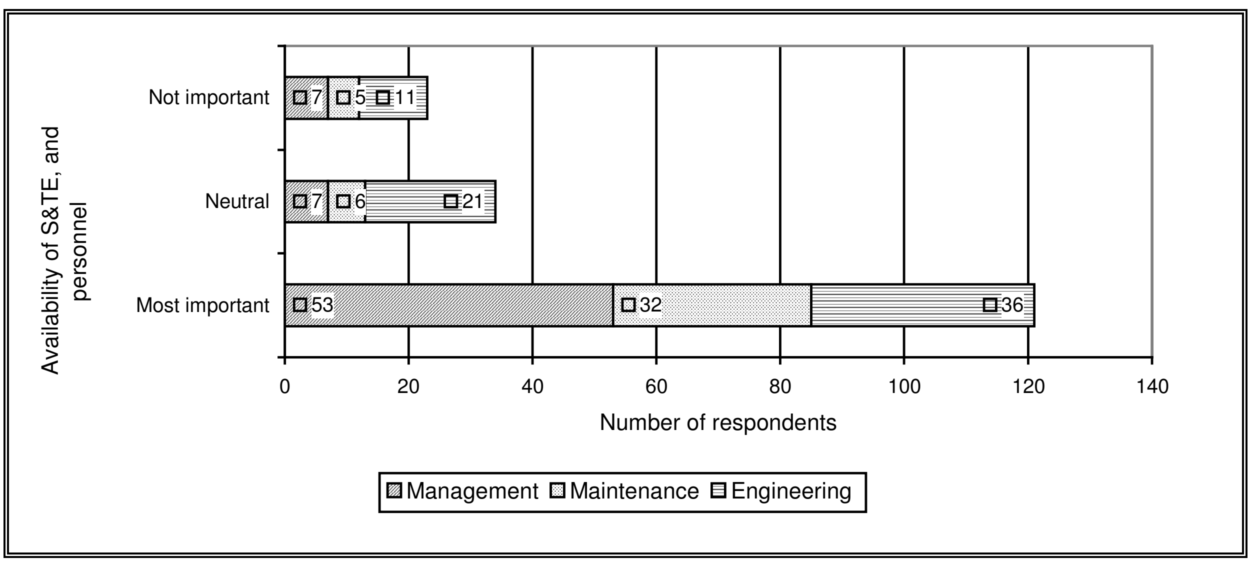


Figure 6–18: Cross tabulation of question 8 (job orientation) by question 18A (availability of S&TE, and personnel)

The cross tabulation of question 8 (job orientation) versus question 18C (S&TE support/maintenance) is depicted in Figure 6–19. Between question 8 (job orientation) and question 18C (S&TE support/maintenance) there are 9 blank fields and have been regarded as missing frequencies. The Chi-Square has a P value of 0.0156, meaning that a conclusion can be drawn that question 8 (job orientation) and question 18C (S&TE support/maintenance) are dependent on each other. The dependence is due to 72.19% of the respondents are in a management or engineering role, of which 45.92% of them rated the question as neutral. The Cramer's V statistic has a value of 0.1855, meaning that a conclusion can be drawn that there is a weak association between question 8 (job orientation) and question 18C (S&TE support/maintenance). 33 of the respondents whom have a management job orientation rated this question as neutral, and 23 rated the question as most important. 88 respondents rated this question as neutral, 48 respondents rated this question most important, and 23 rated this question as least important.

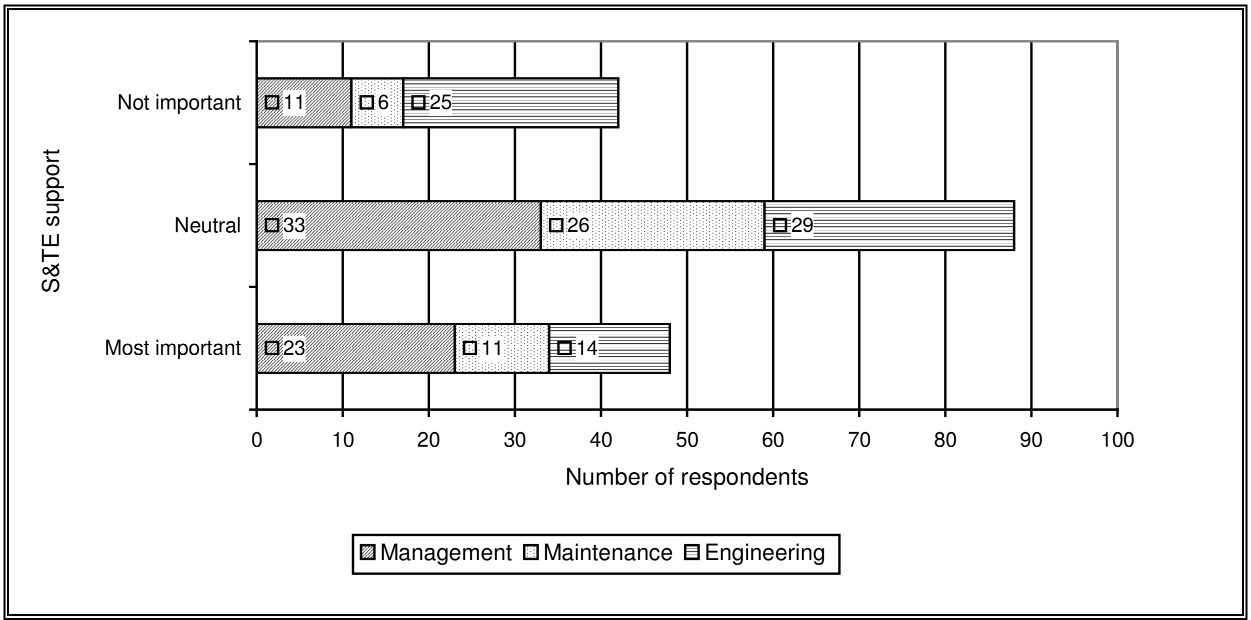


Figure 6–19: Cross tabulation of question 8 (job orientation) by question 18C (S&TE support/maintenance)

The cross tabulation of question 8 (job orientation) versus question 20A (conducting RAM analyses) is depicted in Figure 6–20. Between question 8 (job orientation) and question 20A (conducting RAM analyses) there are 9 blank fields and have been regarded as missing frequencies. The Chi-Square has a P value of 0.0030, meaning that a conclusion can be drawn that question 8 (job orientation) and question 20A (conducting RAM analyses) are dependent on each other. This dependence between question 8 (job orientation) and question 20A (conducting RAM analyses) is due to 72.19% of the respondents being in a management or engineering job orientation, of which 33.33% of them rated the question as most important. The Cramer's V statistic has a value of 0.2121, meaning that a conclusion can be drawn that there is a weak association between question 8 (job orientation) and question 20A (conducting RAM analyses). 24 of the respondents whom have a management job orientation rated this question as most important, and 13 rated the question as least important. 61 respondents rated this question as neutral, 64 respondents rated this question as most important, and 53 rated this question as least important.

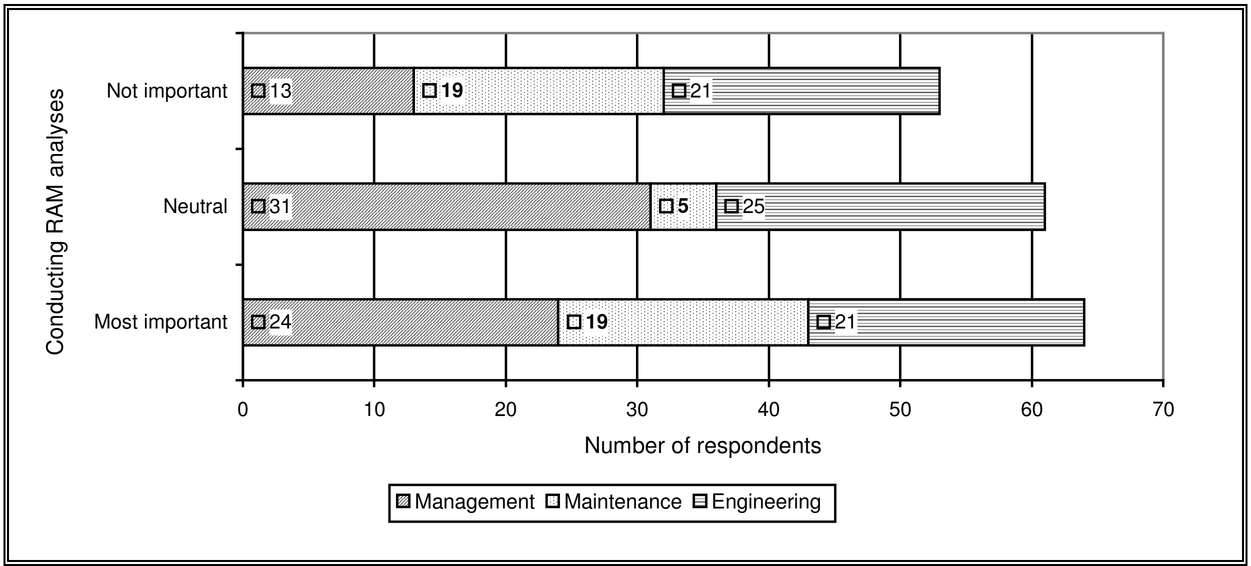


Figure 6–20: Cross tabulation of question 8 (job orientation) by question 20A (conducting RAM analyses)

The cross tabulation of question 8 (job orientation) versus question 20C (identifying parts with excessive failure rates) is depicted in Figure 6–21. Between question 8 (job orientation) and question 20C (identifying parts with excessive failure rates) there are 9 blank fields and have been regarded as missing frequencies. The Chi-Square has a P value of 0.0029, meaning that a conclusion can be drawn that question 8 (job orientation) and question 20C (identifying parts with excessive failure rates) are dependent on each other. This dependence is due to 72.19% of the respondents being in an engineering or management role, and 48.13% of the respondents rated question 20C (identifying parts with excessive failure rates) as most important. The Cramer's V statistic has a value of 0.2128, meaning that a conclusion can be drawn that there is a weak association between question 8 (job orientation) and question 20C (identifying parts with excessive failure rates). 38 of the respondents whom have an engineering job orientation rated this question as most important, and 10 rated the question as least important. 50 respondents rated this question as neutral, 90 respondents rated this question as most important, and 38 rated this question as least important. 4 of the respondents with a maintenance job orientation rated the question as least important.

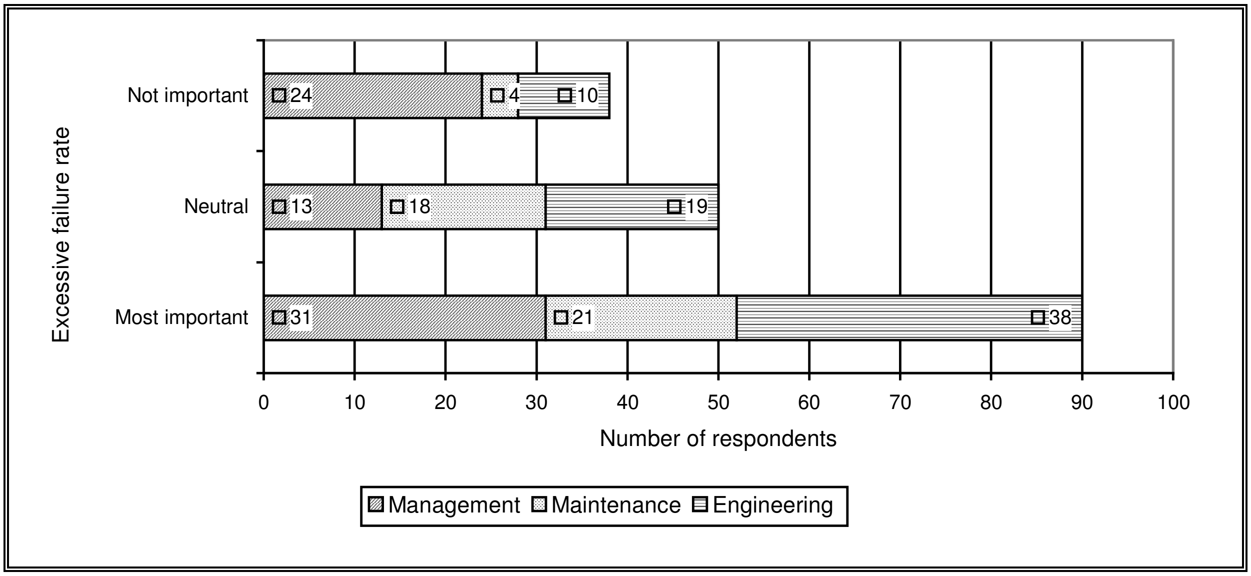


Figure 6–21: Cross tabulation of question 8 (job orientation) by question 20C (identifying parts with excessive failure rates)

The cross tabulation of question 8 (job orientation) versus question 24A (cost to support) is depicted in Figure 6–22. Between question 8 (job orientation) and question 24A (cost to support) there are 8 blank fields and have been regarded as missing frequencies. The Chi-Square has a P value of 0.0123, meaning that a conclusion can be drawn that question 8 (job orientation) and question 24A (cost to support) are dependent on each other. The Cramer's V statistic has a value of 0.1891, meaning that a conclusion can be drawn that there is a weak association between question 8 (job orientation) and question 24A (cost to support). This dependence and weak association between question 8 (job orientation) and question 24A (cost to support) is due to 64.17% of the respondents selecting either most important or important for question 24A (cost to support), where cost to support an important factor in determining a systems' total cost of ownership and life cycle costs. 51 of the respondents whom have a management job orientation rated this question as important or most important, and 6 rated the question as less important or least important. 37 respondents rated this question as neutral, 120 respondents rated this question as important or most important, and 22 rated this question as less important or least important. 3 of the respondents with a maintenance job orientation rated the question as less important or least important.

The cross tabulation of question 8 (job orientation) versus question 25E (lead-time to repair) is depicted in Figure 6–23. Between question 8 (job orientation) and question 25E (lead-time to repair) there are 6 blank fields and have been regarded as missing frequencies. The Chi-Square has a P value of 0.0091, meaning that a conclusion can be drawn that question 8 (job orientation) and question 25E (lead-time to repair) are dependent on each other. The Cramer's V statistic has a value of 0.1931, meaning that a conclusion can be drawn that there is a weak association between question 8 (job orientation) and question 25E (lead-time to repair). The dependence of question 8 (job orientation) and question 25 (lead-time to repair) on each other is due to 68.45% of the respondents selecting either most important or important for question 25E (lead-time to repair). In addition 73.26% of the respondents are either in an engineering or management job function. Lead-time to repair is critically important for high technology systems and plants that have a production schedule to follow and every minute of downtime is critical. 54 of the respondents whom have a management job orientation rated this question as important or most important, and 2 rated the question as less important or least important. 38 respondents rated this question as neutral, 128 respondents rated this question as important or most important, and 15 rated this question as les simportant or least important. One of the respondents with a maintenance job orientation rated the question as less important or least important.

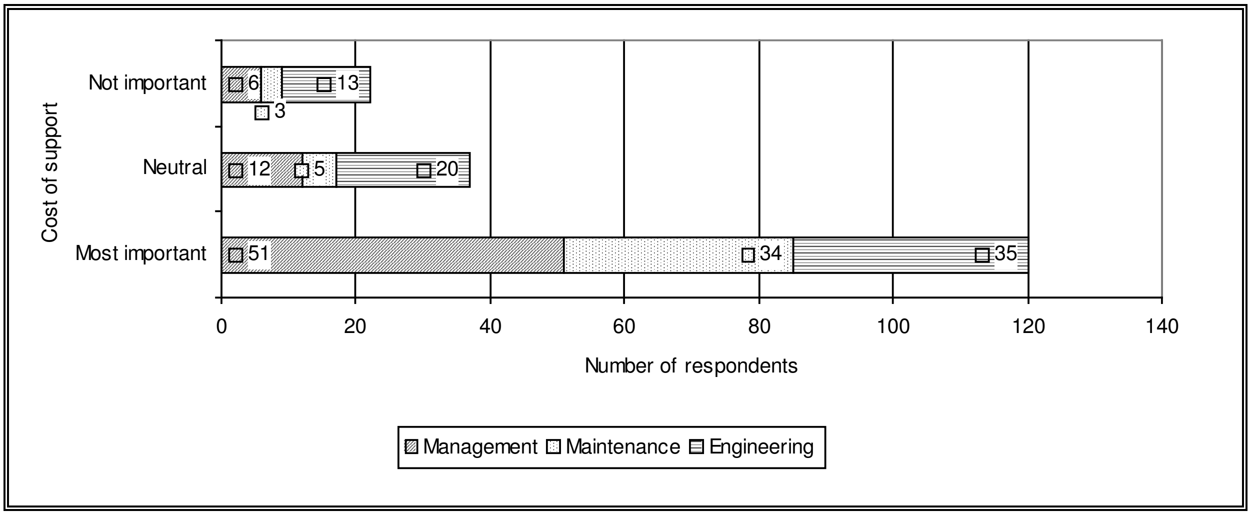


Figure 6–22: Cross tabulation of question 8 (job orientation) by question 24A (cost to support)

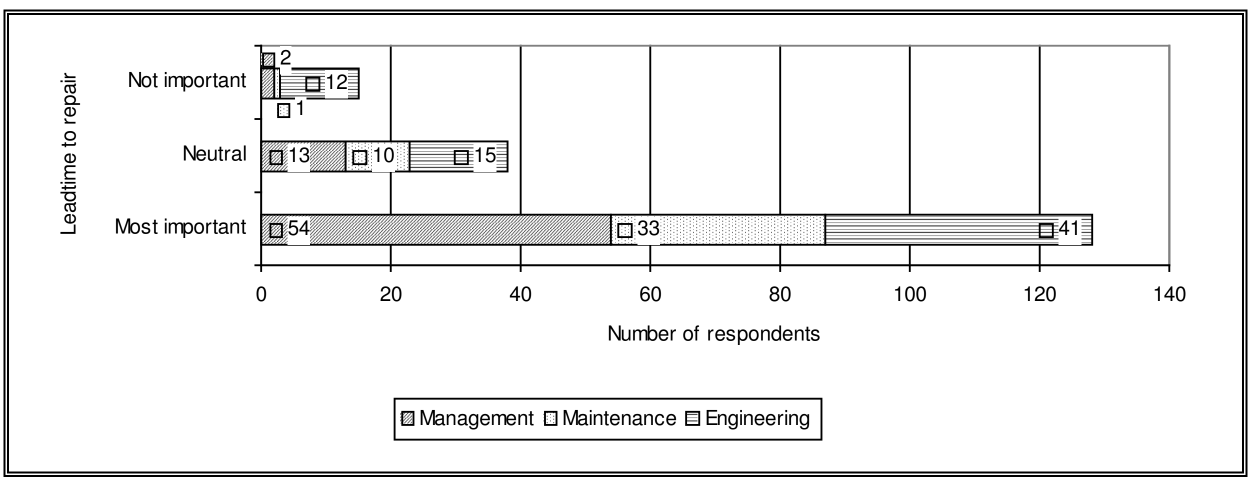
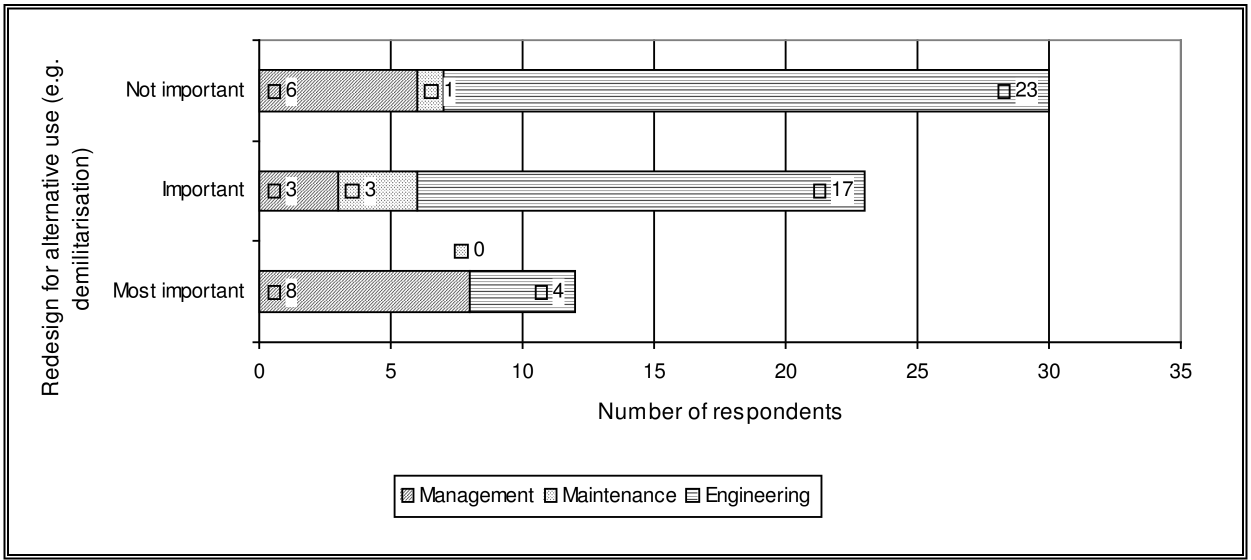


Figure 6–23: Cross tabulation of question 8 (job orientation) by question 25E (lead-time to repair)

The cross tabulation of question 8 (job orientation) versus question 27C (redesign for alternative use (e.g. demilitarisation)) is depicted in Figure 6–24. The Chi-Square has a P value of 0.0048, meaning that a conclusion can be drawn that question 8 (job orientation) and question 27C (redesign for alternative use (e.g. demilitarisation)) are dependent on each other. The Cramer's V statistic has a value of 0.3392, indicating that a conclusion can be drawn that there is a moderate association between question 8 (job orientation) and question 27C (redesign for alternative use (e.g. demilitarisation)). This dependence and moderate association between question 8 (job orientation) and question 27C (redesign for alternative use (e.g. demilitarisation)) is due to the respondents rating question 27C as least important in question 27 (typical disposal costs), and 67.69% of the respondents are in an engineering job function, of which 52.27% of those in an engineering role rated question 27C (redesign for alternative use (e.g. demilitarisation)) as least important. Those respondents in an engineering role would most probably prefer to design new systems than to utilise an existing military system and demilitarise it.



<u>Figure 6–24: Cross tabulation of question 8 (job orientation) by question 27C (Redesign for alternative use (e.g. demilitarisation))</u>

The cross tabulation of question 8 (job orientation) versus question 34A (maintenance induced failures) is depicted in Figure 6–25. The Chi-Square has a P value of 0.0297, meaning that a conclusion can be drawn that question 8 (job orientation) and question 34A (maintenance induced failures) are dependent on each other. The Cramer's V statistic has a value of 0.2874, meaning that a conclusion can be drawn that there is a weak association between question 8 (job orientation) and question 34A (maintenance induced failures). This dependence and weak association between question 8 (job orientation) and question 34A (maintenance induced failures) is due to 44.62% of the respondents selecting a neutral response and only 23.08% of the respondents selecting most important. In addition 6.15% of the respondents are in a maintenance role, and 67.69% of the respondents are in an engineering job function, of which 31.82% rated question 34A (maintenance induced failures) as most important, and might feel that maintenance induced errors are the result of high percentage of the downtime of high technology systems. 14 of the respondents whom have an engineering job orientation rated this question as most important, and 10 rated the question as least important. 29 respondents rated this question as neutral, 15 respondents rated this question as most important, and 21 rated this question as least important. One of the respondents with a maintenance job orientation rated the question as least important.

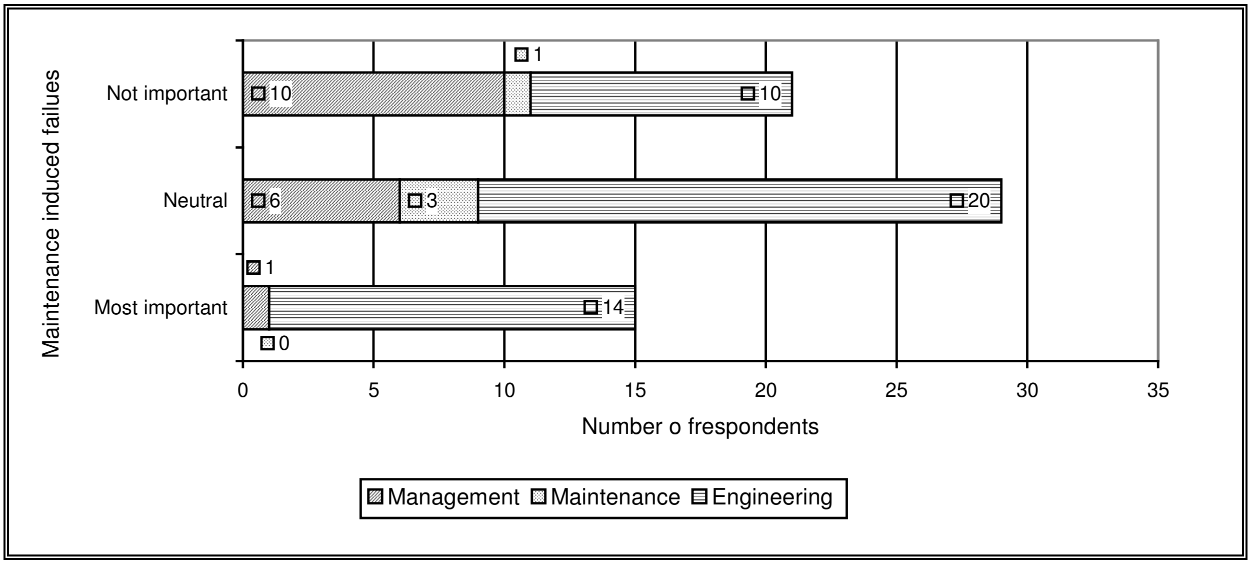


Figure 6–25: Cross tabulation of question 8 (job orientation) by question 34A (maintenance induced failures)

The cross tabulation of question 8 (job orientation) versus question 34B (operator-induced failures) is depicted in Figure 6–26. The Chi-Square has a P value of 0.0330, meaning that a conclusion can be drawn that question 8 (job orientation) and question 34B (operator-induced failures) are dependent on each other. The Cramer's V statistic has a value of 0.2840, meaning that a conclusion can be drawn that there is a weak association between question 8 (job orientation) and question 34B (operator-induced failures). 11 of the respondents whom have an engineering job orientation rated this question as most important, and 15 rated the question as not important. 24 respondents rated this question as neutral, 23 respondents rated this question as most important, and 18 rated this question as least important. One of the respondents with a maintenance job orientation rated the question as most important and neutral, and two respondents rated this question as least important. This dependence and weak association between question 8 (job orientation) and question 34B (operator-induced failures) is the result of 67.69% of the respondents being in an engineering role, of which 25% of them rated question 34B (operator induced failures) as most important. This is a result of the respondents having the opinion that operator induced errors are the result of high percentage of the downtime of high technology systems. Furthermore the respondents have the opinion that maintenance induced and operator induced failures result in many hours of unnecessary downtime of high technology complex systems.

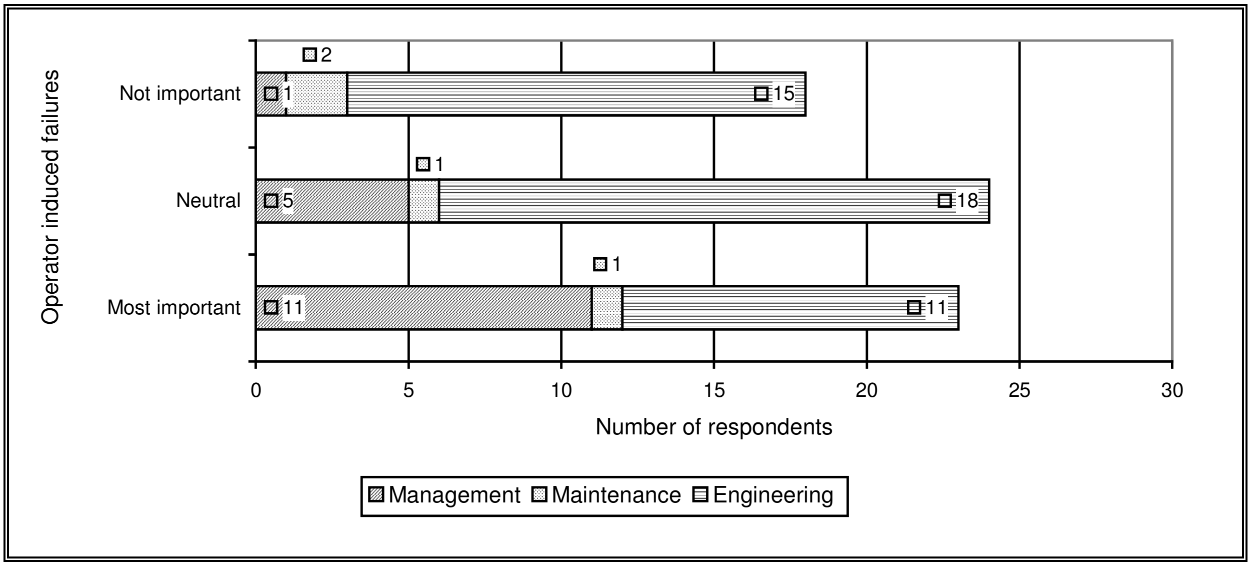


Figure 6–26: Cross tabulation of question 8 (job orientation) by question 34B (operator-induced failures)

The cross tabulation of question 11 (experience and knowledge base) versus question 4 (basic training) is depicted in Figure 6–27. The Chi-Square statistic has a P value of 0.0461, meaning that a conclusion can be drawn that question 11 (experience and knowledge base) and question 4 (basic training) are dependent on each other. This dependence between question 11 (experience and knowledge base) and question 4 (basic training) is due to 77.54% of the respondents having a basic training in engineering. Of which 35.86% of those respondents having a basic training in engineering have knowledge and experience in design and 40.69% of them have knowledge and experience in systems older than five years, where some redesign may be necessary in these systems. In addition 88.14% of those whom have knowledge and experience in design have an engineering basic training. The Cramer's V statistic has a value of 0.1829, meaning that a conclusion can be drawn that there is a weak association between question 11 (experience and knowledge base) and question 4 (basic training). 59 of the respondents whom have a basic training in engineering have more than five years experience and knowledge. 83 of the respondents have more than five years experience and knowledge, whereas 42 of the respondents have less than five years experience and knowledge, compared to 59 whom have experience and knowledge in design. Between the two variables, there are three blank fields and have been regarded as missing frequencies.

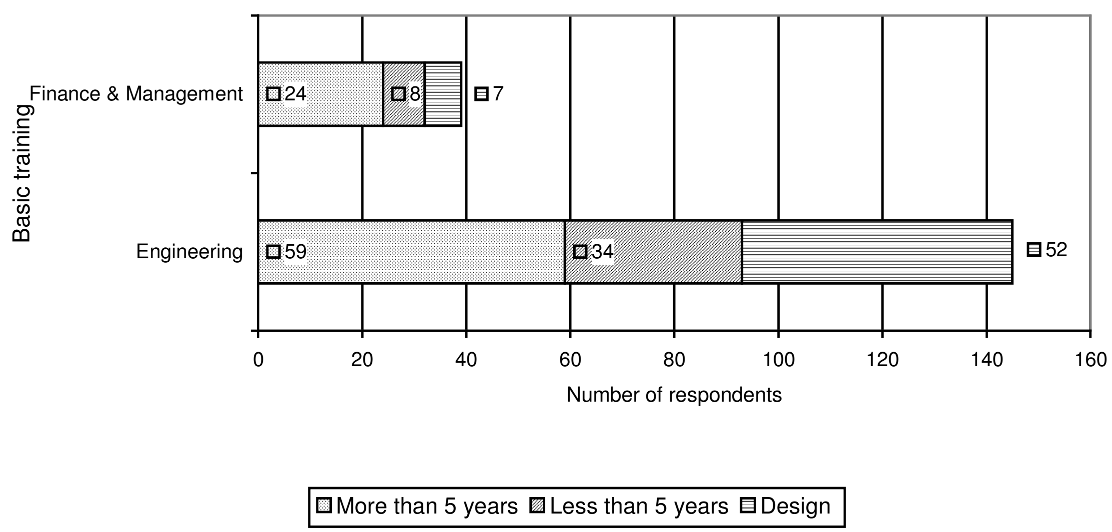


Figure 6–27: Cross tabulation of question 11 (experience and knowledge base) by question 4 (basic training)

The cross tabulation of question 11 (experience and knowledge base) versus question 8 (job orientation) is depicted in Figure 6–28. The Chi-Square statistic has a P value of <0.0001, meaning that a conclusion can be drawn that question 11 (experience and knowledge base) and question 8 (job orientation) are dependent on each other. The Cramer's V statistic has a value of 0.3767, meaning that a conclusion can be drawn that there is a moderate association between question 11 (experience and knowledge base) and question 8 (job orientation). This dependence and moderate association between question 11 (experience and knowledge) and question 8 (job orientation) is due to 36.36% of the respondents are in an engineering role, of which 61.76% of them have knowledge and experience in design. In addition 23.53% of the respondents are in a maintenance role, of which 95.45% have experience and knowledge in systems which are either less than five years old or in systems older than five years. 42 of the respondents whom have an engineering job orientation have experience and knowledge in design of new systems. 83 of the respondents have more than five years experience and knowledge, whereas 42 of the respondents have less than five years experience and knowledge, compared to 58 whom have experience and knowledge in design. Between the two variables, there are four blank fields and have been regarded as missing frequencies. Only two respondents whom have experience and knowledge of the design of a new system are involved with maintenance activities.

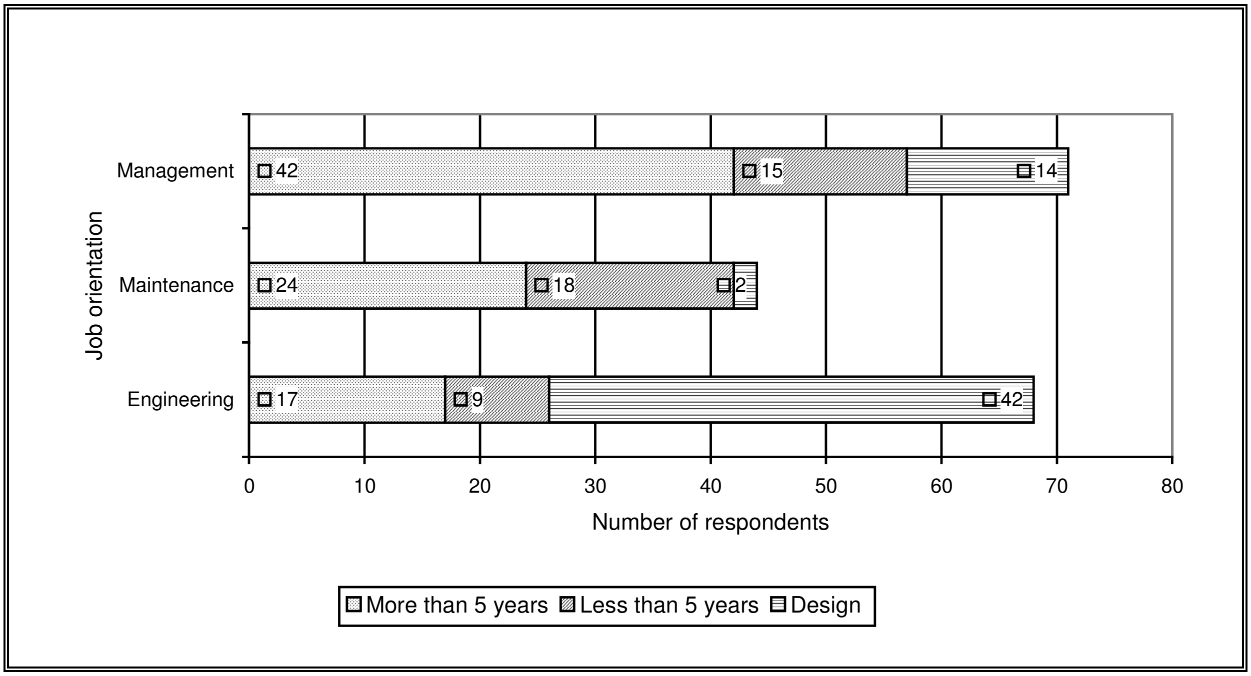


Figure 6–28: Cross tabulation of question 11 (experience and knowledge base) by question 8 (job orientation)

The cross tabulation of question 11 (experience and knowledge base) versus question 18A (availability of S&TE, and personnel) is depicted in Figure 6–29. The Chi-Square statistic has a P value of 0.0339, meaning that a conclusion can be drawn that question 11 (experience and knowledge base) and question 18A (availability of S&TE, and personnel) are dependent on each other. This dependence is due to 66.31% of the respondents have experience and knowledge with systems which are either less than five years old or with systems which are older than five years old, of which 73.38% rated question 18A (availability of S&TE, and personnel) as most important. Standard of the shelf support and test equipment (S&TE) is expensive and specialised support and test equipment is even more costly, as with critical skills that are scarce, they demand high salaries, hence the shortage of S&TE and the necessary skilled personnel results in a longer downtime of the system. The Cramer's V statistic has a value of 0.1692, meaning that a conclusion can be drawn that there is a weak association between question 11 (experience and knowledge base) and question 18A (availability of S&TE, and personnel). 61 of the respondents whom have more than five years experience and knowledge rated this question as most important, whereas nine rated the question as least important. 125 respondents rated this question as most important, compared to 34 with a neutral opinion, and 23 rated the question as least important. Between the two variables, there are five blank fields and have been regarded as missing frequencies.

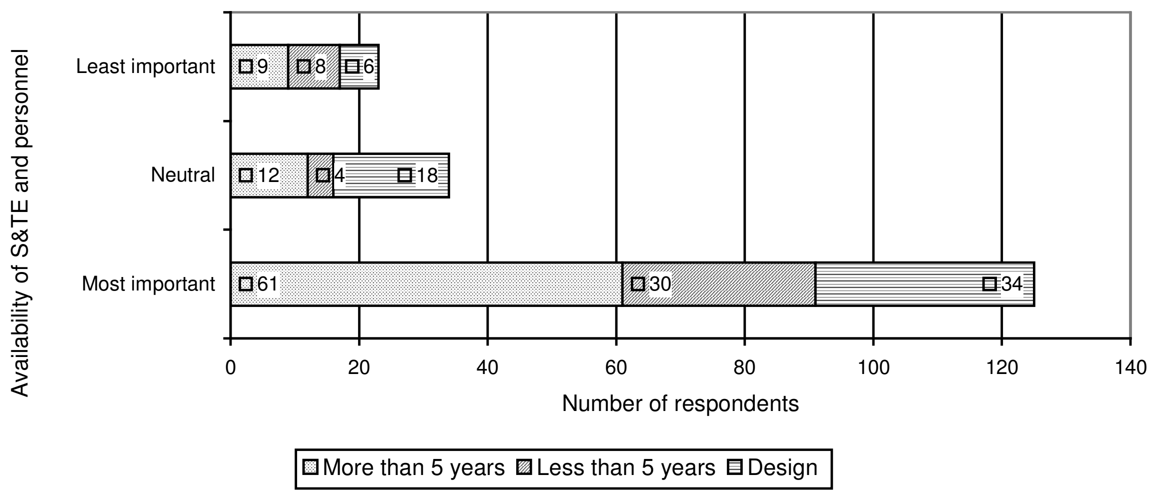


Figure 6–29: Cross tabulation of question 11 (experience and knowledge base) by question 18A (availability of S&TE, and personnel)

The cross tabulation of question 11 (experience and knowledge base) versus question 18C (S&TE support/maintenance) is depicted in Figure 6–30. The Chi-Square statistic has a P value of 0.0132, meaning that a conclusion can be drawn that question 11 (experience and knowledge base) and question 18C (S&TE support/maintenance) are dependent on each other. This dependence is due to 66.31% of the respondents have experience and knowledge with systems which are either less than five years old or with systems which are older than five years old, of which 17.74% rated question 18C (S&TE support/maintenance) as least important. Compared to 33.87% whom rated question 18C (S&TE support/maintenance) as most important. 43.85% of the respondents have experience and knowledge in systems that are more than five years old. S&TE also requires support and maintenance, if they are neglected the S&TE will not perform their primary function and the primary system will suffer further downtime. The Cramer's V statistic has a value of 0.1863, meaning that a conclusion can be drawn that there is a weak association between question 11 (experience and knowledge base) and question 18C (S&TE support/maintenance). 31 of the respondents whom have more than five years experience and knowledge rated this question as most important, whereas 13 rated the question as least important. 50 respondents rated this question as most important, compared to 90 with a neutral opinion, and 42 rated the question as least important. Between the two variables, there are five blank fields and have been regarded as missing frequencies.

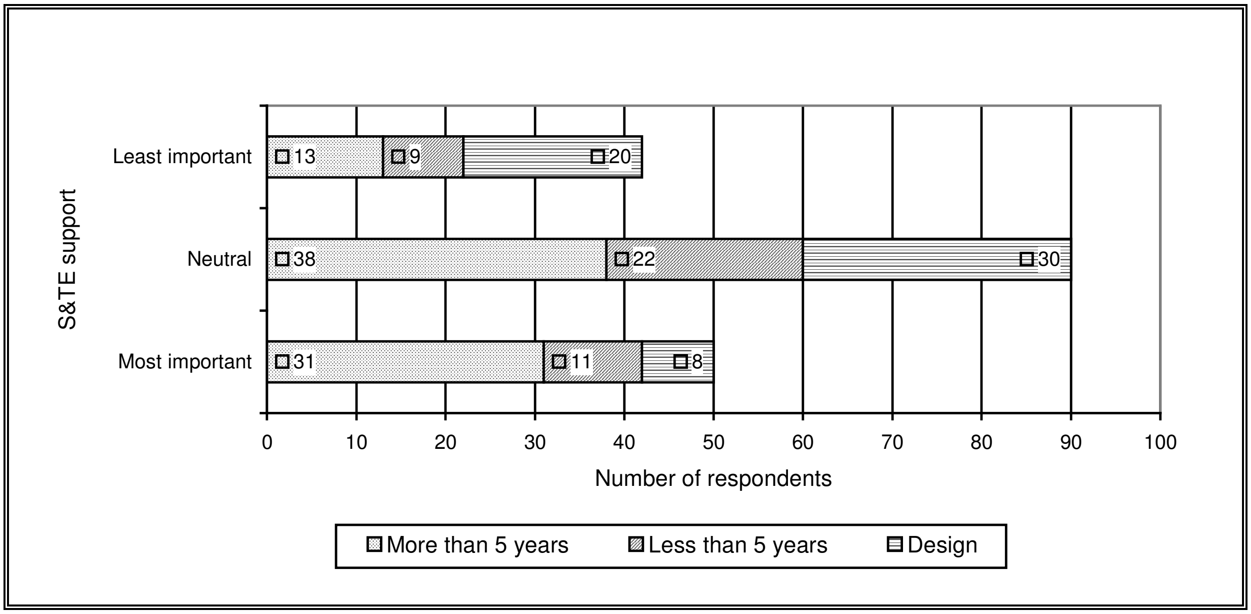


Figure 6–30: Cross tabulation of question 11 (experience and knowledge base) by question 18C (S&TE support/maintenance)

The cross tabulation of question 11 (experience and knowledge base) versus question 25B (cost to repair) is depicted in Figure 6–31. The Chi-Square statistic has a P value of 0.0401, meaning that a conclusion can be drawn that question 11 (experience and knowledge base) and question 25B (cost to repair) are dependent on each other. This dependence between question 11 (experience and knowledge base) versus question 25B (cost to repair) is due to 67.91% of the respondents rating question 25B (cost to repair) as important or most important of which 50.39% have knowledge and experience in systems that are older than five years, these systems which are older than five years could be suffering from obsolescence and their repair costs are high. In addition 67.91% of the respondents either have experience and knowledge in systems, which are less than five years old, or with systems that are older than five years, of which 50.39% have knowledge and experience in systems that are older than five years. The Cramer's V statistic has a value of 0.1641, meaning that a conclusion can be drawn that there is a weak association between question 11 (experience and knowledge base) and question 25B (cost to repair). 64 of the respondents whom have more than five years experience and knowledge rated this question as important or most important, whereas six rated the question as less important or least important. 127 respondents rated this question as important or most important, compared to 41 with a neutral opinion, and 18 rated the question as less important or least important. 3 respondents with less than five years experience and knowledge rated this question as less important or least important. Between the two variables, there is one blank fields and has been regarded as a missing frequency.

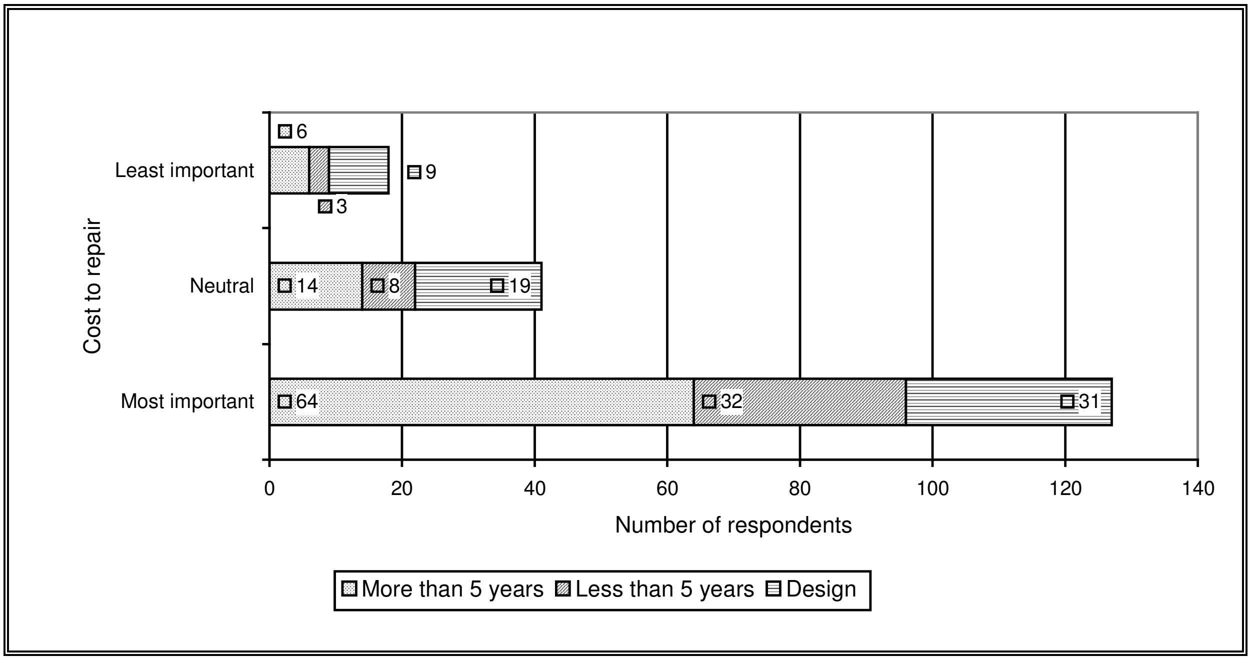


Figure 6–31: Cross tabulation of question 11 (experience and knowledge base) by question 25B (cost to repair)

The cross tabulation of question 11 (experience and knowledge base) versus question 25D (failure probability) is depicted in Figure 6–32. The Chi-Square statistic has a P value of 0.0308, meaning that a conclusion can be drawn that question 11 (experience and knowledge base) and question 25D (failure probability) are dependent on each other. This dependence of question 11 (experience and knowledge base) and question 25D (failure probability) is as a result of 58.29% of the respondents selecting either important or most important for question 25D (failure probability), of which 47.71% have experience and knowledge with system that are more than five years old. It is important for maintenance planning purposes that failure rates are known, in order to ensure the correct amount of resources are available, for example during a routine shutdown to perform preventive maintenance. The Cramer's V statistic has a value of 0.1696, meaning that a conclusion can be drawn that there is a weak association between question 11 (experience and knowledge base) and question 25D (failure probability). 52 of the respondents whom have more than five years experience and knowledge rated this question either important or most important, whereas four rated the question as less important or least important. 109 respondents rated this question as important or most important, compared to 57 with a neutral opinion, and 19 rated the question either less important or least important. 3 respondents with less than five years experience and knowledge rated this question either as less important or as least important. Between the two variables, there are two blank fields and has been regarded as missing frequencies.

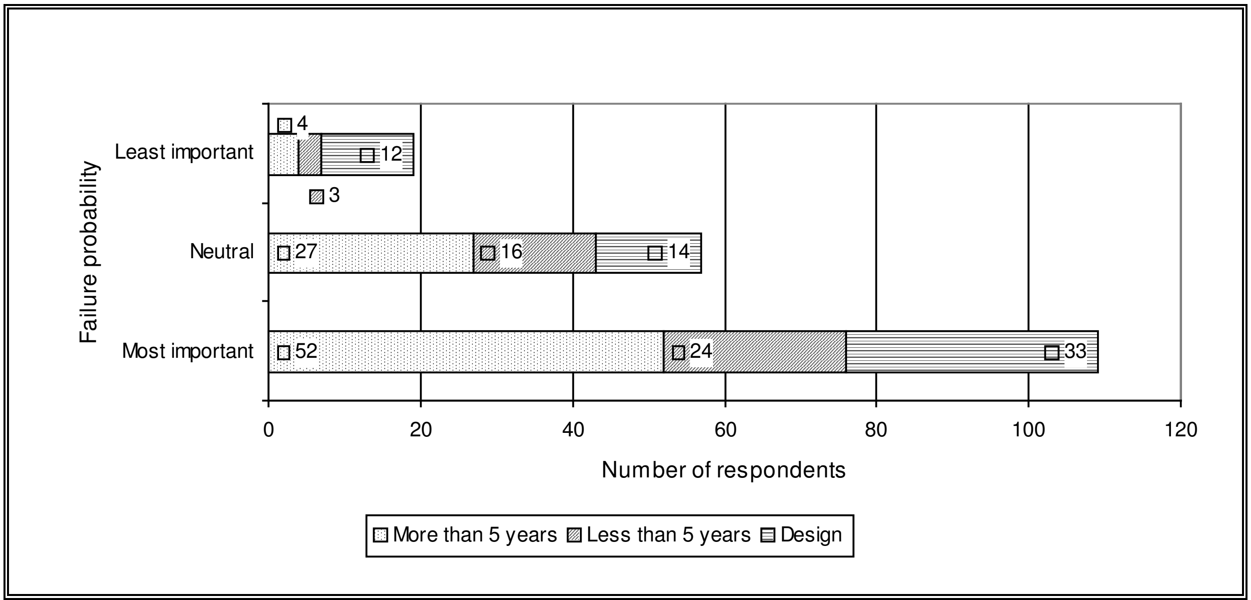


Figure 6–32: Cross tabulation of question 11 (experience and knowledge base) by question 25D (failure probability)

The cross tabulation of question 11 (experience and knowledge base) versus question 25E (lead-time to repair) is depicted in Figure 6–33. The Chi-Square statistic has a P value of 0.0487, meaning that a conclusion can be drawn that question 11 (experience and knowledge base) and question 25E (lead-time to repair) are dependent on each other. This dependence between question 11 (experience and knowledge base) and question 25E (lead-time to repair) is due to 70.59% of the respondents selecting either important or most important, of which 49.24% have knowledge and experience in systems which are older than five years, compared to 24.24% whom have knowledge and experience in systems which are less than five years old, and 26.52% whom have knowledge and experience in design. Furthermore 67.38% of the respondents either have experience and knowledge with systems, which are less than five years old, or systems older than five years. One method to reduce downtime of high technology complex system is to have inventory and resources on hand, by ordering spares, which have long lead times, and scheduling maintenance tasks, the applicable spares and resources are on site when needed. The Cramer's V statistic has a value of 0.1607, meaning that a conclusion can be drawn that there is a weak association between question 11 (experience and knowledge base) and question 25E (lead-time to repair). 65 of the respondents whom have more than five years experience and knowledge rated this question as important or most important, whereas four rated the question as less important or least important. 132 respondents rated this question either as important or most important, compared to 38 with a neutral opinion, and 15 rated the question either as less important or least important. 1 respondent with less than five years experience and knowledge rated this question either less important or least important. Between the two variables, there are two blank fields and has been regarded as missing frequencies.

Figure 6–33: Cross tabulation of question 11 (experience and knowledge base) by question 25E (lead-time to repair)

The cross tabulation of question 11 (experience and knowledge base) versus question 25G (reliability of repaired system) is depicted in Figure 6–34. The Chi-Square statistic has a P value of 0.0049, meaning that a conclusion can be drawn that question 11 (experience and knowledge base) and question 25G (reliability of repaired system) are dependent on each other. The dependence of question 11 (experience and knowledge base) and question 25G (reliability of repaired system) is a result of 84.49% of the respondents selecting either important or most important for question 25G (reliability of repaired system), compare to 4.81% whom rated question 25G (reliability of repaired system) either as less important or least important. Of these 84.49% of the respondents, 71.52% have experience and knowledge with systems, which are either less than five years old or older than five years. In addition 76.27% of the respondents whom have experience and knowledge in design rated question 25G (reliability of repaired system) as both important and most important, compared to 95.24% of the respondents whom have experience and knowledge in systems, which are more than five years old. The Cramer's V statistic has a value of 0.2003, meaning that a conclusion can be drawn that there is a weak association between question 11 (experience and knowledge base) and question 25G (reliability of repaired system). 80 of the respondents whom have more than five years experience and knowledge rated this question as important or most important, whereas one rated the question as less important or least important. 158 respondents rated this question as either important or most important, compared to 19 with a neutral opinion, and nine rated the question aseither less important or least important. One respondent with more than five years experience and knowledge and two respondents with less than five years experience and knowledge rated this question as either less important or least important. Between the two variables, there is one blank field and has been regarded as a missing frequency.

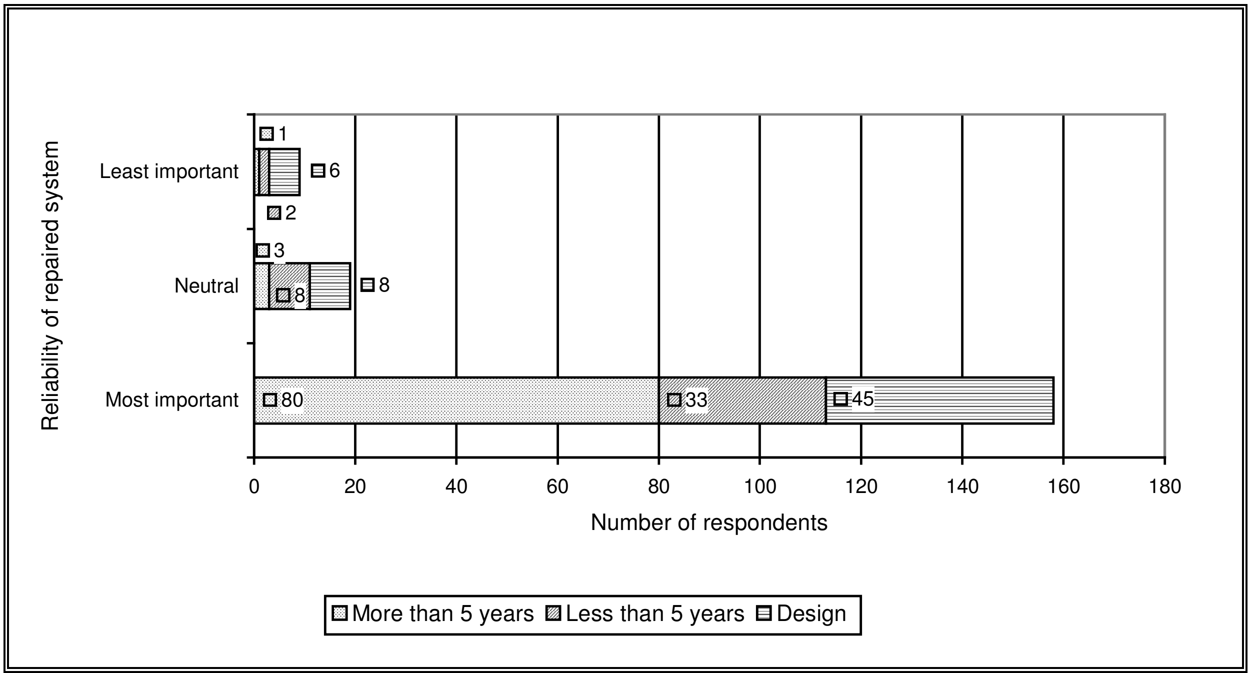


Figure 6–34: Cross tabulation of question 11 (experience and knowledge base) by question 25G (reliability of repaired system)

The cross tabulation of question 11 (experience and knowledge base) versus question 32B (poor supervision) is depicted in Figure 6–35. The Chi-Square statistic has a P value of 0.0209, meaning that a conclusion can be drawn that question 11 (experience and knowledge base) and question 32B (poor supervision) are dependent on each other. The dependence between question 11 (experience and knowledge base) and question 32B (poor supervision) is due to 35.38% of the respondents selecting least important for question 32B (poor supervision), compare to 49.23% whom selected neutral and 15.38% whom selected most important. Furthermore 69.23% of the respondents have experience and knowledge in design, of which 46.66% rated question 32B (poor supervision) as least important, compared to 8.88% whom selected most important. In the respondents opinion they felt that poor supervision was not a major contributing factor towards maintenance personnel error. The Cramer's V statistic has a value of 0.2983, meaning that a conclusion can be drawn that there is a weak association between question 11 (experience and knowledge base) and question 32B (poor supervision) are. Three of the respondents whom have more than five years experience and knowledge rated this question as most important, whereas two rated the question as least important. 10 respondents rated this question as most important, compared to 32 with a neutral opinion, and 23 rated the question as least important. Two respondents with more than five years experience and knowledge rated this question as least important. 21 of the respondents with design experience and knowledge rated this question as least important. There were zero respondents with less than five years experience that rated the question as least important. Between the two variables, there is one blank field and has been regarded as a missing frequency.

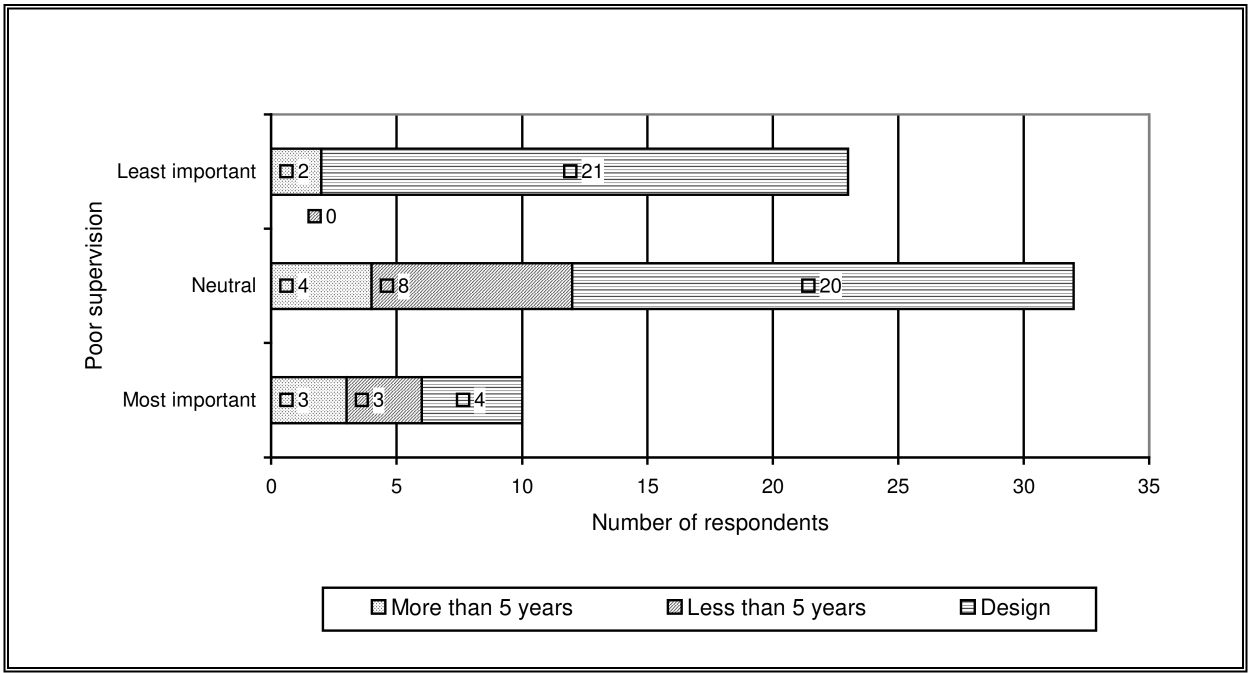


Figure 6–35: Cross tabulation of question 11 (experience and knowledge base) by question 32B (poor supervision)

This section provided the graphical representation and explanation of the cross-tabulation analysis. Only those Chi-square test results that were below 5% have been elaborated on. The next section deals with the collation of phase 3 of research.

6.9 Collation of phase 3 of research

The summary of the collation of phase 3 of the research is provided in Table 6–5. In Chapter 7 the collation of the three phases of research is presented.

Table 6–5: Collation of phase 3 of research

Q No.	QUESTION DESCRIPTION	DESCRIPTIVE STATISTIC RESULTS	INFERENTIAL STATISTICS RESULTS	COLLATED PHASE 3
1	Gender	90.8% male, 9.2% female	N/A	54.4% Respondents - White, Male, Afrikaans; 69.23% Respondents - White, Male, English or Afrikaans
2	Race	17% Black, 2.2% Coloured, 1.7% Indian, 78.6% White	N/A	
3	Home language	62.2% Afrikaans, 20% English, 3.8% N. Sotho, 1.6% S. Sotho, 0.6% Tsonga, 5.4% Tswana, 0.5% Venda, 3.8% Xhosa, 1.1% Zulu, 0.5% German, 0.5% Kiswahili	N/A	
4	Basic training	78.8% engineering, 20.1% management, 1.1% finance	N/A	Due to technical inclination of systems, predominantly engineering/technical background
5	Age	Average age 40.5 years, ranged from 22 to 67 years, most frequent age 38 (13 respondents)	N/A	Typical age range, average age typical of personnel within industry
6	Organisation name	70.4% military or military associated, 11.3% industrial involved with existing system, 18.3% industrial involved with system under development	N/A	Predominantly military or military associated organisations as the majority of the systems are military
7	Current main system /project involved with	33.8% ground systems, 27.3% aircraft, 17.5% mechanical, 21.4% support (excluding maintenance)	N/A	Representative of population and systems chosen for survey, and systems where ILS is currently used in.
8	Job orientation	37.2% engineering, 24% maintenance, 38.8% management	N/A	Representative sample of engineering, maintenance and management personnel within industry, relatively flat distribution. Indicative of developing country where personnel having a basic training in engineering do not necessarily stay in the engineering field.
9	Factors which could improve your organizations efficiency (delivery system)	Best practices = least important, knowledge, & skills both rated most important, best practices has an inverse normal distribution	No direct relevant difference between variables. Best practices shows that the majority of the respondents either selected most important or least important and that a small proportion selected neutral.	Knowledge and skills are viewed as most important, whereas best practices are not viewed as important, the respondents perceive best practices as unusable. Or the respondents have not heard of the terminology of best practices, but understand the terminology of skills & knowledge.

Q No.	QUESTION DESCRIPTION	DESCRIPTIVE STATISTIC RESULTS	INFERENTIAL STATISTICS RESULTS	COLLATED PHASE 3
10	Qualities that make information valuable to an organization	Accuracy = most important, timely = least important, accessibility = neutral	Variable 10 B (accuracy) classified by variable 4 (basic training) inferred significant differences between the two variables. Variable 10 B (accuracy) classified by variable 11 (knowledge and experience) inferred significant differences between the two variables.	Respondents regarded accuracy of information as most important, irrespective of their basic training or background knowledge and experience.
11	Knowledge & experience	31.6% new system design, 23% systems less than 5 years old, 45.5% systems older than 5 years old	Variable 11 (knowledge and experience) classified by variable 4 (basic training) inferred significant differences between the two variables. Variable 11 (knowledge and experience) classified by variable 8 (job orientation) inferred significant differences between the two variables.	Irrespective of the respondents basic training they have vast amounts of basic knowledge and experience across systems (new system design, systems less than 5 years old and systems older than 5 years old)
12	Writing operator & maintenance documentation in such a manner that operating & maintenance personnel are capable of understanding the contents thereof?	68.5% most necessary 87.7% rated most necessary or necessary	No significant differences between variables.	Significantly high percentage (87.7%) perceived this as very necessary
13	Defining the maintenance & operational personnel requirements	75.4% most necessary or necessary	Variable 13 (Defining the maintenance & operational personnel requirements) classified by variable 8 (job orientation) inferred significant differences between the two variables.	Irrespective of the respondents job orientation (engineering, maintenance or management), and that 75.4% of the respondents viewed this question (defining the maintenance and operational personnel requirements) as most important or important, there is a significant difference between their job orientation and their perception regarding defining maintenance and operational personnel requirements
14	Conduct periodic audits?	54.3% most necessary or necessary, 17.2% least necessary or less necessary	No significant differences between variables.	The mean score for this question is 2.46, and the respondents perceive this question between necessary and neutral, 28.5% of the respondents viewed this question as neutral

Q No.	QUESTION DESCRIPTION	DESCRIPTIVE STATISTIC RESULTS	INFERENTIAL STATISTICS RESULTS	COLLATED PHASE 3
15	Applying configuration management?	47.1% most necessary, 1 respondent rated least necessary	No significant differences between variables.	75.9% of the respondents rated this question as most necessary or necessary, the mean score tends towards necessary (2), they view the application of configuration management as necessary
16	Applying configuration management principles with respect to documentation?	50% most important, 5.4% least important or less important	No significant differences between variables.	85.5% of the respondents perceived this question as most important or important. The average score of question 15 and 16 is between 1 and 2, which tends to suggest that the respondents feel quite strongly regarding configuration management principles and the configuration management of documentation. However audits are regarded as one of the functions of configuration management.
17	Attracting & retaining the applicable skilled personnel to maintain & operate the system	59.4% most important	No significant differences between variables.	85% of the respondents regarded this question as either most important or important, hence stressing the fact that attracting and retaining personnel is a major priority for organisation.
18	Support and Test Equipment (S&TE) factors used on your system that require improvement	68.7% rated availability of S&TE, & personnel as most important,	Variable 18A (Availability of S&TE, & personnel) and variable 18C (S&TE support/maintenance) classified by variable 4 (basic training) infered significant differences between the two variables. Variable 18A (Availability of S&TE, & personnel) and variable 18C (S&TE support/maintenance) classified by variable 8 (job orientation) inferred significant differences between the two variables. Variable 18C (S&TE support/maintenance) classified by variable 11 (knowledge and experience) inferred significant differences between the two variables.	Irrespective of the respondents basic training or job orientation, there is a significant difference between responses for variable 18A (availability of S&TE, & personnel), although they regarded this variable as most important. Irrespective of the respondent's job orientation, there is a significant difference between responses for variable 18C (S&TE support/maintenance); they regarded this variable as neutral. Irrespective of their basic training or job orientation they do not regard S&TE as being important nor the support thereof.

Q No.	QUESTION DESCRIPTION	DESCRIPTIVE STATISTIC RESULTS	INFERENTIAL STATISTICS RESULTS	COLLATED PHASE 3
19	Maintenance issues	50% rated analysis as most important	Variable 19C (Strategic, e.g. maintenance concept & responsibilities) classified by variable 4 (basic training) inferred significant differences between the two variables.	50% of the respondents rated analysis the most important factor of maintenance. Irrespective of their basic training there was a significant difference regarding their viewpoints regarding strategic maintenance issues, this is a result of only 20.1% of the respondents having a basic training in management
20	Reliability, availability & maintainability (RAM) - (dependability) issues	50.6% rated identifying parts with excessive failure rates as most important	Variable 20B (Defining the operational availability (A_O)) classified by variable 11 (knowledge and experience) inferred significant differences between the two variables.	Irrespective of the respondents' knowledge and experience there is a significant difference regarding their viewpoints of defining the operational availability, this is due to 45.5% of the respondents working on systems that are older than 5 years.
21	Common maintenance problems	41.5% rated poorly defined & implemented maintenance practices as most important	Variable 21B (Poorly defined & implemented maintenance practices) and variable 21C (Strategic guidelines, philosophy & objectives classified by variable 4 (basic training) inferred significant differences between the two variables. Variable 21A (Faulty maintenance work) classified by variable 11 (knowledge and experience) inferred significant differences between the two variables.	Irrespective of the respondents' basic training there is a significant difference regarding their viewpoints with respect to poorly defined maintenance practices and strategic guidelines, this is due to only 20.1% of the respondents having management as basic training. Irrespective of the respondents knowledge and experience there is a significant difference in their viewpoints regarding faulty maintenance work. This is due to 31.6% of the respondents having experience in design and 45.5% of the respondents having experience and knowledge in systems that are older than 5 years, bathtub curve failure - most failures occur during startup & teething problems. The respondents perceive strategic guidelines as either important or not important and only 27.87% rated the variable as neutral.
22	Material handling principles	41% rated minimum handling as most important	No significant differences between variables.	Minimum handling is regarded as the most important aspect of material handling principles, with 73.8% of the respondents regarding this variable as most important or neutral.

Q No.	QUESTION DESCRIPTION	DESCRIPTIVE STATISTIC RESULTS	INFERENTIAL STATISTICS RESULTS	COLLATED PHASE 3
23	System operational requirements (beyond life cycle)	40.3% rated operational conditions of deployment as most important	No significant differences between variables.	76.8% of the respondents rated operational conditions of deployment as either most important or neutral. Expected life cycle has an inverse distribution, where the majority of respondents rated this variable as either most important or least important and only 24.3% rated this variable as neutral, this is due to 54.6% of the respondents having experience in design or systems that are less than 5 years old.
24	Determinants of obsolescence	64.5% rated reliability as most important	Variable 24A (Cost to support) classified by variable 8 (job orientation) inferred significant differences between the two variables.	Irrespective of the respondents job orientation there is a significant difference with variable 24A (cost to support), this is due to 87.4% of the respondents rating this variable as either most important, important or neutral, further only 24% of the respondents have experience and knowledge in maintenance.
25	Economical decisions as they relate to supply support	55.4% rated reliability of repaired system as most important, 55.4% rated reliability of repaired system as most important	Variable 25E (Lead-time to repair) classified by variable 8 (job orientation) inferred significant differences between the two variables. Variable 25B (Cost to repair), variable 25C (Distance to support) and variable 25E (Lead-time to repair) classified by variable 11 (knowledge and experience) inferred significant differences between the two variables.	Irrespective of the respondents job orientation there is a significant difference with variable 25E (lead-time to repair), this is due to 91.9% of the respondents rating this variable as either most important, important or neutral, further only 24% of the respondents have experience and knowledge in maintenance. Irrespective of the respondents knowledge and experience there are significant differences between this variable and Variable 25B (Cost to repair), variable 25C (Distance to support) and variable 25E (Lead-time to repair), this is due to only 24% of the respondents have experience and knowledge in maintenance.
26	Using the following plans to improve your systems performance	66.2% rated maintenance plan as most important, 6.5% rated disposal plan as most important	No significant differences between variables.	The respondents regarded a maintenance plan as most important, irrespective of their basic training, job orientation or knowledge and experience. An obsolescence plan and disposal plan were rated the two least important plans for their high technology systems, this is concerning as 45.5% of the respondents have knowledge and experience in systems that are older than five years old, and 70.4% of the respondents are from the military or military related organisations.

Q No.	QUESTION DESCRIPTION	DESCRIPTIVE STATISTIC RESULTS	INFERENTIAL STATISTICS RESULTS	COLLATED PHASE 3
27	Typical disposal costs	58.5% rated environmental & safety concerns as most important	Variable 27C (Redesign for alternative use (e.g. demilitarization)) classified by variable 4 (basic training) inferred significant differences between the two variables. Variable 27B (Environmental & safety concerns) classified by variable 8 (job orientation) inferred significant differences between the two variables.	Irrespective of the respondents basic training there is a significant difference between their perceptions regarding redesigning a disposed system for alternative use, although 45.5% of the respondents have knowledge and experience in systems older than five years old, furthermore only 20.1% of the respondents have management training and 38.8% of the respondents are involved in management activities and disposal and method of disposal is typically a management decision. Irrespective of the job orientation of the respondents there is a significant difference regarding their perception of environmental and safety concerns, even though this variable is positively skewed and is rated as most important, furthermore only 38.8% of the respondents are involved in management activities and typically safety policies are written by management, although everyone should be aware of environmental and safety concerns
28	Storage facility requirements	52.3% rated impact on reliability of product mean as most important	No significant differences between variables.	86.2% of the respondents rated impact on reliability of product as important or neutral, hence positively skewed
29	Packaging requirements	52.3% rated protection of equipment during transportation as most important	Variable 29A (Labelling & identification) and variable 29B (Protection of equipment during transportation) classified by variable 4 (basic training) inferred significant differences between the two variables.	Irrespective of the respondents basic training there is a significant difference between their perceptions regarding labeling and identification, and protection of equipment during transportation. This is due to the 78.8% of the respondents having engineering as basic training, only 24% of the respondents are involved in maintenance and 31.6% have experience in designing of new systems. Furthermore the minority (30.8%) of the respondents rated labeling and identification as neutral, majority selected either most important or least important.
30	Training factors	44.6% rated ability of training instructors as most important	No significant differences between variables.	76.9% of the respondents rated ability of training instructors as important or neutral. 24.6% of the respondents selected personnel skill level related training programs neutral, the majority either selected most important or least important

Q No.	QUESTION DESCRIPTION	DESCRIPTIVE STATISTIC RESULTS	INFERENTIAL STATISTICS RESULTS	COLLATED PHASE 3
31	Effectively manage obsolescence	58.5% rated managed obsolescence under risk as most important	No significant differences between variables.	Manage obsolescence under risk was rated as most important by 58.5% of the respondents, only 18.5% of the respondents rated this as neutral and 23.1% rated as least important.
32	Possible causes of maintenance personnel error	78.5% rated poor training & procedures as most important	Variable 32B (Poor supervision) classified by variable 11 (knowledge and experience) inferred significant differences between the two variables.	Irrespective of the respondents knowledge and experience there is a significant difference regarding their viewpoints of poor supervision as a cause of possible maintenance error, this is due to 24% of the respondents being involved with maintenance, furthermore poor supervision has a normal distribution
33	Possible causes of logistics delay time	40% rated administrative & approval activities as most important	No significant differences between variables.	40% of the respondents selected both administrative and approval activities and ordering and shipping time as most important causes of logistics delay time.
34	Types of failures/ defects	72.3% rated operator induced failures as most important	Variable 34A (Maintenance induced failures) and variable 34B (Operator-induced failures) classified by variable 4 (basic training) inferred significant differences between the two variables.	Irrespective of the respondents basic training there is a significant difference regarding their viewpoints with respect to maintenance induced and operator induced failures/defects. 72.3% of the respondents rated operator induced failures as most important. 18.5% of the respondents rated wear out (predictable) failures as neutral, and the majority rated most important or least important.

Legend: Q = Question, No. = Number

'Do not go where the path may lead, go instead where there is no path and leave a trail.'
– Ralph Waldo Emerson.

'A man should look for what is, and not for what he thinks should be.'
– Albert Einstein.

CHAPTER 7 COLLATION OF THREE PHASES OF RESEARCH

7.1 Introduction

The problem presented in chapter 1 implies that there is no framework available for the development of an integrated logistics support system (ILSS) for a complex system, which does not necessarily mean that ILS must be developed simultaneously with the design of the system. An ILS is required in high technology complex systems currently in use, especially where there is a high consequence of failure. If such a system is operated in a developing world context the level of complexity is raised further. In the present chapter, the three phases of the study are collated into a single structure, critically reviewing the information to develop grounded technological rules. In the next section the framework's grounded elements are discussed.

7.2 Grounded elements of the framework

The background to the said rules is to be found in chapter 3; these are based on the *'Mode 2'* research science of Gibbons (2002:3-11), the 'grounded technological rule' (van Aken, 2005:19), design science research (van Aken, 2005:21-22), and grounded theory as put forward by Glaser and Strauss (1967a), and Glaser (1998:3). The aim of this research is to propose grounded technological rules for use in practice as regards an ILSS within the industry being studied.

The elements that will be discussed are:

1) Maintenance;
2) Support and test equipment;
3) Supply support;
4) Packaging, handling, storage and transportation;
5) Technical data and documentation;
6) Facilities;
7) Manpower and personnel;
8) Training and training devices;

9) Computer resources;
10) Reliability, availability, and maintainability;
11) Configuration management;
12) Obsolescence; and
13) Disposal.

7.2.1 ***Maintenance – three phases collated***

Specific conclusions can be drawn from the literature related to maintenance presented in chapter 2, which was deconstructed in chapter 4. A summary of these critical aspects is provided in the paragraphs that follow. The maintenance philosophy of a specific organisation or system is used to generate a maintenance concept. The maintenance concept, maintenance planning and the logistics support analysis (LSA) results comprise additional inputs to the maintenance plan. The maintenance concept details the different maintenance actions (predictive, preventive, or corrective) to be performed by the different maintenance levels. It further includes the repair policies (repair or discard) and organisational responsibilities for the different maintenance levels, the scheduling of maintenance tasks, and availability of resources. The maintenance plan documents at what level the maintenance will be performed, how the maintenance action will be performed, who will perform the maintenance actions, and what resources will be required throughout the utilisation phase or all phases of the system's life cycle. Furthermore the maintenance plan needs to be developed and then regularly updated, based on information obtained throughout the process.

In system Charlie, as examined in chapter 5, a failure modes, effects, and criticality analysis (FMECA) approach is applied to determine possible failure modes, their probability of occurrence, the severity of the postulated failure, and the resultant criticality of any failure. Furthermore a reliability centred maintenance (RCM) approach (based on Moubray, 1997) is used to determine whether the failure modes are categorised as requiring on-condition monitoring, a scheduled restoration activity, a scheduled discard, scheduled fault finding (or diagnosis), or the necessity of a redesign. An implemented maintenance concept and maintenance philosophy has been devised for System Charlie. Four lines of maintenance are envisaged.

Systems Alpha, Bravo, Delta, Echo, and Foxtrot, likewise examined in chapter 5 also contain a logistics support concept or maintenance concept, and a maintenance philosophy has been implemented, including repair policies of repair or discard. These systems differ with regards to their levels of maintenance: whereas system Alpha has only organisational (O-level), and Depot (D-level) maintenance, Systems Bravo, Delta, Echo, and Foxtrot employ three levels of maintenance. These systems all employ separate preventive and corrective maintenance actions.

Systems Alpha, Bravo, Delta, Echo, and Foxtrot have not employed an FMECA-RCM approach to determine possible failure modes or scheduled tasks. The overseas original equipment manufacturer (OEM) probably employed such a technique of analysis, and this may be used by applying a modified FMECA process in specific risk environments. A support contract exists between the end-user and a contractor, where the end-user typically performs O-level maintenance (or black box exchange), and the contractor performs D-level repair. In order to conduct repairs, the respective OEM's provided the systems with operator and maintenance manuals. From the deconstruction of the literature and cases, it was clear that the maintenance element needed to be examined further by using a questionnaire.

Following from the questionnaire analysis it can be determined that the respondents perceive analysis, in the form of analysis of logistic support, level of repair, and FMECA-RCM to be an important contributing factor in determining the appropriate maintenance philosophy, concept and plan. Furthermore components with a high rate of failure have an impact on the reliability and support of a system and should be investigated in more detail. This in effect influences the decisions taken. Inadequate strategic maintenance guidelines, philosophy and objectives can adversely affect maintenance work since the actions, processes and procedures are not clearly defined, causing the maintainers to exchange line replaceable units (LRU's) until the fault is no longer apparent, instead of following set diagnostic guidelines. In addition it is evident that an inadequately defined maintenance concept results in errors being committed by maintenance personnel due to poor training and procedures. Faulty maintenance work was regarded as the most important factor contributing to maintenance problems, and operator induced failures are considered to represent the major contributor to the types of failures and defects occurring on systems.

In order for maintenance to be performed effectively and efficiently in a high technology complex system environment, the following prescriptive grounded technological rules are proposed:

1) Utilise the defined business strategy;
2) Establish the organisation's maintenance philosophy;
3) Delineate the maintenance concept of the specific system and its linkage to other systems;
4) Develop maintenance planning, including analysis;
5) Document a maintenance plan for the specific system;
6) Implement the maintenance plan across all maintenance levels;
7) Conduct specific analysis of the system; and
8) Ascertain the risks associated with the maintenance of the system and manage these risks.

In this section the three phases of research regarding maintenance have been collated. Furthermore, grounded technological rules regarding maintenance planning were furnished. In the following section the three collated phases of support and test equipment research are considered.

7.2.2 ***Support and test equipment – three phases collated***

Specific conclusions can be drawn from the literature related to support and test equipment (S&TE), presented in chapter 2 and deconstructed in chapter 4. A high technology complex system requires maintenance and support throughout its life cycle. One aspect of doing so is by means of support and test equipment (S&TE). Support equipment can be regarded as all the equipment required to perform maintenance on a system. S&TE trade-offs are required to determine the optimal type of S&TE required, which takes the personnel skill levels into account. The skills levels assessment required for S&TE operation is not mentioned in the literature. The S&TE needs to be compatible with the primary system on which it will be used and can be fixed or mobile. S&TE is categorised as common S&TE, which is readily available off the shelf and used in a number of applications, or special test equipment which is specifically designed and used in one or limited applications. S&TE itself requires maintenance and support, that is, calibration and repairs. The cost of the actual S&TE equipment makes it very vulnerable to cost cutting exercises, and in the literature this is not considered as an option.

In system Charlie, a ILSA approach is used to determine the optimal S&TE requirements. Conceptually specialised tools and equipment, commercially-off-the-shelf (COTS) equipment, and equipment handling systems are identified. Interfaces with the building, for example cranes, are investigated.

Systems Alpha, Bravo, Delta, Echo, and Foxtrot have their respective S&TE requirements defined by the original equipment manufacturer (OEM); the end-user procures S&TE according to the specific system's operational requirements, where applicable. The S&TE is compatible with the primary system and is calibrated periodically; calibration certificates are kept for audit purposes. The actual radio navigation systems of systems Delta and Echo are also calibrated periodically according to international standards and their respective calibration certificates are also retained for audit purposes. Equipment is either sent to a specific calibration facility or is calibrated at the end-user's premises. Personnel are trained in the proper use of the S&TE in order to reduce maintenance-induced failures on the S&TE and primary system. Availability of S&TE and personnel is a concern, as the S&TE and/or personnel may be used at a specific site and are then required a distance away at another location, delaying the actual diagnostic and repair time for another component, thereby increasing the time to repair. Too few people are trained regarding the proper use of S&TE, which results in maintenance-induced failures and delays in repairs of failures. Owing to financial constraints, not much specialised (special to type) test equipment is procured, resulting in the different systems sharing S&TE, resulting in a priority based repair philosophy, for example, deciding which system is the most urgent to repair based on contractual obligations, availability of S&TE and personnel, availability of supply support resources, etcetera. An S&TE plan is in place for these systems currently in use.

Following from the analysis of the questionnaire it can be determined that the most important factor requiring improvement, in the respondents' opinions, was the availability of S&TE, and personnel. This is prevalent in some of the systems since a limited amount of S&TE is procured due to budget constraints, and the actual period during which the S&TE takes place. Furthermore the availability of personnel and of S&TE is of concern. In the systems investigated the standardisation of S&TE is not perceived to be problematic and the systems have been designed in order to do so.

From the analysis of the literature, case studies, and question 18, it is evident that the S&TE requirements need to be defined, planned, and managed. S&TE availability, and its support and maintenance, are important factors requiring consideration when procuring and using the S&TE. Furthermore the S&TE needs to be reliable, ensuring minimum delays when repairing the primary system. In order for the S&TE resource to be managed successfully, the following grounded technological rules are proposed:

1) Design of S&TE and compatibility thereof with main system;
2) Trade-offs, constraints and availability of S&TE;
3) Scheduling of multi-system S&TE;
4) S&TE concept and plan; and
5) Support and maintenance, (including calibration) of S&TE.

In this section the three phases of research regarding S&TE were collated and described. Furthermore grounded technological rules were furnished. In the next section the three collated phases of supply support research are considered.

7.2.3 ***Supply support – three phases collated***

Supply support can be regarded as a management function applying specific methodologies for the acquiring, receiving, cataloguing, transferring, storing, distribution, issuing, preservation, packaging, and disposal not only of secondary items, but also of primary ones. This element also includes the initial provisioning of spares and the replenishment of such spare and repair parts.

Spares can be regarded as assemblies or components for maintenance purposes, whereas repair parts are non-repairable components used to repair spares. The literature related to supply support was presented in chapter 2 and deconstructed in chapter 4. Here we will critically review a collated framework.

Supply support, as a management activity, is dependent on the LSA, and involves trade-offs, concepts, limitations, constraints, planning requirements, determining initial and replenishment spares and repair parts, and establishing provisioning requirements in order to support a system throughout its life cycle. Supply support activities involved include, apart from those mentioned above, failure rates, utilisation rates, operational hours, transfer, issuing, documentation, cataloguing, and disposal of initial and replenishment repair and spares parts at all levels of maintenance and at all locations where the system will require support. Use of an inventory cycle and of economic quantities of orders are required to project stock levels and order quantities. Although most of what is in the literature regarding supply support consists of statistical projections and thought, based on an ideal world situation, in practice there are many constraints that need consideration, especially in a developing world context. A risk-based approach may be the best solution in this situation to determine requirements per situation.

In System Charlie a LSA approach will be used to determine the supply support requirements, based on a specific philosophy and concept of periodic outages and expected failure rates.

Systems Alpha, Bravo, Delta, Echo, and Foxtrot have their respective initial supply support requirements defined by the OEM, while the replenishment spares and repair parts are defined by the end-user. The systems currently in use employ the strategy of stocking certain frequently used components. In systems Alpha, Bravo, and Delta the strategy used is that certain components are not kept in stock, but only procured once required. This causes delays and affects the time taken to repair the failed unit. However, critical and long-lead items have been identified in system Alpha and some of these items are kept in inventory. A supply support plan is in place for the systems currently in use. It documents the said strategy for each of the systems, including lists of initial and replenishment spares and repair parts. In addition the economic quantities in which to order the item and the inventory cycle are furnished; however, this is an ideal theoretical solution and is not applied in practice to the systems owing to the realistic practical constraints, budgets and other critical risks.

Following from the questionnaire analysis it can be ascertained that the respondents perceive the reliability of repaired systems as the most important aspect relating to the economic facets of supply support, while distance to support, and consequence of failure, were both rated as the least important. From the analysis of the literature, case studies, and question 25, it is evident that the supply support requirements need to be defined, planned, and managed efficiently and effectively. Irrespective of the respondent's job orientation, and experience and skills, there was a weak but dependent association with the lead-time to repair.

In order for the supply support resource to be managed successfully, the following grounded technological rules are suggested:

1) Define the system support strategy, philosophy, and concept;
2) Derive the supply support strategy, philosophy, and concept from the above;
3) Determine the specific risks and calculate spares levels, based on risks and cost effectiveness; and
4) Document the supply support plan, defining the various processes and procedures required to efficiently and effectively manage the supply support function.

7.2.4 ***Packaging, handling, storage, and transportation – three phases collated***

Specific conclusions can be drawn from the literature related to packaging, handling, storage, and transportation (PHS&T). This review was presented in chapter 2 and deconstructed in chapter 4. The purpose of PHS&T is to ensure that an item is packed carefully in order to eliminate or reduce damage and to protect the item from harsh environmental conditions, including an indication of shock levels. Adequate handling mechanisms need to be used to move the packed item from one point to another, manually or mechanically. Furthermore the item must be stored in a storage location (fixed or mobile, and permanent or temporary), which preserves the item for a certain period of time in an environmentally controlled environment. Finally the item needs to be transported and to reach its destination in a serviceable condition. PHS&T includes, but is not limited to, the procedures, policies, materials, supplies, and equipment required to support a high technology system including S&TE, personnel, and other logistic elements.

The packaging of an item ensures that it is ready to be transported; this includes labelling and the use of reusable containers. Furthermore packages must withstand vibration, drop and topple tests, as well as environmental condition tests for dust, rain, pressure, sand, immersion, and wind. Storage requirements depend on the quantity of the item and the characteristics (weight, dimensions, required temperature of storage, etc.) of the item to be stored.

Transportation includes the materials moved into the organisation and the physical distribution of the finished goods to suppliers; location affects the transportation mode used, as do, transportation costs and time. Various characteristics can affect the transportability of an item; these include its physical properties (e.g., its mass), dynamic limitations (acceleration, deflection, securing, vibration, leakage, and skin loading), environmental factors (pressure, temperature, sterilization and cleanliness, and humidity), and hazardous effects (radiation, explosives, personnel safety, biologic or etiologic, and electrostatic) (Jones, 1995:13.2, 13.7-13.8).

A PHS&T plan theoretically describes all the policies, procedures, and requirements for the main system, its S&TE, and its other logistic support elements. In the literature it is assumed that packaging requirements are stipulated and that all users will comply with these. However in reality PHS&T aspects that are specified and documented are not always followed adequately and depend on what resource is available; for example a different mode of transportation with a lower specification may be used, such as a modified trolley, which imposes a risk if the item falls off the trolley and is damaged.

Labelling written in English providing critical information regarding the various constraints assumes that the end-user understands the wording, which is not always the case. Hence labels which depict critical information graphically may be more easily understood. Items susceptible to vibration, shock or fragility, etcetera need to be labelled as such and have the necessary monitoring devices placed on the packaging. However, in some cases where these labels and monitoring devices are evident, in reality the items are not necessarily handled with the required care.

In one of the systems examined in chapter 5, a LSA approach will be used to determine the PHS&T requirements. Conceptually such requirements have been defined; however, the detailed requirements will be only known after an LSA, FMECA-RCM, and other analysis. As a preliminary comment, nuclear waste needs to be stored in such a manner as to eliminate radiological contaminants entering the environment. Failed components, which are removed and disposed of, need to be ‘bagged’, and/or packaged in suitable containers with appropriate labels and markings indicating the hazardous nature of the packaged component. These components need to be carefully handled and transported to suitable storage and disposal facilities for prolonged storage. They may require specific handling equipment such as cranes, etcetera.

The other five systems as examined in chapter 5 have their respective basic PHS&T requirements defined by the OEM; however some of these packaging, handling, and storage interfaces are obsolete and consequently new, more applicable interfaces have been designed and utilised.

System Bravo uses airfreight to transport the repairable items to a contractor for repair, but the packaging in which these items arrived at the contractor was damaged, which in turn physically damaged some of the repairable items. Subsequently different packing and packaging have been used. With systems Alpha, Delta, Echo, and Foxtrot the PHS&T policy is subjected to stringent control and a PHS&T plan is in place for these systems.

Following from the questionnaire analysis it can be determined that minimum handling of material is regarded as most important, while the size and dimensions of handled material are regarded as least important. Furthermore, the impact on the reliability of a product is perceived as most important when considering storage facility requirements. In addition the respondents viewed the protection of equipment during transportation as the most important factor related to packaging requirements. From the analysis of the literature, case studies, and questions 22, 28, and 29, it is evident that the PHS&T requirements need to be defined, planned, and managed continuously.

Minimum handling was viewed as most important, owing to technological advances in equipment design and the lower frequency of failure of items requiring handling. The reliability of the product is important, as this will reduce the storage area required for failed and unserviceable components. Equipment being transported needs to be packed, packaged and labelled or marked appropriately. The user of the equipment, knowing how valuable the asset is, may appropriately pack, package, and label the item, and insert monitoring devices, in the form of tilt monitors or vibration monitors, in the packages for quality insurance purpose.

In order for the PHS&T resource to be managed successfully, the following grounded technological rules are proposed:

1) Define the PHS&T (including packing, preservation, and labelling or marking) policies, procedures, requirements and specifications;
2) Ensure stringent adherence to the PHS&T (including packing, preservation, and labelling or marking) policies, procedures, requirements and specifications;
3) Ensure adequate maintenance and support of the PHS&T infrastructure, and equipment;
4) Conduct analysis and trade-offs regarding PHS&T mechanisms, in order to minimise and standardise PHS&T interfaces;
5) Ensure understandable labelling and marking of items susceptible to vibration, shock, fragility, correct orientation, environmental constraints, etcetera; and
6) Ensure adherence to recommendations through usage of monitoring techniques in packages.

In this section the three phases of research regarding PHS&T were collated and described. Furthermore, grounded technological rules regarding planning in this respect were suggested. In the next section the three collated phases of technical data and documentation research are discussed.

7.2.5 *Technical data and documentation – three phases collated*

The literature review in this regard was presented in chapter 2 and was deconstructed in chapter 4. Technical data and documentation can be regarded as all the necessary supporting data media and documentation (e.g. manuals, specifications, etc.), and other forms of information which are necessary. This includes all documentation required to support software, hardware, and firmware. Data and documentation are needed to support the installation, operation, maintenance and support of the primary system, and also the S&TE, facilities, training devices including training manuals, PHS&T, supply support, etc. Data and documentation are not just limited to manuals, but include all the other media that may be necessary to support a system.

Technical publications should be written with the reader and the reality of the circumstances in mind. The items on which maintenance will be performed also need to be identified in the documentation, including the tools and S&TE requirements. In addition, personnel requirements and the location of the activities also need to be made clear in documentation. A technical data and documentation plan contains all the necessary information and relevant planning required in order to support a system during operation, maintenance and training on the system at all levels of responsibility.

A technical data and documentation plan has been implemented for systems Alpha, Delta, Echo and Foxtrot, as examined in chapter 5. Within this plan are contained processes, procedures and lists of applicable publications relevant to the operation and maintenance of the respective systems. Master copies are stored at a central depot, and working copies are used at the respective operating areas. Configuration management is applied regarding amendments and the incorporation thereof. One of the systems expressed concern regarding its data and documentation in that there is a language barrier regarding the manuals, which are written in English though the end user of the system speaks a dialect of Spanish as a first language. Furthermore, amendments have not been fully incorporated into the technical manuals. The issues of language and computer literacy are not addressed adequately in the ILS literature. In a developing country such as South Africa, English is not necessarily the first or second language of some of the population, and hence not all technical publications in this language are fully understood. Another concern is that with a recent upgrade on system Alpha a newer, technologically advanced sub-system replaced the legacy sub-system, the course manuals and technical publications were in English and a prerequisite for the course was basic computer literacy; however, one of the students was not adequately proficient in basic computer literacy and struggled during the course, slowing down the progress of the other students.

With System Charlie, an LSA will be conducted to determine the specific requirements for the technical data and documentation element. Conceptually, operator manuals, maintenance manuals, and specific processes and procedures are envisaged.

Following from the questionnaire analysis it is essential to compile operator and maintenance documentation which is easily and quickly understandable. Furthermore the respondents regarded applying configuration management principles with respect to documentation as important. The analysis of the literature, case studies, and questions 12 and 16, supports this point. Furthermore, applying configuration management to all documentation is deemed important in order to ensure that applicable modifications on the systems are sufficiently documented and that the system manuals are amended appropriately in order to reduce operator and maintenance induced errors. The language barrier is of concern owing to the risk that mistakes may be made, time wasted and maintenance not sufficiently carried out since personnel tend to perform black box changing, which further induces operating and maintenance errors

In order for the technical data and documentation resources to be managed successfully, the following grounded technological rules are proposed:

1) Ensure technical documentation is written at an appropriate level, which the user of such documentation will understand;
2) Ensure technical data and documentation is sufficiently detailed to assist the end user in correctly following operator and maintenance tasks;
3) Document all relevant technical data and documentation in order to endure efficient and effective support of the system;
4) Apply strict configuration management principles to all technical data and documentation;
5) Document all relevant technical data and documentation information in a technical data and documentation plan; and
6) Ensure all master data and documentation are stored in a security controlled fireproof location and under strict configuration management control, thereby reducing the risk of accidentally destroying or misplacing valuable information.

In this section the three phases of research regarding technical data and documentation were collated and described. Furthermore, grounded technological rules regarding technical data and documentation planning were proposed. In the next section the three collated phases of facilities research are considered.

7.2.6 ***Facilities – three phases collated***

The literature related to facilities was presented in chapter 2 and deconstructed in chapter 4; specific issues were probed by the questionnaire, as discussed in chapter 6. Facilities can be regarded as any area required for the support of a system; ranging from a building to a tent, and including a training facility, personnel facilities, a maintenance facility, a storage facility, a calibration facility and utilities.

The facility element of ILS involves evaluating requirements, identifying deficiencies and the necessary modifications, construction of facilities, and trade-offs. Maintenance facilities need to be sufficiently sized in order that the necessary tasks can be performed efficiently and effectively. Training facilities will require a different assessment, taking into consideration the number of students attending, whether the training is theoretical or practical in nature, or a mixture, whether simulators will be required at specific levels of maintenance and the scope of training required on them, and establishing whether additional infrastructure and training devices are required. However, in developing countries and especially when the systems are already in operation, simulators are not always procured and used, as the financial expenditure is not deemed warranted. Furthermore the OEM's specified controlled environmental conditions are not always followed adequately, and this may be due to financial constraints. Dilapidated facilities and storage facilities are often provided free of charge at the end-users' premises and require lengthy negotiations to upgrade.

Facility requirements at all maintenance levels need to be determined. Identification of a facility can take time; studies may need to first be conducted to assess environmental impacts, space requirements, health and safety standards, duration and frequency of use of the facility. Therefore facilities must be identified as early as possible in the system's life cycle. A facilities concept needs to be developed.

A facilities plan identifies all the requirements necessary to support a system, including the S&TE and training. It further details the facilities required.

The operational equipment of system Alpha as examined in chapter 5 is housed in cabins on trailers, and depending on the site it is either stored or used in an open area, or in an open area under a roof. The cabins are subjected to harsh environmental conditions, were designed to withstand these and are regularly serviced and maintained. The main stores are housed in a hangar; however a limited number of spares are held within a stores cabin for the purposes of short trips. Training facilities are provided for classroom and practical training. Workshop facilities are provided to service the vehicles and the smaller mechanical components, whereas the electronic components are ‘black box exchanged’ in the cabins and the failed LRU is sent to stores to be sent to the contractor for depot level repair. The contractor maintains a fully equipped workshop facility to cater for repairs of LRU’s at I- and D-level, but due to specific constraints the facility is not always fully operational.

System Bravo is similar to system Alpha in that it is housed in cabins on trailers. The cabins are similarly subjected to harsh environmental conditions, and were designed as such. The stores are housed in a building. Training facilities are provided for classroom and practical training. Failed components are ‘black box exchanged’ in the cabins and the failed LRU is sent to stores to be despatched to the contractor for D-level repair.

One of the systems examined in chapter 5 will be housed in a building, where the reactor will be contained within the building in a confined area. A control room, specific workshops, storage areas, and a laboratory are envisaged. A decontamination room and facilities will be used to decontaminate components. Radioactive waste disposal procedures will be strictly followed within the building. Such radioactive waste is both liquid (e.g. oil, and cleaning solvents, etc.) and solid (e.g. components, and cleaning material, etc.) in nature. Training facility requirements are expected to be simulator and classroom based, together with practical training on some of the actual components.

Two of the systems examined in chapter 5 are housed in containers at different premises of the respective end-users. Facilities for O-level are not required since maintenance is performed via a remote control system. Facilities at I-level consist of workshops for I-level repairs and stores for distribution and receiving of LRU’s. A technical library is housed within a container at the base workshop. Training facilities are situated at the end-user and contractor facilities.

One of the systems examined in chapter 5 is situated in a building housing its respective equipment, though certain assemblies are situated outside the confines of the building. Facilities for the user and support levels of maintenance are situated within the main building at the site, which is also the spares holding location, and offices for personnel. Also included in the main building is a workshop for user and support level repairs. Training on the system takes place at the end-user’s premises.

Based on critically reviewing the literature and case studies, and identifying aspects that are not adequately addressed upfront, or during an upgrade, the following findings from the questionnaire analysis support concerns identified in the case deconstruction. The respondents regarded the impact on the reliability of a product as the most important factor regarding storage facility requirements, and the product quantity distributed as the least important. It is evident that the facilities requirements need to be clearly specified early in the design of a system to ensure the most cost effective solution and optimised space allocation.

In order for the facilities resource to be managed successfully, the following grounded technological rules are proposed:

1) Define the facilities requirements for the operational system as early as possible in the life cycle of the system;
2) Define the associated support system infrastructure as early as possible in the life cycle of the system and support system (once the support system has sufficient information to define its requirements);
3) Ensure adequate training facilities to simulate as closely as possible the actual operating environment;
4) Ensure the facilities requirements are documented into a facilities plan;
5) Regularly update the facilities plan with new knowledge;
6) Maintain the facilities at regular intervals; and
7) Ensure availability of facility resources.

In this section the three phases of research regarding facilities were collated and described. Furthermore grounded technological rules regarding facilities planning were furnished. In the next section the three collated phases of manpower and personnel research are considered.

7.2.7 *Manpower and personnel – three phases collated*

Well defined conclusions can be drawn from the literature related to manpower and personnel, as presented in chapter 2 and deconstructed in chapter 4. The human element ultimately maintains a high technology system and influences its reliability. High technology systems are more complex than in the past, and with technological advances the systems become more ‘autonomous’, so that the human element using these systems needs the required skills, knowledge and experience to successfully support the system.

Manpower and personnel requirements are specified in order for a system to meet its operational requirements. These include the quantity and type of personnel and the skills required. Furthermore, planning of task requirements is a necessity. Constraints and requirements include, the gender mix, cost of personnel, psychological and physiological considerations.

Furthermore an elementary background set of skills is needed for one to be able to operate even the most basic S&TE. Additional skill sets are gained through training. In a developing country the skills shortage is a serious issue, resulting in high technology complex systems being maintained poorly or not at all. In South Africa skilled people are emigrating, draining the country of these resources. Language is a concern. In addition, in a developing country, although manpower and personnel requirements are specified, the more appropriately skilled candidate may not always be the first choice for employment, which could result in a poorly maintained system, ultimately influencing the bottom line.

Systems Alpha, Bravo, Delta, Echo, and Foxtrot, all have their respective operational and maintenance personnel requirements specified. System Charlie, although under development, has its conceptual requirements documented, which will be detailed once an LSA has been conducted.

Following the questionnaire analysis, 75.40% of the respondents perceived the defining of the maintenance and personnel requirements as either most necessary or necessary. Furthermore, 85.03% of the respondents regarded attracting and retaining the applicable skilled personnel as either most important or important. Regarding the importance of certain plans in order to improve their system's performance they considered the manpower and personnel, including a training plan as third out of five plans, with 45.31% rating this plan as a 1 (most important). From the analysis of the literature, case studies, and questions 13, 17, and 26, it is evident that the manpower and personnel resource is unmistakably an important aspect. Not specifying the correct criteria for the job position can cause the incorrect person, with inadequate skills, knowledge and experience, to be employed for a specific position. This in turn will influence the maintenance and support of the high technology complex system.

In order for a system to be support efficiently and effectively the manpower and personnel resource needs to be managed successfully, and for this purpose the following grounded technological rules are proposed:

1) Define the operational and maintenance personnel requirements in accordance with the maintenance concept;
2) Attract and retain the applicable skills, knowledge and experience to support the system; and
3) Document all the manpower and personnel requirements, specifications, analysis, and succession planning explicitly in a manpower and personnel plan.

In this section the three phases of research regarding manpower and personnel were collated and described. Furthermore, grounded technological rules in this respect were proposed. In the next section the three phases of training and training devices research are collated.

7.2.8 ***Training and training devices – three phases collated***

The literature review in this regard was presented in chapter 2 and deconstructed in chapter 4: a summary is contained in the paragraphs that follow. Training and training devices involve all activities necessary to train personnel in a specific skill set, to plan such training, and to provide for training devices and supporting infrastructure required to enhance the learning experience. A training philosophy, objectives and concept need to be identified.

The training concept details the development of the training, and information regarding its presentation. Training requirements are defined, and methods identified. A training and training devices plan also details the necessary training devices required, such as simulators, training materials, handbooks, manuals, and guides, etc. Training can be theoretical or practical, or a combination of both.

System Alpha has defined training requirements for each artisan's trade and level. It currently uses self-paced training with periodic evaluations. Training courses are offered when the system is upgraded; these courses contain both a theoretical and practical aspect. Training aids are used to enhance the learning experience.

System Bravo employs a theoretical and practical training strategy. After a recent system upgrade, the specific D-level contractor provided training at the end-user's sites. The training material was in English, which created a language barrier

System Charlie is currently under development. Conceptually, training will be provided on a number of aspects, ranging from basic to more complex procedures. Training manuals and visual training aids are envisaged.

Systems Delta and Echo employ both theoretical and practical training, followed by on-the-job training under a mentor. Training premises depend on the nature of the training, and vary between the end-user's premises and that of the D-level contractor. Training aids include manuals, visual aids, and a system on which to conduct practical training.

System Foxtrot employs a theoretical, practical, and on-the-job training philosophy. Initial training was conducted on the system during installation, and sustainment training is conducted periodically. Training manuals, visual aids, and the physical system are used as training aids. The training and training devices plan includes the training strategy for the theoretical, practical and hands-on training, the number of required students per course, and course curricula.

Following from the questionnaire analysis, 45.31% of the respondents rated a manpower and personnel (including training) plan as the most important factor in order to improve their system's performance. 66.15% of the respondents rated a maintenance plan as most important. The respondents rated the ability of training instructors as the most important factor regarding training factors, while the adequacy of training material was rated next most important, and personnel skill level related programmes least important. Regarding possible causes of maintenance personnel error, poor training and procedures were perceived to be the most important cause, while inadequate workspace or work layout was viewed as the least contributing factor towards maintenance personnel error. The respondents' views on poor supervision as a possible cause of such error are dependent on their experience and knowledge, even though there is a weak association of dependence present.

The respondents further regarded technical knowledge and specification as the factor contributing the least towards logistics delays, and administrative and approval activities as the factor contributing most in this respect. With regards to the types of failures/defects, the respondents rated maintenance-induced failures as least important, and operator induced failures as the factor contributing the most. The respondents' views on maintenance-induced and operator-induced failures are dependent on their job orientation, even though a weak association of dependence is present.

From the analysis of the literature, case studies, and questions 8, 11, 26, 30, 32, and 34, it is clear that training and training devices are undoubtedly an important aspect when it comes to maintaining and supporting a high technology complex system. If the type of training required and the development of personnel through training exercises are not specified, system support cannot be performed effectively and efficiently.

Since the training and training devices resource needs to be managed successfully, the following grounded technological rules are proposed:

1) Define the operational and maintenance personnel training requirements in accordance with the maintenance concept;
2) Specify the types of training to be conducted and the training aids that will be required;

3) Explicitly document all the training and training devices requirements in a training and training devices plan, including sustainment training and succession planning training; and
4) Develop a long-term plan to ensure trained resources are available when needed.

In this section the three phases of research regarding training and training devices were collated and described. Furthermore, grounded technological rules regarding training and training devices planning were devised. In the subsequent section the three collated phases of computer resources research are discussed.

7.2.9 ***Computer resources – three phases collated***

There is very little directly available in the ILS literature regarding computer resources; what is accessible was presented in chapter 2 and deconstructed in chapter 4. Computer resources include all aspects related to firmware, hardware, embedded software, and standalone software, which culminate in a computer resources plan. All aspects of computer software related to a high technology complex system should be kept under configuration control, baselines established and the configuration package audited periodically. Computer software should be classified into one or more configurable items, i.e. hardware configuration items (HWCI), or computer software configuration items (CSCI). The topic of computer resources is very well specified for a complex environment in other information systems' research; however for the purpose of this study, limited literature was available.

A computer resources plan details the requirements for system specific hardware and software items, configuration management of software, procedures with respect to changes in software, etcetera.

Systems Alpha and Bravo use strict procedures in order to control and audit their operational software, the latter is developed and distributed by the D-level contractor. Configuration management principles are applied with respect to the operational software, where the D-level contractor stores a master copy and sub-master copies of each version of software, and distributes a working copy to the end-user technical staff, under licence. However audits were not conducted periodically in the past, so that software has been mixed up between systems. Furthermore, non-current versions of the operational software are not sent back to or collected by the D-level contractor, causing configuration management and audit concerns. Software versions are upgraded by means of an engineering change procedure. These operational software media are kept under stringent security control in a fireproof safe.

System Charlie is still under development. However, conceptually, software systems have been identified, including the control and instrumentation software to be used to monitor critical characteristics of the system. All this monitoring will take place from the plant control room. Configuration management principles are and will be applied to the computer resources element.

Systems Delta and Echo are maintained at O-level by means of a remote control maintenance and monitoring system, allowing the technical staff to correct simple errors remotely, and informing the technician whether the fault has been corrected. Configuration management principles are applied with respect to the operational and remote control system software. Periodic audits are conducted. System Foxtrot currently has a computer resources plan in place, which theoretically details the baseline of the computer resources required and used on the system. Also included in the computer resources plan is the configuration management of the computer resources element, including the auditing and verification processes for all operational software management.

Following from the questionnaire analysis, 54.30% of the respondents rated the conducting of periodic audits as most necessary or necessary, while 17.20% rated this activity either as less necessary or as least necessary. With regards to the necessity of applying configuration management, 75.94% rated this as either most necessary (1) or necessary (2), while only one respondent rated this as least necessary (5).

From the analysis of the literature, case studies, and questions 14 and 15, it is evident that identification of computer resources, development, configuration, and the audit thereof is deemed most necessary to ensure a system operates in accordance with its end user specification. High technology complex systems use software to operate and maintain the system. If this software is not built correctly, tested, and audited it can have devastating consequences. Although configuration management of computer resources and periodic audits were deemed necessary, concerns regarding the actual implementation and usage thereof are evident. Some of the systems have an actual computer resources plan in place, but these guidelines are not followed correctly.

In order for a system to be supported efficiently and effectively by successful management of the computer resources, the following grounded technological rules are proposed:

1) Utilise best practices in developing required computer resources that will meet performance requirements in complex environments;
2) Develop processes and procedures to effectively develop, test, audit operational software and other related computer resources related aspects;

3) Ensure that the computer resources element is kept under strict configuration management and subjected to periodic audits;

4) Ensure all computer resources aspects are subjected to stringent security controls and kept in fireproof safes;

5) Ensure master copies and working copies of all computer resource related aspects are kept separately at different premises; and

6) Document all system computer resources aspects in a computer resources plan, describing the processes and procedures for software version control, security control of media, etc.

In this section the three phases of research regarding computer resources were collated and described. Furthermore grounded technological rules regarding computer resources planning were suggested. In the following section the three collated phases of reliability, availability, and maintainability research are described.

7.2.10 *Reliability, availability, and maintainability – three phases collated*

The literature related to reliability, availability, and maintainability (RAM) was presented in chapter 2 and deconstructed in chapter 4. The reliability of a system can be regarded as the likelihood of a system functioning as specified, under prescribed operational conditions, for a stipulated time frame. Reliability engineering requires some form of a checklist of items (Blanchard, 2004:456).

There are three measures of availability, viz. inherent, achieved and operational availability. Inherent availability can be regarded as a theoretical measure of how ready a system will be when needed (Jones; 1995:5.2 and 2006:10.2, Langford; 1995:72, and Blanchard; 2004:72). Blanchard (2004:72) further mentions that measures of inherent availability exclude maintenance actions and delays. Achieved availability is similar to inherent availability, except that it includes scheduled maintenance (Blanchard, 2004:73). Operational availability is the actual measure of the system's availability (Jones; 1995:5.3 and 2006:10.5, Langford; 1995:82, and Blanchard; 2004:73). Operational availability should be as close as possible to inherent availability.

According to Jones (2006:4:18) maintainability is predicted statistically, and is influenced by environmental conditions and resource availability: *'The probability that a failed item can be repaired in a specified amount of time using a specified set of resources.'* (Jones, 2006:4.18). However the inherent complexity of a developing world situation makes this statistical prediction much more uncertain and unreliable. Maintainability is therefore often a theoretical concept, especially when skills shortages are taken into account.

Logistics delays cause major problems concerning mean time to repair (MTTR), as maintenance personnel have no control over these. Langford (1995:64) defines a logistics delay as pertaining *'… to the time other than the actual repair time and scheduled maintenance time which contributes to the downtime of the equipment.'* This is especially true in distributed systems and in developing countries where the infrastructure is often not all at the level of that in a first world country.

Blanchard (1986:329) proposes that a reliability and maintainability plan should at least include prediction tasks, design reviews, requirements to test reliability, liaison tasks, programme functions pertaining to maintainability and reliability, analysis tasks, requirements to demonstrate maintainability, and production phase activities regarding maintainability and reliability. However, as discussed, there are inherent assumptions in many of these terms that may not hold true in a developing world context.

Systems Alpha, Delta, Echo, and Foxtrot apply RAM with respect to identifying the operational availability of their respective systems. These systems employ a failure reporting, analysis, and corrective action system (FRACAS) to capture data regarding failure and to employ principles of corrective action. This takes the reality of the operating and maintenance environment into account. System Alpha has implemented a reliability growth programme in order to improve the overall reliability of the system, and to mitigate the effects of obsolescence; once again, within a developing country these assumptions may not be true.

System Bravo does not employ a RAM process, but system Bravo is similar to system Alpha except for some minor differences in the configuration of the system. Systems Alpha and Bravo are supported at D-level by the same independent contractor, and as a result the data applicable to system Alpha can be applied to system Bravo, and tailored as such, depending on the contractual obligations and budget constraints.

System Charlie is still under development: possible future systems and analyses include FRACAS and a RAM programme. All of the issues as mentioned under manpower and personnel, and training and training devices, etc. are being taken into account.

Following from the questionnaire analysis, 50.55% of the respondents rated the identification of parts with excessive failure rates as the most important factor contributing to RAM, while defining the operational availability was regarded as least important. Where the systems do not have a RAM programme in place, or a limited RAM programme, the respondents may feel that the RAM programme is inadequate and that realistic instead of theoretical figures have been determined. Some of the systems included in the case studies have been in operation for more than five years;

and have a theoretical RAM plan in place, including an MIS or a FRACAS. However these MIS/FRACAS systems do not function as originally planned, one cause being that inadequate information is captured on these systems, causing the results of calculations to be misrepresented, resulting in inaccurate RAM figures. It is felt that the relevant parties do not complete the job card correctly, and that the software does not take all possible variables, constraints and variations into account. Furthermore the respondents may perceive this to be a cause for excessive failure rates, and had the output of the MIS/FRACAS system been more realistic the response could have been different.

The respondents' replies to questions with respect to identifying parts with excessive failure rates, and conducting RAM analysis, are dependent on their job orientation, with a weak association present between the variables. The respondents regarded administrative and approval activities as the most important factor causing logistics delays, and technical knowledge and specification as the factor contributing least towards such delays.

From the analysis of the literature, case studies, and questions 20 and 33, it is evident that although the respondents are not too concerned regarding defining or knowing the operational availability of their high technology system, they wish to identify parts with excessive failure rates, which have a direct effect on the operational availability of their high technology system. The respondents regard conducting RAM analysis and identifying parts with excessive failure rates as important, irrespective of their job orientation. The respondents also regard administrative and approval activities as the major factor contributing to logistics delays.

In order for a system to be supported efficiently and effectively the RAM resource needs to be managed successfully, so that the following grounded technological rules are proposed:

1) Develop an efficient and effective RAM analysis process, taking reality into account and all possible constraints, variables, and variations, instead of a theoretical statistical projection;
2) Identify components with excessive failure rates, i.e. define reliability of components and system;
3) Reduce logistics delay times which have a high risk factor;
4) Calculate the operational availability of the system;
5) Ensure the system is maintainable and supportable;

In this section the three phases of research regarding RAM were collated and described. Furthermore grounded technological rules regarding RAM planning were proposed. In the next section the three collated phases of configuration management research are considered.

7.2.11 *Configuration management – three phases collated*

The literature related to configuration management regarding ILS was presented in chapter 2, and deconstructed in chapter 4. The configuration management of computer resources was discussed in 7.2.9. Configuration management entails identifying characteristics (physical and functional) of items which perform a specific function as defined by a specification (or drawing or other relevant documentation), for which change control is applied to the item throughout its life cycle, that is, configuration management can be regarded as baseline traceability management. It involves four functions, viz. configuration identification, configuration control, configuration status accounting, and configuration audits. A configuration management plan entails a process identifying all physical and functional characteristics of items, all necessary procedures regarding the control of items within a system, including the auditing process. An item can be a document, a drawing, a physical piece of hardware, etcetera.

Systems Alpha, Delta, Echo, and Foxtrot apply configuration management principles with regard to, but not limited to, the physical structure of the system, supply support, and documentation. These four systems are subjected to change control processes, including engineering change proposals (ECP's), configuration control boards (CCB's), master record index (MRI), and audits. In the past, owing to budget cuts that affected system Alpha, the configuration management, logistics engineering and other contractual line items were removed from the maintenance contract, but subsequently, due to an inefficiently maintained system, these line items have been contracted again. Although a configuration management system has been implemented, System Bravo does not strictly follow the prescribed guidelines. In the past, configuration management was not applied adequately on system Alpha, causing LRU's to be exchanged between the sub-systems of system Alpha; however, stricter control is currently being applied, including frequent audits. It is nevertheless perceived that communications related to the purpose of configuration management and training therein were inadequate with regards to system Alpha. System Charlie, although it is currently being developed, applies strict configuration management principles, substantiating the need for configuration management from early in the system's life cycle: as the design matures, change management is a necessity.

Following from the questionnaire analysis, 54.30% of the respondents rated the conducting of periodic audits as most necessary or necessary, while 17.20% rated this question either as less necessary or least necessary. With regards to the necessity of applying configuration management, 75.94% rated this as either most necessary (1) or necessary (2), whereas only one respondent rated this as least necessary (5). The importance of applying configuration management principles with respect to documentation was rated as most important (1) or important (2) by 85.48% of the respondents.

From the analysis of the literature, case studies, and questions 14, 15 and 16, it is evident that the respondents deem configuration management and audits as a necessity. Furthermore the systems which do not apply configuration management effectively suffer from cannibalisation.

In order for a system to be supported efficiently and effectively the RAM resource needs to be managed successfully, and the following grounded technological rules are consequently proposed:

1) Implement sound configuration management principles;
2) Conduct periodic audits;
3) Educate personnel regarding the purpose of configuration management, the use thereof and the benefits of configuration management; and
4) Explicitly document the configuration management principles and audits.

In this section the three phases of research regarding configuration management were collated and described. In addition, grounded technological rules regarding configuration management planning were suggested. In the subsequent section the three collated phases of research into obsolescence management are discussed.

7.2.12 ***Obsolescence – three phases collated***

The ILS literature related to obsolescence management was presented in chapter 2 and deconstructed in chapter 4. Planning for obsolescence of equipment is important, as obsolescence could cause a system to become non-operational due to a lack of components and result in a redesign to ensure that the new component functions in the system. Obsolescence occurs due to technological advances where components are no longer manufactured, owing to being superseded by a different product line, if the previous one was no longer cost effective to manufacture, or if suppliers alter their line of business to focus on a different product. Obsolescence and Diminishing Manufacturing Sources and Material Shortages (DMSMS) with respect to high technology complex systems can be regarded as the point in the system's life cycle when spare and repair parts are short in supply or are no longer available. Not only may the primary system, or components within the primary system, become obsolete, but obsolescence can also affect the support and test equipment, organisation procedures, and the knowledge and skills of the personnel.

Typically there is a misconception regarding what obsolescence is and what it actually means; in addition, obsolescence needs to be managed proactively instead of reactively. In this respect DMSMS concerns:

> *'… the loss or impending loss of manufacturers or suppliers of critical items and raw materials due to discontinuance of production'* (ARINC, 2000:1-1).

High technology systems with long life cycles (and sometimes extended life cycles) can be affected if the components have a shorter life cycle which results in more system upgrades than in the past, and thereby increases overall life cycle cost and therefore total cost of ownership.

Numerous authors propose solutions to, or mitigating factors regarding, obsolescence as discussed in 4.3.12. These include performance-based logistics (PBL), value engineering, engineering change proposals, logical trouble-shooting diagrams, maintenance task analysis, alternative source, substitution, redesign, and a dual path methodology.

An obsolescence plan details the risk associated with obsolescence, that is which components are likely to become obsolete within a certain time period, and identifies which equipment is likely to be phased-out and disposed of. It further provides information on how this should be done, and on which ILS elements are required.

System Alpha currently has an obsolescence plan in place, due to the system operating past its intended life cycle, while some components have been replaced with recent upgrades. Similarly, system Bravo is also suffering from obsolescence and has been upgraded with some components being replaced by new products. Systems Delta, Echo, and Foxtrot are relatively new compared to systems Alpha and Bravo; their obsolescence requirements have not been defined, and will be managed when the need arises.

Following from the questionnaire analysis, reliability was regarded as the most important determinant of obsolescence, followed by the ability of the supplier to offer support, and its cost. New technology was regarded as the factor contributing least towards obsolescence. The responses to the cost of support as a determinant of obsolescence were dependent on the job orientation of the respondents, even though there is a weak association of dependence present.

The respondents regarded the maintenance plan as the most important plan required to improve the performance of their high technology system. This was followed by the importance of a risk management plan, and the personnel (including training) plan. The obsolescence plan, along with the disposal and system retirement plan, were rated as the two least important in this regard. The low priority accorded to such a plan raises concerns as some of the systems used in the study are more than five years old, and two of the systems are already being subjected to obsolescence risks; although the respondents rated a risk plan as a high priority, it can be deduced that they may be prioritising other risks instead of obsolescence or disposal.

From the analysis of the literature, case studies, and questions 24 and 26, only systems Alpha and Bravo regard obsolescence as important. Systems Alpha and Charlie have considered disposal as a factor requiring consideration in their planning.

In order for a system to be supported efficiently and effectively the issue of obsolescence needs to be managed successfully, and the following grounded technological rules are proposed:

1) Implement an obsolescence programme (including processes and procedures) and document it in a plan;
2) Conduct active risk management with respect to obsolescence and review regularly, among other aspects conducting a regular technology scanning as part of risk review;
3) Manage the obsolescence constraint in order to improve system performance;
4) Ensure that there are multiple suppliers of components, to eliminate single supplier problems;
5) Ensure that reliability and component life cycle data are specific to the operating environment;
6) Attract and retain skilled and knowledgeable resources;
7) Establish excellent client relationships with suppliers; and
8) Ensure accurate obsolescence data and systems.

In this section the three phases of research regarding obsolescence were collated and described. Furthermore, grounded technological rules regarding obsolescence planning were furnished. In the next section the three collated phases of disposal management research are discussed.

7.2.13 ***Disposal – three phases collated***

The ILS literature related to disposal management was presented in chapter 2 and deconstructed in chapter 4. All equipment eventually reaches the end of its design or extended life and needs to be disposed of in various ways. Once high technology systems reach the end of their useful operational phase, they are withdrawn from service, and are seen as in the stage of ‘retirement’, where they are for example mothballed, cannibalised, or disposed of. Disposal is often not considered until the necessity arises and organisations often do not set a disposal plan or strategy in place as it is costly to develop one, and prefer to deal with the issue as the need arises.

The equipment/system/product needs to be designed for disposability and procedures need to be in place to cover the system's disposal, while some of the materials or components could be recycled for use in another system. The retirement, phase-out, decommissioning, and disposal of a high technology complex system are an important phase within its life cycle. Disposal of components need to be considered during the design phase as this may influence the design of an assembly. Finkelstein and Guertin (1988:205) argue that in 1988 waste management was a new field of study, since few academic institutions and academic books cater for the topic. Since 1988, the field of disposal and waste management has received a significant amount of attention from numerous authors including Leenders and Fearon (1997), Blanchard (1992, 1998 and 2004), and Jones (1995, 1998 and 2006).

A disposal plan details the risks associated with disposal, defining which equipment is likely to be phased-out and disposed off, and how. Disposal plans are required to manage such activities, amongst others such as day-to-day disposal of spare, repair parts, and other disposable or used items of other high technology complex systems. Blanchard (2004:387) proposes a system retirement plan, which includes equipment phase-out and retirement; disassembling and salvage of appropriate items; ILS; PHS&T; support and test equipment; facilities; data; and personnel requirements, amongst others.

System Alpha currently has a disposal plan in place, due to the system originally comprising ten fleets (or sub-systems) of which only four are currently operational, various disposal options have been considered regarding the others. The day-to-day disposal of beyond economical to repair (BER) line replaceable units (LRU's) is performed and managed by the end-user, according to stringent guidelines. System Bravo has not set a disposal plan in place. Systems Delta, Echo, and Foxtrot are relatively new compared to systems Alpha and Bravo, therefore their disposal requirements have not been defined, and will be managed when the need arises; however, their day-to-day disposal of consumables, spare and repair parts, and BER LRU's is in accordance with specified processes.

With one of the systems examined in chapter 5, the disposal of radioactive waste needs to be considered and managed effectively. Furthermore the intended life cycle of the system is expected to be in the region of 40 years, after which it will be decommissioned and disposed of, most probably after another 40 years.

The respondents regarded environmental and safety concerns as the largest contributor towards disposal costs, followed by dismantling and disassembly costs. Redesign for alternative use, e.g. demilitarisation, was regarded as the least important factor with regards to disposal costs. The respondents' views on a redesign for alternative use are dependent on their job orientation. There is a moderate association of dependence present between redesign for alternative use and job orientation.

The respondents regarded the maintenance plan as the most important plan required to improve the performance of their high technology system. This was followed by a risk management plan, and the personnel (including training) plan. The obsolescence plan and the disposal and system retirement plan were rated as the two least important. The result of the disposal plan being rated as least important could be due to the respondents not perceiving their system as needing to be disposed of in the near future and thereby not contributing to system improvement. Furthermore some components within a system become beyond economical to repair (BER) and need to be disposed of in an appropriate and safe manner. Although the respondents rated a risk plan as a high priority, it can be deduced that they may perceive other risks than obsolescence or disposal.

From the analysis of the literature, case studies, and questions 26, and 27, only System Alpha regards disposal as important, since only four of the original 10 systems are operational, and the six non-operational systems are being considered for disposal. Systems Alpha and Charlie have considered disposal as a factor requiring consideration in their planning.

In order for a system to be supported efficiently and effectively the issue of disposal needs to be managed successfully, and the following grounded technological rules are consequently proposed:

1) Plan for system phase-out/retirement/disposal and manage effectively;
2) Plan and manage day-to-day disposal of components, consumables, and spare and repair parts;
3) Effectively manage and acknowledge the cost element of disposal;
4) Consider disposal of components in the design phase; and
5) Document all phase-out/retirement/disposal activities in a disposal plan.

In this section the three phases of research regarding disposal were collated and described. Furthermore, grounded technological rules regarding disposal planning were devised. In the next section the proposed framework is furnished.

7.3 Framework

A high technology complex system may have an estimated utilisation or operational life of some 30 to 40 years, if not longer. Such a system requires support (and maintenance) during its utilisation phase, which occurs in a complex environment including the challenges offered by the developing world, and systems with a high consequence of failure. The support consists of the ILS elements as depicted in Figure 7–1, and consists of maintenance, S&TE, supply support, PHS&T, technical data and documentation, facilities, manpower and personnel, training and training devices, computer resources, RAM – dependability, configuration management, obsolescence, disposal and risk management.

Each ILS element, the system itself, and the complex environment calls for risk management. The integrated logistics support system (ILSS) of a high technology complex system requires an annual evaluation of effectiveness and risk. The output of the effectiveness and risk review may affect one or more of the ILS elements. The affected ILS element/s must then be adapted and the subsequent result fed back into the ILSS. Should the ILS elements not be affected then the output of the effectiveness and risk review and evaluation will not necessitate any adaptation.

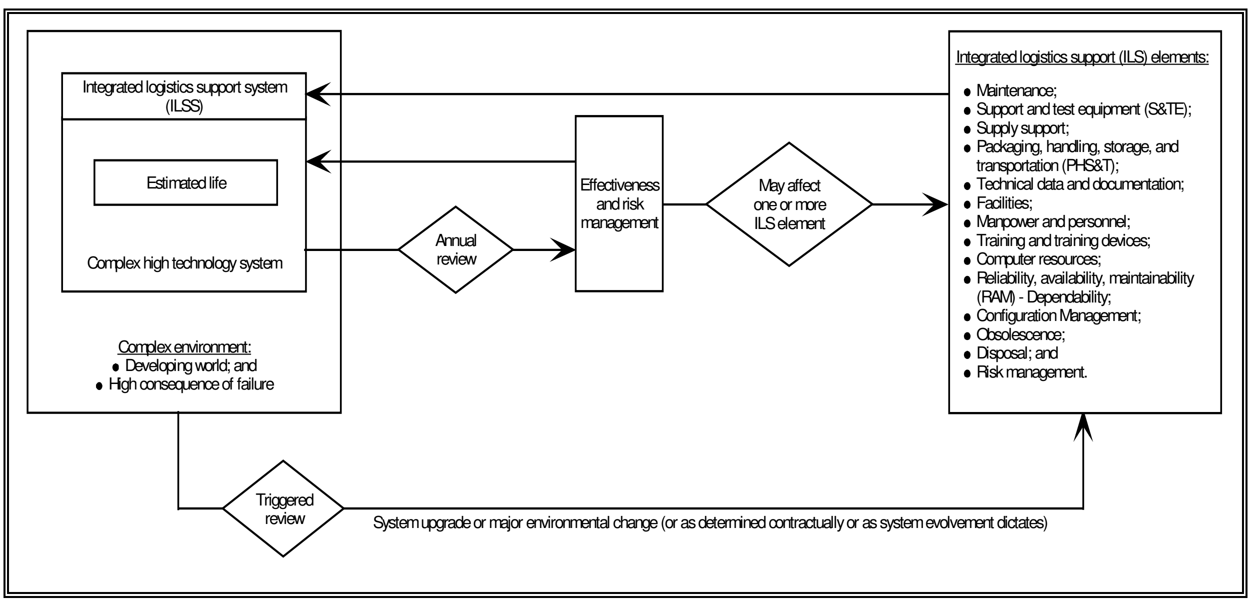


Figure 7–1: Integrated logistics support system (ILSS) framework

Though it is conducted in order to effectively and efficiently operate the ILSS of a high technology complex system within its complex environment, the annual review may not fully address the relevant issues in the system's life cycle. When this occurs an automatic trigger is prompted in order to review the ILSS and adapt the affected ILS elements. These triggers could include upgrades, partial replacement, life extension, technology changes, and etcetera. The adapted ILS elements are directly fed back to the ILSS in order to improve such a system's performance.

An upgrade or modification may require the entire or part of the maintenance process and procedures to be amended. These changes directly influence the maintenance philosophy of a high-technology system including all the affected ILS elements, and associated organizational processes and procedures.

In the event of the manpower and personnel element requiring adaptation, the requirements are communicated to the human resources department, where the manpower and personnel requirements may include the need for more personnel or more stringent prerequisites are necessary for employing personnel. With the training and training devices element the adaptation may require that the personnel need more specific training in a certain critical task or improved training devices are required.

When an item of support and test equipment is replaced by a new advanced S&TE, personnel will be need to be trained for a period of time on this new item of S&TE, which will directly influence the availability of personnel during this training period. In addition the new item of support and test equipment could be very expensive, which limits the quantity procured due to budget constraints, which directly influences the availability of the new S&TE, as it might be required at another site, while being utilised elsewhere, which directly affects the downtime of a high technology system.

Supply support can have a substantial effect on the availability of any high technology complex system, in that when spares and repair parts are not readily available at the time of demand, the downtime of the high technology complex system increases. Not only is it important to have critical spares in stock, but the exact time of order is also critical as some items may have excessive lead times of weeks, if not months and years, depending on when the original equipment manufacturer or supplier can fit the demanded item into their production run.

Protection of items from damage by means of appropriate packaging and marking/labelling is important in that if a critical item is damaged during transportation or handling, another item needs to be acquired which can negatively affect the availability of the high technology complex system and its resources, as personnel time is wasted by re-ordering another item. Ensuring that appropriate transport and handling mechanisms are in place reduces this risk of damage to items. In addition items, which are required to be kept in inventory, needs a specific environmentally controlled storage location, especially items which are required to be kept in inventory for long periods of time.

It is critically important that the technical data and documentation be kept up to date with various amendments, which are the result of upgrades or modifications to the high technology complex system. As incorrect revisions of documentation inadvertently used by personnel may result in them incorrectly utilising and supporting the system, which will affect the availability of the system.

All of the ILS elements interface with each other in the sense that a change to one of the ILS elements could influence one or more of the other ILS elements, all of which directly influences the organisation in many different ways. A summary of the ILS grounded technological rules is offered in the next section.

7.4 Grounded technological rules summary

In terms of the discussion in this chapter, the following grounded technological rules deriving from the three collated phases of research are proposed. A summary is provided in Table 7–1.

Table 7–1: Grounded technological rules of ILS research

ILS ELEMENT	GROUNDED TECHNOLOGICAL RULE
Maintenance	1) Utilise the defined business strategy; 2) Establish the organisation's maintenance philosophy; 3) Delineate the maintenance concept of the specific system and its linkage to other systems; 4) Develop maintenance planning, including analysis; 5) Document a maintenance plan for the specific system; 6) Implement the maintenance plan across all maintenance levels; 7) Conduct specific analysis of the system; and 8) Ascertain the risks associated with the maintenance of the system and manage these risks.
Support and test equipment (S&TE)	1) Design of S&TE and compatibility thereof with main system; 2) Trade-offs, constraints and availability of S&TE; 3) Scheduling of multi-system S&TE; 4) S&TE concept and plan; 5) Support and maintenance (including calibration) of S&TE.
Supply support	1) Define the system support strategy, philosophy, and concept; 2) Derive the supply support ditto from the above strategy; 3) Determine specific risks and calculate spares levels based on risks and cost effectiveness; and 4) Document the supply support plan, defining the various processes and procedures required to efficiently and effectively manage the supply support function.
Packaging, handling, storage and transportation (PHS&T)	1) Define the PHS&T (including packing, preservation, and labelling or marking) policies, procedures, requirements and specifications; 2) Ensure stringent adherence to the PHS&T (including packing, preservation, and labelling or marking) policies, procedures, requirements and specifications; 3) Ensure adequate maintenance and support of the PHS&T infrastructure, and equipment; 4) Conduct analysis and trade-offs regarding PHS&T mechanisms,

ILS ELEMENT	GROUNDED TECHNOLOGICAL RULE
	in order to minimise and standardise PHS&T interfaces; and 5) Ensure comprehensible labelling and marking of items susceptible to vibration, shock, fragility, correct orientation, environmental constraints, etc.
Technical data and documentation	1) Ensure technical data and documentation are written for the skill level of its user; 2) Ensure the above is sufficiently detailed to assist the end user in correctly following operator and maintenance tasks; 3) Document all relevant technical data and documentation in order to endure efficient and effective support of the system; 4) Apply strict configuration management principles to all technical data and documentation; and 5) Document all relevant technical information into a technical data and documentation plan.
Facilities	1) Define the facilities requirements for the operational system as early as possible in the latter's life cycle; 2) Define the support system infrastructure for the facilities requirements as early as possible in the life cycle of the system and support system (once the support system possesses sufficient information to define its respective requirements); 3) Ensure adequate training facilities to simulate as closely as possible the actual operating environment; 4) Ensure the facilities requirements are documented into a facilities plan; 5) Regularly update the facilities plan with new knowledge; 6) Maintain the facilities at regular intervals; and 7) Ensure availability of facility resources.
Manpower and personnel	1) Define the operational and maintenance personnel requirements in accordance with the maintenance concept; 2) Attract and retain the applicable skills, knowledge and experience to support the system; and 3) Document all the manpower and personnel requirements, specifications, analysis in a manpower and personnel plan.
Training and training devices	1) Define the operational and maintenance personnel training requirements in accordance with the maintenance concept; 2) Specify the types of training to be conducted and the training aids that will be required; 3) Document all the training and training devices requirements in a training and training devices plan, including sustainment training; and 4) Develop a long-term plan to ensure trained resources are available when needed.
Computer resources	1) Utilise best practices in developing required computer resources that will meet performance requirements in complex environments; 2) Develop processes and procedures to effectively develop, test, audit operational software and other related aspects; 3) Ensure that the computer resources element is kept under strict configuration management and subjected to periodic audits; 4) Ensure all computer resources aspects are subjected to stringent security controls and stored in fireproof safes; 5) Ensure master copies and working copies of all computer resource related aspects are stored separately at different premises; and 6) Document all system computer resources aspects in a computer

ILS ELEMENT	GROUNDED TECHNOLOGICAL RULE
	resources plan, describing the processes and procedures of software version control, security control of media, etc.
Reliability, availability, and maintainability (RAM) – Dependability	1) Develop an efficient and effective RAM analysis process taking reality into account and all possible constraints, variables, and variations, instead of a theoretical statistical projection; 2) Identify components with excessive failure rates, i.e. define reliability of components and system; 3) Reduce logistics delay times which have a high risk factor; 4) Calculate the operational availability of the system; 5) Ensure the system is maintainable and supportable.
Configuration management	1) Implement sound configuration management principles; 2) Conduct periodic audits; 3) Educate personnel regarding the purpose of configuration management, its use and benefits; and 4) Document the configuration management principles and audits.
Obsolescence	1) Implement an obsolescence programme (including processes and procedures) and plan for obsolescence; 2) Conduct regular technology scanning as part of risk review; 3) Manage the obsolescence constraint in order to improve system performance; 4) Ensure multiple suppliers of components, to eliminate single source supplier problems; 5) Ensure reliability data and component life cycle data is specific to the operating environment; 6) Attract and retain skilled and knowledgeable resources; 7) Establish excellent client relationships with suppliers; and 8) Ensure accurate obsolescence data and systems.
Disposal	1) Plan for system phase-out/retirement/disposal and manage effectively; 2) Plan and manage day-to-day disposal of components, consumables, and spare and repair parts; 3) Effectively manage the cost element of disposal; 4) Consider disposal of components in the design phase; and 5) Document all phase-out/retirement/disposal activities in a disposal plan.

In Chapter 7 the three phases of research were collated, resulting in grounded technological rules being derived. In chapter 8 the conclusions and recommendations of the study are dealt with.

'It's not where you take things from – it's where you take them to.'

– Jean-Luc Godard.

'Some people take no mental exercise apart from jumping to conclusions.'

– Harol Acton.

CHAPTER 8 CONCLUSION AND RECOMMENDATIONS

8.1 Introduction

In Chapter 8, the conclusions and recommendations to the study are presented. The business problem, research problem and research approach described in chapter 1 are repeated here for clarity, and the research problem is answered. In addition, the contribution to the fields of integrated logistics support (ILS), supply chain management and operations management is provided. Recommendations, in the form of grounded technological rules are put forward and the framework is presented. Lastly, future research areas are proposed.

8.1.1 *Business problem*

In South Africa, Africa, and the remainder of the developing world, there are significant leadership and management challenges. Traditional engineering approaches may be used in addressing these challenges, if the risks and constraints of a developing world are taken into account. The dynamic business environment presents an organisation with the constant problem of finding new and diverse methodologies to gain and maintain its competitive advantage in the marketplace."

A competitive advantage can be gained by utilising an integrated logistics support system (ILSS) to effectively and efficiently support all the high technology assets owned and utilised by a firm. A well-implemented ILSS can improve management of the organisation's asset base. This is particularly true in developing countries where scarce resources are required to successfully operate high technology complex systems. These scarce resources include the lack of appropriate skills, where experience and knowledge is limited. From an ILS perspective, certain aspects influence drivers in the supply chain; these include, amongst others:

1) Location;
2) Facilities;
3) Responsiveness;

4) Obsolescence;
5) Maintenance;
6) Disposal;
7) Training;
8) Manpower and personnel;
9) Packaging, handling, storage, and transportation (PHS&T);
10) Supply support;
11) Computer resources;
12) Configuration management;
13) Support and test equipment (S&TE);
14) Technical data and documentation;
15) Reliability, availability, and maintainability (RAM); and
16) The risk involved with all the aforementioned ILS elements.

There is a lack within the current body of supply chain knowledge, supply chain management, and operations management literature, which forms the basis of ILS in terms of its formulation and usage.

The lack of knowledge concerns the support of high technology complex systems where assets are frequently utilised beyond their intended life cycle, and skills shortages exist. This is particularly true when these systems suffer from obsolescence, or diminishing manufacturing sources and material shortages (DMSMS). Life cycle support of high technology systems is further lacking, due to continuous improvement of technological processes, and components and systems becoming obsolete. Furthermore, obsolescence and DMSMS are evident where suppliers are improving their 'time to market' philosophies in order to remain competitive in a turbulent environment.

Many organisations are not willing to divulge their intellectual property, product information, and support philosophies and strategies as this will reduce their competitive advantage, market share, and profitability. Furthermore, the increase of industrial espionage is a major contributing risk factor resulting in organisations protecting their information and knowledge base. The formulation of the research problem evolved from the business problem, and is discussed in the next section.

8.1.2 ***Research problem***

Complex support infrastructures are required to ensure that high technology complex systems with a high consequence of failure accomplish their operational objectives. These systems require support and maintenance over their intended, and sometimes extended, life cycles, and therefore require complex management systems to ensure an integrated supply network. These high technology complex systems suffer from component obsolescence or DMSMS, which necessitates the need to refurbish and/or upgrade the systems to extend their life cycle.

Due to technological advancement over the last few years, high technology complex systems have become more complex. This complexity is caused by the fact that component life cycles are becoming shorter, while system life cycles are extended. In addition, many systems have gone through many component changes, even before they are delivered to the marketplace because of the ever-increasing shorter component life cycles. Most high technology systems are complex and consist of many individual complicated sub-systems, which, in turn require support in order to deliver their designed functions. A sub-assembly may progress through numerous upgrades with newer components before the sub-assembly is actually used by the end user. This is especially evident in systems where the entire fleet consists of the same systems to enable a network, and the first system may or may not contain exactly the same components as the last system in the fleet.

Numerous constraints are evident when an ILSS is implemented for high technology complex systems, particularly in developing countries. The most complex systems requiring ILS have been defined as:

1) High technology industries;
2) Systems with significant consequence of failure;
3) Developing countries; and
4) Systems currently in use and adapted from original design, and especially beyond designed life.

The research problem was identified as the absence of a framework for the development of an ILSS for a complex system that does not assume that the ILS is developed simultaneously with the design of the system. ILS is required in high technology complex systems currently in use, which are situated in developing countries and which have a high consequence of failure.

This section discussed the research problem, which was reiterated from chapter 1. The ILSS framework is provided in the next section.

8.2 Integrated logistics support system framework (ILSS)

A high technology complex system has an estimated utilisation or operational life of approximately 30 to 40 years, if not longer. Given the fact that these high technology complex systems function within a complex environment, it requires support (and maintenance). The complex environment in which a system operates includes developing world challenges, and systems with a high consequence of failure. The developing world offers greater challenges than the developed world or an ideal theoretical context. It follows then that the right support is essential for these systems to operate successfully. The support consists of the ILS elements as depicted in Figure 8–1 (a repeat of Figure 7-1), and includes:

1) Maintenance;
2) S&TE;
3) Supply support;
4) PHS&T;
5) Technical data and documentation;
6) Facilities;
7) Manpower and personnel;
8) Training and training devices;
9) Computer resources;
10) RAM – dependability;
11) Configuration management;
12) Obsolescence management;
13) Disposal management; and
14) Risk management.

Risk management is required by each ILS element, by the system itself, and by the complex environment, due to the associated risks. The ILSS of a high technology complex system requires an annual evaluation of its effectiveness and a risk review. The output of the effectiveness and risk review may affect one or more of the ILS elements. The affected ILS element/s must then be adapted and the subsequent result fed back into the ILSS. Should the ILS elements not be affected, the information regarding the output of the effectiveness and risk review and evaluation is fed back into the ILSS without necessitating any ILS element adaptation.

In the process of operating the ILSS of a high technology complex system within a complex environment, it may occur that the annual review does not fully address the relevant issues in the system's life cycle, therefore hampering effective and efficient operation. When this occurs, an automatic trigger is prompted in order to review the ILSS and adapt affected ILS elements.

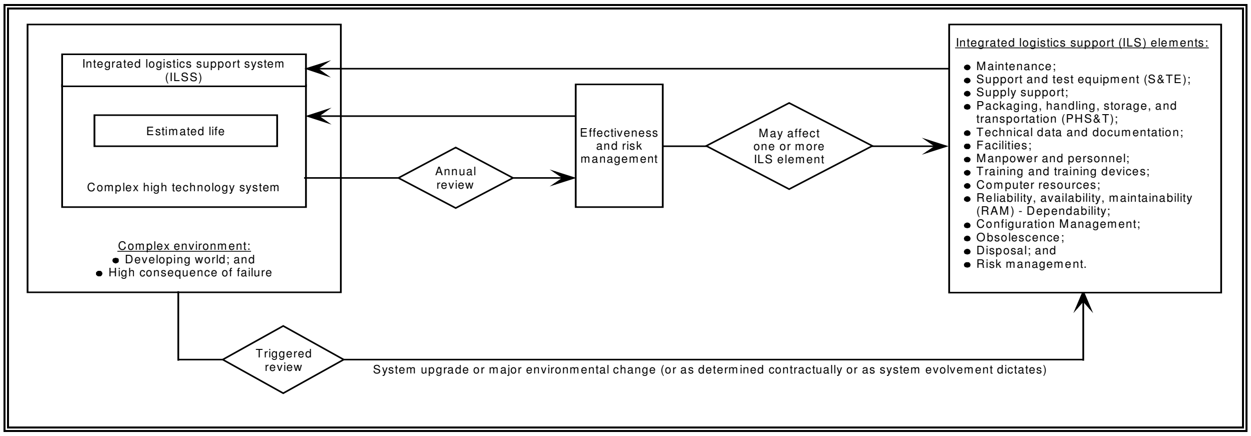


Figure 8–1: Integrated logistics support system (ILSS) framework – (a repeat of Figure 7-1)

These triggers could include upgrades, partial replacements, life extension, technology changes, and so forth. The adapted ILS elements are fed back directly into the ILSS to improve the high technology complex system's performance. A summary of the ILS grounded technological rules are provided in the next section.

8.3 Recommendations - Grounded technological rules summary

From the discussion in this chapter, the following recommendations in the form of grounded technological rules from the three collated phases of research are proposed. A summary of these rules is provided in Table 8–1 (a repeat of Table 7-1).

Table 8–1: Grounded technological rules of ILS research – (a repeat of Table 7-1)

ILS ELEMENT	GROUNDED TECHNOLOGICAL RULE
Maintenance	1) Utilise the defined business strategy; 2) Establish the organisation's maintenance philosophy; 3) Delineate the maintenance concept of the specific system and its linkage to other systems; 4) Develop maintenance planning, including analysis; 5) Document a maintenance plan for the specific system; 6) Implement the maintenance plan across all maintenance levels; 7) Conduct specific analysis of the system; and 8) Ascertain the risks associated with the maintenance of the system and manage these risks.
Support and test equipment (S&TE)	1) Design of S&TE and compatibility thereof with main system; 2) Trade-offs, constraints and availability of S&TE; 3) Scheduling of multi-system S&TE; 4) S&TE concept and plan; 5) Support and maintenance (including calibration) of S&TE.
Supply support	1) Define the system support strategy, philosophy, and concept; 2) Derive the supply support ditto from the above strategy; 3) Determine specific risks and calculate spares levels based on

ILS ELEMENT	GROUNDED TECHNOLOGICAL RULE
	risks and cost effectiveness; and 4) Document the supply support plan, defining the various processes and procedures required to efficiently and effectively manage the supply support function.
Packaging, handling, storage and transportation (PHS&T)	1) Define the PHS&T (including packing, preservation, and labelling or marking) policies, procedures, requirements and specifications; 2) Ensure stringent adherence to the PHS&T (including packing, preservation, and labelling or marking) policies, procedures, requirements and specifications; 3) Ensure adequate maintenance and support of the PHS&T infrastructure, and equipment; 4) Conduct analysis and trade-offs regarding PHS&T mechanisms, in order to minimise and standardise PHS&T interfaces; and 5) Ensure comprehensible labelling and marking of items susceptible to vibration, shock, fragility, correct orientation, environmental constraints, etc.
Technical data and documentation	1) Ensure technical data and documentation are written for the skill level of its user; 2) Ensure the above is sufficiently detailed to assist the end user in correctly following operator and maintenance tasks; 3) Document all relevant technical data and documentation in order to endure efficient and effective support of the system; 4) Apply strict configuration management principles to all technical data and documentation; and 5) Document all relevant technical information into a technical data and documentation plan.
Facilities	1) Define the facilities requirements for the operational system as early as possible in the latter's life cycle; 2) Define the support system infrastructure for the facilities requirements as early as possible in the life cycle of the system and support system (once the support system possesses sufficient information to define its respective requirements); 3) Ensure adequate training facilities to simulate as closely as possible the actual operating environment; 4) Ensure the facilities requirements are documented into a facilities plan; 5) Regularly update the facilities plan with new knowledge; 6) Maintain the facilities at regular intervals; and 7) Ensure availability of facility resources.
Manpower and personnel	1) Define the operational and maintenance personnel requirements in accordance with the maintenance concept; 2) Attract and retain the applicable skills, knowledge and experience to support the system; and 3) Document all the manpower and personnel requirements, specifications, analysis in a manpower and personnel plan.
Training and training devices	1) Define the operational and maintenance personnel training requirements in accordance with the maintenance concept; 2) Specify the types of training to be conducted and the training aids that will be required; 3) Document all the training and training devices requirements in a training and training devices plan, including sustainment training; and 4) Develop a long-term plan to ensure trained resources are available when needed.

ILS ELEMENT	GROUNDED TECHNOLOGICAL RULE
Computer resources	1) Utilise best practices in developing required computer resources that will meet performance requirements in complex environments; 2) Develop processes and procedures to effectively develop, test, audit operational software and other related aspects; 3) Ensure that the computer resources element is kept under strict configuration management and subjected to periodic audits; 4) Ensure all computer resources aspects are subjected to stringent security controls and stored in fireproof safes; 5) Ensure master copies and working copies of all computer resource related aspects are stored separately at different premises; and 6) Document all system computer resources aspects in a computer resources plan, describing the processes and procedures of software version control, security control of media, etc.
Reliability, availability, and maintainability (RAM) – Dependability	1) Develop an efficient and effective RAM analysis process taking reality into account and all possible constraints, variables, and variations, instead of a theoretical statistical projection; 2) Identify components with excessive failure rates, i.e. define reliability of components and system; 3) Reduce logistics delay times which have a high risk factor; 4) Calculate the operational availability of the system; 5) Ensure the system is maintainable and supportable.
Configuration management	1) Implement sound configuration management principles; 2) Conduct periodic audits; 3) Educate personnel regarding the purpose of configuration management, its use and benefits; and 4) Document the configuration management principles and audits.
Obsolescence	1) Implement an obsolescence programme (including processes and procedures) and plan for obsolescence; 2) Conduct regular technology scanning as part of risk review; 3) Manage the obsolescence constraint in order to improve system performance; 4) Ensure multiple suppliers of components, to eliminate single source supplier problems; 5) Ensure reliability data and component life cycle data is specific to the operating environment; 6) Attract and retain skilled and knowledgeable resources; 7) Establish excellent client relationships with suppliers; and 8) Ensure accurate obsolescence data and systems.
Disposal	1) Plan for system phase-out/retirement/disposal and manage effectively; 2) Plan and manage day-to-day disposal of components, consumables, and spare and repair parts; 3) Effectively manage the cost element of disposal; 4) Consider disposal of components in the design phase; and 5) Document all phase-out/retirement/disposal activities in a disposal plan.

Following from Table 8–1, it is evident that by postulating these ILS grounded technological rules in theory, they can be applied in practice – in the real world, thereby providing the validity, reliability, relevance, and applicability to the study. Mode 2 research was utilised to ensure that the research conducted was not just applicable to academia, but also to a wider organisational audience, thereby qualifying the validity, reliability, and relevance of the research. It was necessary to ground the theory in operations management so that the theory generated can be applied in other settings. In addition, grounded technological rules were used to ensure that the ILS framework developed can be applied to leadership and management hierarchies within an organisation, in a high technology industry, in a developing country.

A summary of the grounded technological rules of the ILS research was presented in this section. Next, a discussion follows regarding the contribution to the operations management and ILS body of knowledge.

8.4 Contribution

In this section, a discussion follows of the contribution of an ILSS to the body of knowledge in the disciplines of ILS, supply chain management and operations management. There is limited reference in the operations management body of knowledge regarding maintenance and ILS; in addition, most analysis techniques and references to ILS are from the military in the form of military standards and regulations. Furthermore, there are numerous definitions and explanations of logistics, ILS, and ILS elements, which make the understanding of this distinctive subject even more complicated.

The ILS framework as presented in Figure 8–1 (and Figure 7-1) and the ILS grounded technological rules as provided in Table 8–1 (and Table 7-1) are robust in nature, implying that they are not only applicable in the most difficult circumstances and environment in a developing country where resources are scarce, but they are also applicable in other less complex environments. The constraints of the developed world are fewer and less limiting in designing and applying an ILS framework to high technology complex systems.

An organisation can reap substantial value added benefits in gaining a considerable competitive advantage in the market place by applying this developed ILS framework and associated ILS grounded technological rules.

It is evident from the research that job orientation and basic training are dependent on one another. This dependence is also evident between basic training and knowledge and experience. In addition job orientation and basic training have a strong association between them. What is evident is that if a person has a basic training in engineering, there is a high probability that they are currently in an engineering or maintenance job function and that their skills base is in the specific discipline in which their basic training is. This is similar to those whom have a basic training in finance or management that they are currently in a management role. In addition this pattern of dependence is also evident between the respondents job orientation and their experience and knowledge.

With regards to writing operator and maintenance documentation in such a manner that operating and maintenance personnel are capable of understanding the contents thereof, the majority of the respondents (87.43%) of them selected this as most important, where 90.91% of the respondents involved with maintenance activities rating this most important. It is evident that irrespective of job orientation the respondents felt very strongly regarding the importance of writing operator and maintenance documentation in such a manner that operating and maintenance personnel are capable of understanding the contents thereof.

The respondents felt very strongly regarding the improvement of the availability of S&TE, and personnel irrespective of their job orientation or their knowledge and experience. This was similar with the improvement of S&TE support/maintenance.

The respondents irrespective of their job orientation felt quite strongly regarding the necessity of conducting RAM analyses and the need of identifying parts with excessive failure rates. In addition the cost to support was regarded as an important determinant of obsolescence by the respondents irrespective of their job orientation. This could be due to excessive total cost of ownership costs and life cycle costs.

Maintenance induced and operator induced failures seems to be high on the respondents' list of reasons for failure irrespective of the respondents job orientation.

The respondents, irrespective of their experience and knowledge base, regarded cost to repair, reliability of repaired system, and failure probability as a most important economical decision relating to supply support. In addition lead-time to repair was rated as most important by the respondents irrespective of their job orientation, or their experience and knowledge base.

The respondents did not regard poor supervision as a major contributor towards possible causes of maintenance personnel error, but however they regarded poor training and procedures as the major contributing factor towards maintenance personnel error.

These substantial value added benefits include, among others, as identified previously:

1) Improving the organisation's bottom line;
2) Decreasing the total life cycle cost and associated total cost of ownership;
3) Increasing the firm's market share, thereby increasing its competitive advantage;

4) Increasing the firm's customer support base, thereby meeting its customer's requirements;
5) Reducing the risk of obsolescence and DMSMS;
6) Mitigating the effects of long lead times, and long repair times;
7) Attracting, and retaining the appropriately skilled personnel, (in other words introduce stringent prerequisite requirements for skill levels to support the system);
8) Improving the necessary knowledge and skills within the organisation;
9) Maintaining and supporting a high technology complex system effectively and efficiently, (including all supporting ILS resources) throughout the intended and extended life cycle of the system and supporting ILS resources;
10) Managing the phase-out and disposal of components and the system adequately;
11) Managing system refurbishment, modifications, and upgrade programmes successfully;
12) Managing cannibalisation and mothball programmes successfully;
13) Improving the reliability, availability, and maintainability (RAM) - dependability of the system, and components;
14) Managing any language inadequate interfaces between personnel and documentation (including labels, marking, and etcetera) successfully; and
15) Managing (rather than reactively) the risk associated with system support and maintenance proactively.

This section discussed the contribution of ILSS to the body of knowledge in the fields of ILS and operations management. The next section provides the conclusion of the study.

8.5 Conclusion

An assessment of the business problem and research problem was done by applying Mode 2 research, grounding the ILS theory in supply chain management and operations management, and providing grounded technological rules according to which a high technology complex system can be supported and maintained over its intended or extended life cycle. An organisation can gain a competitive advantage from such an implemented ILSS by managing the skills shortage and the obsolescence and DMSMS constraints, which in turn reduce the risk associated with an inadequately implemented ILSS. The reduction in risk can ensure that a system reaches its intended life span and possible extended life span.

To ensure effective maintenance, an organisation has to define its business strategy. From this, the organisation's maintenance philosophy is established. Once the maintenance philosophy is delineated, it is possible to develop the maintenance concept of the specific system, including its interface with other systems. At this stage, the analysis and maintenance planning can occur, resulting in a maintenance plan for the specific system. The maintenance plan ensures that the system is managed effectively in order to reduce the risk associated with the system support.

Performing maintenance on any system requires the use of S&TE. This S&TE needs to be compatible with the main system, that is, decisions taken regarding S&TE should be the result of trade-off studies involving various constraints. It is essential to manage the availability of S&TE and the scheduling of multi-system S&TE effectively in order to obtain the best added value for the acquired S&TE. When evaluating the availability of S&TE, the regular calibration of the S&TE and corrective maintenance of the S&TE should be taken into account. The S&TE plan includes all relevant aspects to efficiently manage the S&TE element.

High technology complex systems require supply support in order to repair and maintain the line replaceable units (LRUs). Supply support consists of all consumables, repair parts, and spare parts. The supply support strategy, philosophy, and concept depend on the maintenance philosophy, the level of repairs, who these repairs will be performed by, and the maintenance contract between the end user and the contractor. The supply support plan defines the various procedures and processes needed to effectively and efficiently manage the supply support function.

Supporting a high technology complex system requires items to be packaged, handled, stored and transported. An item cannot just be placed or packed in a plastic bag or loosely inside a container, as this will result in damage to the item. The item needs to be packed, and packaged in some form of protective material, in order to protect the item from possible damage, such as environmental elements, humidity, vibration, and so forth, in other words vibration and humidity monitors, amongst others, should be supplied. In addition, the packaging has to be labelled and marked to ensure the user handles and transports the item properly, in other words, labels should display the correct orientation and destination. The item needs to be handled in some form or another, either by hand or by a device used to manoeuvre the item. The more complex the handling device, the more complex the support infrastructure required to support the handling device. The item needs to be stored in a storage location or facility where it is not susceptible to damage; it may need to be stored at specific environmental conditions. Transportation is critical, as loose lying items inside transportable cabins may induce failures; in addition, the planned route also needs to be assessed, as its state may require additional unplanned packing, packaging, marking, and labelling of items.

Technical data and documentation assist personnel to support a high technology complex system. The skill level of the user of the documentation should be a determining factor when writing documentation, taking into account any possible language barriers, or background technical proficiency already gained by the personnel who support the system. A technical data and documentation plan details all relevant aspects applicable to the technical data and documentation element, including processes, procedures, lists of technical publications and manuals, and so forth.

Facilities entail all buildings, locations, sites (covered and uncovered), land, storage facilities, roads, equipment plants, warehouses, training rooms, workshops, and any area required to support a system throughout its life cycle. Facilities have a long lead time and need to be defined and acquired as early as possible in the system's life cycle. Facilities also require a support infrastructure that needs to be maintained.

It is critically important to set requirement specifications for manpower and personnel to ensure that the appropriately profiled and skilled personnel are employed and retained by the organisation in order to effectively and efficiently maintain a high technology complex system. This necessitates stringent job and manpower specifications, documented in a manpower and personnel plan. These requirements and specifications may include (without being discriminatory):

1) The necessity to ascend high structures;
2) The requirement to work in enclosed areas or dangerous environments;
3) Manoeuvrability in small and restricted areas; and
4) An ability to work in specific protective clothing (for example, full body suit with enclosed hood and breathing apparatus).

Skills shortage is another serious concern as this affects the support of a high technology complex system, that is, skills shortage may cause operator- and maintenance-induced errors. Specific operational and maintenance personnel training requirements need to be well defined. Training aids play an important role in training, as an accurately simulated maintenance environment can ensure that actual maintenance time is reduced, and maintenance-induced errors are reduced. In addition, long-term training requirements need to be defined, including cross-training on sub-systems, sustainment training, and planned succession training. All these specifications and requirements need to be documented in a training and training devices plan.

Best practices can be utilised to develop computer resources that will meet specified performance requirements in complex environments. This development requires stringent processes and procedures to effectively develop, test, and audit operational software and other computer resources related aspects. It is vitally important that the computer resources element is kept under strict configuration management control in order to ensure that the correct versions of the software are updated and distributed. It is essential to protect the computer resources and software media against potential fire, loss, theft, and environmental elements, as loss or damage of computer resources (for example software discs, and so forth) can result in many wasted man-hours and incurred costs for loss and rework. This vigilance includes the protection of master copies, and the use of working-copies by the maintenance personnel.

Reliability, availability, and maintainability (RAM – dependability) requires more realistic considerations when determining the actual reliability and availability of a system. In theory the RAM statistical projections do not take realistic environments and constraints into account, and tend to be 'nice-too-have' figures whereby contracts can be measured and managed. It is critical that an efficient and effective RAM analysis process is developed taking reality into account and all possible constraints, variables, and variations, instead of theoretical statistical projections. In addition, components with excessive failure rates need to be identified as this will inevitably impact on the system's reliability figures, and performance. Operational availability of a system is critical in measuring contract performance, but this calculated figure depends on various factors, including:

1) The accuracy of the software programme being used;
2) The skill level and motivation of the personnel performing maintenance and who complete the necessary data on a jobcard;
3) The skill level and motivation of the data capturer; and

Configuration management principles are extremely important with regards to system product (or physical) breakdown structures as any unnecessary exchange of LRUs affects the configuration of the system. Not only that, but it also affects the buildstate so that unnecessary man-hours are spent during an audit to determine which LRU is in which location, and to find the misplaced LRUs. Sound configuration management principles, which are implemented, documented in a configuration management plan, and followed, reduce the exchange of LRUs, while periodic audits ensure that the configuration management principles are followed correctly. In addition, personnel who are educated, are able to fully appreciate the purpose, principles, and benefits of configuration management.

Obsolescence and DMSMS result in systems becoming obsolete, phased-out or disposed of before the end of their (intended) designed life span. Not only do components and systems become obsolete, but so do skills, S&TE, PHS&T, facilities, and so forth. It is a necessary requirement that obsolescence and DMSMS are planned for. In other words, a proactive approach should be followed, rather than a reactive approach – all the applicable procedures and processes relevant to obsolescence and DMSMS should be documented in a plan. It is critical that a management action list on obsolescence is developed and reviewed regularly, that is, regular technology scanning should be conducted as part of a risk review. It is vital to manage the obsolescence constraint in order to improve system performance. Many mitigating factors of obsolescence have been proposed, including multiple suppliers of components, performance based logistics (PBL), maintenance task analysis, dual path methodology, and so forth. An important aspect of reducing the risk of obsolescence and DMSMS is to ensure that the accurate obsolescence data and systems exist, and that reliability data and component life cycle data are operating environment specific.

A typical example of a reactive approach, versus a proactive approach is when the disposal of components, LRUs and the actual system is only really considered when it (the disposal) has to occur. Phase-out, retirement, and disposal of a system need to be planned well in advance of the actual date to make sure that the relevant aspects are in place to secure a successful process. Such aspects include all relevant ILS elements, that is, specific PHS&T may be required, personnel may need to be trained to properly dispose of items, and especially hazardous items, specific S&TE may be required to dismantle equipment, and so forth. Not only does long term planning need to be in place, but also day-to-day disposal of consumables, spare and repair parts, and beyond economical to repair (BER) items. Planning for disposal includes considerations in the design phase of how to successfully dispose of items in later life cycle phases. By planning well in advance, the cost of disposal can be reduced. All the applicable processes and procedures relevant to the disposal of items need to be documented in a specific plan, be it a phase-out plan, retirement plan, disposal plan, or one combined plan. In addition, systems, which are mothballed or used for cannibalisation, also need to be planned for, and the applicable processes and procedures documented as such.

8.6 Future research

Future research that can emanate from this study include the following:

1) Develop education frameworks for all industries regarding obsolescence and DMSMS, and the risks associated with life cycle support and the effects these have on the intended and extended life cycles of systems;
2) Develop education frameworks for all industries and the general public regarding waste, general disposal of components, and disposal of hazardous waste and components, and the detrimental effects non-compliance will have on global warming and the environment;
3) Conduct an ILS comparison and/or a longitudinal study of different high technology complex systems in different industries and/or different countries, with the emphasis on the effects of skills shortages and technological advancements, particularly with respect to obsolescence and DMSMS;

4) Determine the influence of organisational culture (for example military versus industry, or different industries), in their willingness to participate in research studies, and particularly the use of measuring instruments (for example paper-based versus website-based questionnaires) and their completion; and
5) Assess the influence of technological advancements and its effects on skill retention, and obsolescence and DMSMS with respect to the different phases within a system's life cycle.

8.7 Summary of conclusions and recommendations

In concluding this study it is clear that there are significant challenges in supporting and maintaining a high technology complex system in a developing country. This is especially evident where the systems in use have a high consequence of failure, are susceptible to obsolescence and DMSMS, and where resources are scarce, particularly skills shortages. It can be argued that the provision of a framework and associated grounded technological rules can assist in the successful implementation of an ILSS in a developing country within the high technology industry, given these rules are applied in practice (instead of just in theory). Furthermore, such an ILSS can contribute significantly to the body of knowledge in the disciplines of supply chain management, operations management and ILS.

'The more you see the less you know. The less you find out as you go. I knew much more then than I do now.'

– U2, ('City of Blinding Lights', from 'How to Dismantle an Atomic Bomb').

'Science does not select or mold specially honest people: it simply places them in a situation where cheating does not pay.'

– S. E. Luria.

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APPENDIX A: RELEVANT WORLD INDICES

Table A–1: Military expenditure ($) compared to GDP

COUNTRY	MILITARY EXPENDITURE $ (MILLION)	MILITARY EXPENDITURE (% OF GDP)	GDP $ (MILLION) EST.
Sao Tome and Principe	0.5	0.80	214
South Africa	2,653.4	1.70	456,700
United Kingdom	42,836.5	2.40	1,666,000
United States	370,700	3.30 (FY03, est.)	10,990,000
World	Not available	2.00 (1999, est.)	51,480,000

Source: CIA World Factbook, 2004a, b &c.
FY: Financial Year.
Est.: Estimated.

Table A–2: Commitment to education: public spending

THEME	PUBLIC EXPENDITURE ON EDUCATION {a}				PUBLIC EXPENDITURE ON EDUCATION BY LEVEL {b} (% OF ALL LEVELS)					
	AS % OF GDP		AS % OF TOTAL GOVERNMENT EXPENDITURE		Pre-primary And primary		Secondary		Tertiary	
COUNTRY	1990 {c, f}	1999-2001 {d, g}	1990 {c, f}	1999 2001 {d, g}	1990 {c, f}	1999-2001 {d, h}	1990 {c, g}	1999-2001 {d, g}	1990 {c, g}	1999-2001 {d, g}
NORWAY	7.1	6.8	14.6	16.2	39.5	48.3	24.7	20.6 {e}	15.2	25.4
USA	5.2	5.6	12.3	15.5	No data	39.2	No data	34.5	No data	26.3
ECUADOR	2.8	1.0 {e}	17.2	8.0 {e}	34.4	45.3 {e}	34.2	44.5 {e}	18.3	9.1 {e}
SOUTH AFRICA	6.2	5.7	No data	No data	75.6	47.2	No data	31.3	21.5	14.5

Source: Extracted from UNDP (2004)
Note: As a result of limitations in the data and methodological changes, comparisons of education expenditure data across countries and over time must be made with caution. For detailed notes on the data see http://www.uis.unesco.org/.
a. Data refer to total public expenditure on education, including current and capital expenditure.
b. Data refer to current public expenditure on education. Data may not be strictly comparable between 1990 and 1999-2001 as a result of methodological changes. Expenditures by level may not sum to 100 as a result of rounding or the omission of the categories expenditures in post-secondary education and expenditures not allocated by level.
c. Data may not be comparable between countries as a result of differences in method of data collection.
d. Data refer to the most recent year available during the period specified.
e. Data refer to an UNESCO Institute for Statistics estimate where no national estimate is available.
f. Source: UNESCO Institute for Statistics 2003c.
g. Source: UNESCO Institute for Statistics 2004b
h. Source: Calculated on the basis of data on public expenditure on education by preprimary and primary levels from UNESCO Institute for Statistics 2004b.

Table A–3: total population, commitment to health, HIV, and life expectancy at birth

COUNTRY / THEME	NORWAY	USA	ECUADOR	LATIN AMERICA AND THE CARIBBEAN	SOUTH AFRICA	SUB-SAHARAN AFRICA	WORLD
Total Population (millions)							
1975 {a}	4.0	220.2	6.9	317.9	25.8	305.8	4,068.1 {c}
2002 {a, b}	4.5	291.0	12.8	530.2	44.8	641.0	6,225.0 {c}
2015 {a, b}	4.7	329.7	15.2	622.5	44.3	843.1	7,197.2 {c}
Commitment to health: resources, access and services							
BIRTHS ATTENDED BY SKILLED HEALTH PERSONNEL (%) 1995-2002 {d, g}	100 {e}	99	69	83	84	42	58 {f}
PHYSICIANS (PER 100,000 PEOPLE) 1990-2003 {d, h}	367	279	145	No data	25	No data	No data
Leading global health crises and risks							
HUMAN IMMUNODEFICIENCY VIRUS (HIV) PREVALENCE {i} (% AGES 15-49) 2003	0.1 [0.00-0.2]	0.6 [0.3-1.1]	0.3 [0.1-0.5]	0.7 [0.4-1.0]	[17.8-24.3]	7.4 [6.3-9.7]	1.1 [0.9-1.5]
Life expectancy at birth (years)							
1970-75 {a, j}	74.4	71.5	58.8	61.1	53.7	45.2	59.8
2000-05 {a, j}	78.9	77.1	70.8	70.6	47.7	46.1	66.9

Source: UNDP (2004)
a. Source: (UN 2003).
b. Data refer to medium-variant projections.
c. Data refer to the total world population according to UN 2003.The total population of the 177 countries included in the main indicator tables was estimated to be 4,063 million in 1975,and projected to be 6,217 million in 2002 and 7,188 million in 2015.
d. Data refer to the most recent year available during the period specified. Source:
e. Data refer to a year or period other than that specified, differ from the standard definition or refer to only part of a country.
f. Data refer to the world aggregate from United Nations Children's Fund (UNICEF) 2003.
g. Source: (UNICEF 2003).
h. Source: (World Health Organization {WHO} 2004b).
i. Data refer to 1999. Source UNAIDS (Joint United Nations Programme on HIV/AIDS) 2004; aggregates calculated for the Human Development Report Office by UNAIDS.
j. Data refer to estimates for the period specified.

APPENDIX B: DEFINITION OF TERMS

Note 1: The indicators for 'Internet Users', 'Phone Lines', 'Mobile Phone Subscriptions', 'Radios', and 'Television Sets' list the number of the '… appliances/users that exist for every thousand people in a country's population. Data are supplied by annual questionnaires sent by the International Telecommunications Union (ITU) to telecommunication authorities and operating companies, supplemented by annual reports and statistical yearbooks of telecommunication ministries, regulators, operators and industry associations. Data on radios is the only exception. The World Bank obtains their data on radio receivers from statistical surveys conducted by the United Nations Educational, Scientific, and Cultural Organization (UNESCO).' (EarthTrends: 2003).

1) **Adult literacy rate:** 'The adult literacy rate is defined as the percentage of people ages 15 and above who can, with understanding, both read and write a short simple statement related to their everyday life. Literacy data using this definition are usually collected during national population censuses, generally conducted every 5 or 10 years, or from household surveys.' (UNDP, 2004).

2) **Area of visibility:** '… an area limited by earth station elevation angle from which communication with the satellite is possible.' (UN, 1981 in Smith, 1990).

3) **Availability:** 'The measure of the degree a system is in the operable and committable state at the start of a mission when the mission is called for at an unknown random point in time.' (Source: Blanchard, 1992: 22). Three predictions of availability are:

   i) **Inherent availability (A_i):** 'Net percentage of the time that the system should theoretically be available for its intended use.' (Source: Jones, 1995:5.2).

   A_i=MTBF/(MTBF+MTTR)

   Where: MTBF: Mean Time Between Failure.

   MTTR: Mean Time To Repair.

   ii) **Achieved availability (A_a):** 'Probability that a system or equipment, when used under stated conditions in an ideal support environment, will operate satisfactorily at any point in time.' (Source: Blanchard, 1992: 70).

   A_a=MTBM/(MTBM+M_{CMT}+M_{PMT}), (Source: Jones, 1995:5.2).

   Where: MTBM: Mean Time Between Maintenance.

   M_{CMT}: Mean Corrective Maintenance Time.

   M_{PMT}: Mean Preventive Maintenance Time.

iii) **Operational availability (A_o):** ‘Probability that a system or equipment, when used under stated conditions in an actual operational environment, will operate satisfactorily when called upon.’ (Source: Blanchard, 1992: 70).

A_o=MTBM/(MTBM+MDT), (Source: Jones, 1995:5.3).

Where: MTBM: Mean Time Between Maintenance.

MDT: Maintenance Delay Time.

4) **Births attended by skilled health personnel:** ‘… the percentage of deliveries attended by personnel (including doctors, nurses and midwives) trained to give the necessary care, supervision and advice to women during pregnancy, labour and the postpartum period, to conduct deliveries on their own and to care for newborns.’ (UNDP, 2004).

5) **Cellular subscribers:** ‘… (also referred to as cellular mobile subscribers) Subscribers to an automatic public mobile telephone service that provides access to the public switched telephone network using cellular technology. Systems can be analogue or digital.’ (UNDP, 2004).

6) **Civil Liberties:** ‘… a scale of 1 to 7, with 1 representing the most free and 7 representing the least free. Countries with a rating of 1 generally have an established and equitable rule of law with free economic activity. Citzens [sic] enjoy freedom of expression, assembly, association, and religion. A rating of 2 indicates some deficiencies, but these countries are still relatively free. A rating of 3, 4, or 5 may indicate partial compliance with all of the elements of civil liberties; it may also indicate complete freedom in some areas coupled with complete denial in others. Countries with a rating of 6 enjoy partial rights— a few social and religious freedoms and some restricted business activity. A rating of 7 indicates virtually no freedom. Freedom House notes that a poor rating for a country “is not necessarily a comment on the intentions of the government, but may indicate real restrictions on liberty caused by non-governmental terror.”’ (Freedom House, cited in EarthTrends, 2003).

7) **Combined gross enrolment ratio for primary, secondary and tertiary schools:** ‘Gross enrolment ratios are produced by the UNESCO Institute for Statistics based on enrolment data collected from national governments (usually from administrative sources) and population data from the United Nations Population Division’s 2002 Revision of World Population Prospects (UN 2003). The ratios are calculated by dividing the number of students enrolled in all levels of schooling by the total population in the official age group corresponding to these levels. The tertiary age group is set to five cohorts immediately following on the end of upper secondary school in all countries.’ (UNDP, 2004).

8) **Combined gross enrolment ratio for primary, secondary and tertiary schools:** ‘… the number of students enrolled in primary, secondary and tertiary levels of education, regardless of age, as a percentage of the population of official school age for the three levels. See education levels and enrolment ratio, gross.’ (UNDP, 2004).

9) **Configuration Management:** ‘Systematic approach that establishes and maintains the identification, control and accounts of the configuration of selected products and component parts.’ (Source: Finkelstein and Guertin, 1988:91).

10) **Conventional arms transfers:** ‘… refers to the voluntary transfer by the supplier (and thus excludes captured weapons and weapons obtained through defectors) of weapons with a military purpose destined for the armed forces, paramilitary forces or intelligence agencies of another country. These include major conventional weapons or systems in six categories: ships, aircraft, missiles, artillery, armoured vehicles and guidance and radar

systems (excluded are trucks, services, ammunition, small arms, support items, components and component technology and towed or naval artillery under 100-millimetre calibre).' (UNDP, 2004).

11) **Corruption Perception Index (CPI):** '… ranks 91 countries in terms of the degree to which corruption is perceived to exist among public officials and politicians. Scores range between 10 (highly clean) and 0 (highly corrupt). CPI focuses on corruption in the public sector, defining corruption as the abuse of public office for private gain. It is a composite index, derived from 14 different polls and surveys carried out among business people and country analysts, including surveys of residents, both local and expatriate. CPI is based solely on perceptions instead of hard empirical data such as cross country comparisons of prosecutions or media coverage of corruption.' (EarthTrends, 2003).

12) **Coverage area:** '… is the area, within the area of visibility, that is actually covered by the satellites communications antennas.' (UN, 1981 in Smith, 1990).

13) **Creation of technology:** '… as measured by the number of patents granted to residents per capita and by receipts of royalties and license fees from abroad per capita.' (CountryWatch, 2002).

14) **Data:** System installation and checkout procedures, operating and maintenance instructions, inspection and calibration procedures, overhaul procedures, modification instructions, facilities information, drawings, and specifications that are necessary in the performance of system operation and maintenance functions. (Source: Blanchard, 1992:12).

15) **Determinants of quality of life:** 'The nine quality-of-life factors, and the indicators used to represent these factors, are:

1. **Material wellbeing**
GDP per person, at PPP in $. Source: Economist Intelligence Unit
2. **Health**
Life expectancy at birth, years. Source: us Census Bureau
3. **Political stability and security**
Political stability and security ratings. Source: Economist Intelligence Unit
4. **Family life**
Divorce rate (per 1,000 population), converted into index of 1 (lowest divorce rates) to 5 (highest). Sources: UN; Euromonitor
5. **Community life**
Dummy variable taking value 1 if country has either high rate of church attendance or trade-union membership; zero otherwise. Sources: ILO; World Values Survey
6. **Climate and geography**
Latitude, to distinguish between warmer and colder climes. Source: CIA World Factbook
7. **Job security**
Unemployment rate, %. Sources: Economist Intelligence Unit; ILO.
8. **Political freedom**
Average of indices of political and civil liberties. Scale of 1 (completely free) to 7 (unfree). Source: Freedom House
9. **Gender equality**
Ratio of average male and female earnings, latest available data. Source: UNDP Human Development Report' (The Economist, 2005).

16) **Diffusion of new innovations:** '… as measured by the number of Internet hosts per capita and the share of high-and medium- technology exports in total goods exports.' (CountryWatch, 2002).

17) **Diffusion of old innovations:** '…as measured by telephones (mainline and cellular) per capita and electricity consumption per capita.' (CountryWatch, 2002).

18) **Education index:** '… one of the three indices on which the human development index is built. It is based the adult literacy rate and the combined gross enrolment ratio for primary, secondary and tertiary schools.' (UNDP, 2004).

19) **Education levels:** '… categorized as pre-primary, primary, secondary or tertiary in accordance with the International Standard Classification of Education (ISCED).Pre-primary education (ISCED level 0)is provided at such schools as kindergartens and nursery and infant schools and is intended for children not old enough to enter school at the primary level. Primary education (ISCED level 1) provides the basic elements of education at such establishments as primary and elementary schools. Secondary education (ISCED levels 2 and 3) is based on at least four years of previous instruction at the first level and provides general or specialized instruction, or both, at such institutions as middle schools, secondary schools, high schools, teacher training schools at this level and vocational or technical schools. Tertiary education (ISCED levels 5 –7) refers to education at such institutions as universities, teachers colleges and higher level professional schools — requiring as a minimum condition of admission the successful completion of education at the second level or evidence of the attainment of an equivalent level of knowledge.' (UNDP, 2004).

20) **Extinct language:** 'Languages that no longer have first-language speakers are described as "Extinct" in place of a population', (Gordon, 2005)

21) **Facilities:** 'All special facilities needed for system operation and the performance of maintenance functions at each level. Physical plant, real estate, portable buildings, housing, intermediate maintenance shops, calibration laboratories, and special depot repair and overhaul facilities must be considered. Capital equipment and utilities (heat, power, energy requirements, environmental controls, communications, etc.) are generally included as part of facilities.' (Source: Blanchard, 1992:12).

22) **Failure Modes, Effects, and Criticality Analysis (FMECA):** 'The identification of all probable ways in which parts, assemblies, and the equipment may fail, the causes for each failure, and the effect that each failure will have on the capability of the equipment to perform its mission …' (Source: Jones, 1995: 2.10).

23) **Freedom House Indices:** '… evaluate governments and levels of freedom within countries. They measure real world situations caused by state and nongovernmental factors, rather than government intentions or legislation. Freedom House is a US - based, non-profit organization that advocates for American-style leadership in international affairs; the organization conducts extensive research about the level and nature of freedom and civil liberties around the world. To determine each country's political rights, researchers answer a series of survey questions through country visits and an extensive network of sources.' (EarthTrends, 2003).

24) **GDP (gross domestic product):** '… the sum of value added by all resident producers in the economy plus any product taxes (less subsidies)not included in the valuation of output. It is calculated without making deductions for depreciation of fabricated capital assets or for depletion and degradation of natural resources. Value added is the net output of an industry after adding up all outputs and subtracting inter- mediate inputs.' (UNDP, 2004).

25) **GDP (US$):** '… GDP converted to US dollars using the average official exchange rate reported by the Inter- national Monetary Fund. An alternative conversion factor is applied if the official exchange rate is judged to diverge by an exceptionally large margin from the rate effectively applied to transactions in foreign currencies and traded products. See GDP (gross domestic product).' (UNDP, 2004).

26) **GDP per capita (PPP US$):** 'To compare standards of living across countries GDP per capita needs to be converted into purchasing power parity (PPP) terms that eliminates differences in national price levels.' (UNDP, 2004). See definitions of PPP and GDP.

27) **Gross enrolment ratio:** '… the number of students enrolled in a level of education, regardless of age, as a percentage of the population of official school age for that level. The gross enrolment ratio can be greater than 100%as a result of grade repetition and entry at ages younger or older than the typical age at that grade level. See education levels.' (UNDP, 2004).

28) **Health expenditure per capita (PPP US$):** '… the sum of public and private expenditure (in PPP US$), divided by the population. Health expenditure includes the provision of health services (preventive and curative), family planning activities, nutrition activities and emergency aid designated for health, but excludes the provision of water and sanitation. See health expenditure, private; health expenditure, public; and PPP (purchasing power parity)' (UNDP, 2004).

29) **High-technology exports:** '… exports of products with a high intensity of research and development. They include high-technology products such as in aerospace, computers, pharmaceuticals, scientific instruments and electrical machinery.' (UNDP: 2004).

30) **HIV prevalence:** '… the percentage of people ages 15 –49 who are infected with HIV.' (UNDP, 2004).

31) **Human development index (HDI):** '… A composite index measuring average achievement in three basic dimensions of human development —a long and healthy life, knowledge and a decent standard of living.' (UNDP, 2004).

32) **Human skill:** '… as measured by mean years of school in the population age 15 and above and the gross tertiary science enrolment ratio.' (CountryWatch, 2002).

33) **Interference:** 'degradation of performance of a communications system due to unwanted signals'. (UN 1981, in Smith 1990). The ITU defines interference as '[t]he effect of unwanted energy due to one or a combination of emissions, radiations, or inductions upon reception in a radiocommunication system, manifested by any performance degradation, misinterpretation, or loss of information which could be extracted in the absence of such unwanted energy.' (ITU, 1982 in Smith, 1990).

34) **Integrated Logistics Support (ILS) definitions:**

i) **Department of Defence Directive 5000.39:** 'A disciplined, unified, and iterative approach to the management and technical activities necessary to

(a) *integrate support considerations into system and equipment design;*
(b) *develop support requirements that are related consistently to readiness objectives, to design, and to each other;*
(c) *acquire the required support; and*
(d) *provide the required support during the operational phase at minimum cost.'* (DoD Directive 5000.39, 1983 cited in Blanchard, 1992:13).

ii) **MIL-STD-1369-A:** 'The disciplined, unified, and iterative approach to the management and technical activities necessary to:

(a) *integrate support considerations into system and equipment design;*
(b) *develop support requirements that are related consistently to readiness objectives, to design, and to each other;*
(c) *acquire support; and*
(d) *provide the required support during the operational phase at minimum cost.'* (MIL-STD-1369-A, 1988:7).

iii) U.S. Army Regulation 700-127, there are four different definitions of integrated logistics support from this source, two are from the 1999 edition, and two are from the 2005 edition:

Where: NDI - Non Developmental Item, LCC - Life Cycle Costing, PBL – Performance Based Logistics, SS – Supportability Strategy.

a) **U.S. Army Regulation 700-127**, (1999:5-6, first citation): *'The ILS is defined as a unified and iterative approach to the management and technical activities needed to—*

(1) Influence operational and materiel requirements, system specifications, and ultimate design or selection (in the case of commercial and NDI). This includes minimizing environmental impact and complying with environmental regulations.
(2) Define the support requirements best related to system design and to each other.
(3) Develop and acquire the required support.
(4) Provide required operational phase support for best value.
(5) Seek readiness and LCC improvements in the materiel system and support systems throughout the operational life-cycle.'

b) **U.S. Army Regulation 700-127**, (1999:53-54, second citation): *'A unified and iterative approach to the management and technical activities needed to—*

a. Influence operational and materiel requirements and design specifications.
b. Define the support requirements best related to system design and to each other.
c. Develop and acquire the required support.
d. Provide required operational phase support at lowest cost.
e. Seek readiness and LCC improvements in the materiel system and support systems during the operational life cycle.
f. Repeatedly examine support requirements throughout the service life of the system.'

c) ***U.S. Army Regulation 700-127**, (2005:1-2, first citation): 'The ILS process is a unified and iterative approach to the management and technical activities needed to—*

(1) Influence the operational and materiel requirements/capabilities, system performance specifications, the integration of sustainability and maintainability during the acquisition process as well as influence the ultimate design or selection (in the case of commercial and nondevelopmental items (NDIs)) of a materiel system.
(2) Implement PBL.
(3) Emphasize supportability early during the system life cycle.
(4) Define and refine the required product support during the development and implementation of the supportability strategy (SS) during the system life cycle.
(5) Provide required operational phase product support for best value.
(6) Seek readiness and LCC improvements in the materiel system and support systems throughout the operational life cycle.
(7) Define the product support requirements best related to system design and to each other.'

d) **U.S. Army Regulation 700-127**, (2005:35, second citation): 'A unified and iterative approach to the management and technical activities needed to influence operational and materiel requirements and design specifications, define the support requirements best related to system design and to each other, develop and acquire the required support, provide required operational phase support at lowest cost, seek readiness and LCC improvements in the materiel system and support systems during the operational life cycle, and repeatedly examine support requirements throughout the service life of the system.'

iv) **Department of the Army Pamphlet 700-55:** 'A unified, and iterative approach to the management and technical activities needed to:

a. Influence operational and materiel requirements, and design specifications.
b. Define the support requirements best related to materiel system design and to each other.
c. Develop and acquire the required support.
d. Provide required operational phase support at lowest cost.
e. Seek readiness and LCC improvements in the materiel system and support systems during the operational life cycle.
f. Repeatedly examine support requirements throughout the service life of the system.' (Department of the Army Pamphlet 700-55, 1989:17).

v) **Department of Defense Directive 4100.35 (G):**

a) **DoDD 4100.35G:** *'a composite of all support considerations necessary to assure the effective and economical support of a system or equipment at all levels of maintenance for its programmed life cycle. It is an integral part of all other aspects of system acquisition and operation.'* (DoDD 4100.35G; 1967, cited in Blanchard; 2004:7).

b) **DoDD 4100.35:** *'… a composite of the elements necessary to assure the effective and economical support of a system or equipment at all levels of maintenance for its programmed life cycle. It is characterized by the harmony and coherence obtained between each of its elements …' (DoDD 4100.35; 1968, cited in Rossi; 1990:24).*

vi) **DoD directive 5000.39:** 'A unified and interactive approach to the management and technical activities necessary to:

a) cause support considerations to influence requirements and design;
b) define support requirements that are optimally related to the design and to each other;
c) acquire the required support; and
d) provide the required support during the operational phase at minimum cost.' (DoD Directive 5000.39; 1980, Cited in Rossi; 1990: 25).

vii) **DoD pamphlet TM38-710, APF 800-7, NAVMAT P-4000:** *'ILS is a composite of all support considerations necessary to assure the effective and economical support of a system for its intended life cycle. It is an integral part of all other respects of system acquisition and operation. ILS is characterized by harmony and coherence among all logistics elements.'* (DoD Pamphlet TM38-710; APF 800-7; NAVMAT P-400; 1972, Cited in Rossi; 1990:25).

viii) **Department of the Army Pamphlet 700-127:** *'… the process through which the composite of management and analysis actions necessary to assure effective and economical support of a materiel system, both before and after fielding, are accomplished. The basic management principle of the ILS process is that logistic support resources must be developed, acquired, tested, and deployed as an integral part of the materiel acquisition process.'* (Department of the Army Pamphlet 700-127, 1989:1).

ix) **AMS (Acquisition Management System) UK (United Kingdom) MOD (Ministry of Defence):** *'… ILS provides the disciplines for ensuring that supportability and cost factors are identified and considered during the design stage of an equipment so that they may influence the design, with the aim of optimizing the Whole Life Cycle (WLC).'* (UK MoD, 2007:1).

x) **UK DEF-STAN 00-60, 2004:A-7:** *'A disciplined management approach, … aimed at optimizing equipment Life Cycle Costs (LCC). It includes elements for influencing equipment design and determining support requirements to achieve supportable and supported equipment.'* (DEF-STAN 00-60, 2004:A-7).

xi) **Blanchard, B. S. ('Logistics Engineering and Management'):** *'A management function that provides the initial planning, funding, and controls which help to assure that the ultimate consumer (or user) will receive a system that will not only meet performance requirements, but one that can be expeditiously and economically supported throughout its programmed life cycle. A major ILS objective is to assure the integration of the various elements of support (i.e., test and support equipment, spare/repair parts, etc.)' (Blanchard, 1992:13).*

xii) **Hutchinson:** *'Integrated logistic support, when properly understood and applied, can provide the means to identify and resolve any logistics problems, frequently before they develop. Logistics, in its broadest sense of the word, can be considered as a scope of activity comprised of three major areas or subsets:*
(1) subsistence logistics,
(2) operations logistics, and
(3) systems logistics' (Hutchinson, 1987:2).

xiii) **Quayle:** 'ILS is a structured and co-ordinated approach to support planning that will produce the most technically efficient and cost effective support solution for the aircraft industry.' *(Quayle, 1993:278).*

xiv) **Jones, J. V. (Integrated Logistics Support Handbook):**

a) 'Integrated Logistics Support (ILS) is the disciplined and unified management of the technical logistics disciplines that plan and develop support for military forces. In general this means that ILS is the management organisation that plans and directs the activities of many technical disciplines associated with the identification and development of logistics support requirements for military systems. There are comparable organisations outside the military which provide the same capabilities. In a commercial company this organisation may be called product support, customer services, or many other similar names.' (Jones, 1998:1.4).

b) 'Integrated Logistics Support (ILS) is the disciplined and unified management of all activities necessary to produce a supportable system design and a reasonable support capability to achieve a predetermined set of measurable objectives within an acceptable cost of ownership.' (Jones, 2006:1.1).

xv) **Lambert and Stock:** 'Integrated logistics management refers to administering logistics activities as an integrated system.' (Lambert & Stock; 1993, cited in Juga; 1996:28).

xvi) **Adler:** 'The key to integration is total cost analysis, which seeks to minimize the total cost of logistics at a given level of customer service objectives. Underlying the concept is the systems view promoting formal efforts to apply rational, fact-based methods for solving management problems.' *(Adler; 1967, cited in Juga; 1996:28).*

35) **Internet Users:** '… are people that have used the internet at any point in time during a specific year.' (EarthTrends, 2003). See note 1 of this annexure.

36) **Internet users:** '… people with access to the worldwide network.' (UNDP, 2004).

37) **Level of Democracy/Autocracy:** '… is measured on a scale from -10 to +10 measuring the degree to which a nation is either autocratic or democratic. A score of +10 indicates a strongly democratic state; a score of -10 a strongly autocratic state. A fully democratic government has three essential elements according to the Polity index: fully competitive political participation, institutionalized constraints on executive power, and guarantee of civil liberties to all citizens in their daily lives and in political participation.' (EarthTrends, 2003).

38) **Level of Freedom:** '… one of three levels of freedom for each country: Free (F), Partly Free (PF), or Not Free (NF). In Free countries, a broad range of political rights and civil liberties are respected. Partly Free countries have a mixed record or political rights and civil liberties, often accompanied by corruption, weak rule of law, and the inordinate political dominance of a ruling party, in some cases characterized by ethnic or religious strife. In Not Free countries, basic political rights and civil liberties are denied.' (Freedom House, cited in EarthTrends, 2003).

39) **Level of Political Competition:** '… measures the extent to which alternate preferences for policy and leadership can be pursued in the political arena, on a scale of 0- 5, as follows: "Not Applicable" (0) is used for an "unregulated" government without stable political groups. "Repressed" (1) is assigned to any regime where oppositional activity is not permitted outside of the ruling party. "Suppressed" (2) governments contain some limited political competition outside of government; however, peaceful political competition and large classes of people are excluded from the political process. "Factional" (3) polities contain parochial or ethnic-based political factions that compete for influence in order to promote agendas that favor [sic] the interests of group members over common interests. "Transitional" (4) arrangements accommodate competing interests, but parochial interests are not fully linked with broader, general interests. "Competitive" (5) groups are characterized by relatively stable and enduring political groups with regular competition and voluntary transfer of power.' (EarthTrends, 2003).

40) **Life Cycle Costing (LCC):** 'Encompasses every conceivable direct and indirect cost that will be related to the acquisition, operation, support, and disposal of the system.' (Source: Jones, 1995: 18.1).

41) **Life expectancy at birth:** '… the number of years a newborn infant would live if prevailing patterns of age-specific mortality rates at the time of birth were to stay the same throughout the child 's life.' (UNDP, 2004).

42) **Logistic Support Analysis (LSA):** 'Is an iterative analytical process by which the logistics support necessary for a new system is identified and evaluated.' (Source: Blanchard, 1992:14).

43) **Logistic Support Analysis Record (LSAR):** 'Standard medium to systematically record, store, process, and report various data that supports the LSA objectives.' (Biedenbender, et al, 1993:10). 'The results of the logistic support analysis (LSA) process are recorded in a single database, the logistic support analysis record (LSAR).' (Jones, 1995:20.1)

44) Logistics definitions:

i) **Doctrine for United States Logistics Support of Joint Operations:** *'Seldom will all logistics principles exert equal influence; usually one or two will dominate in any given situation. Identifying those principles that have priority in a specific situation is essential to establishing effective support.'* (United States Joint Pub 4-0, Doctrine for Logistics Support of Joint Operations, 1992).

ii) **Encyclopaedia Britannica:** *'… all the activities of armed-force units in roles supporting combat units, including transport, supply, signal communication, medical aid, and the like.'* (Encyclopaedia Britannica: 2004).

iii) **Council of Supply Chain Management Professionals, (previously Council of Logistics Management):** *'… that part of Supply Chain Management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements.' (Council of Supply Chain Management Professionals, 2005).*

iv) **Society Of Logistics Engineers:** *'the art of science and management, engineering, and technical activities concerned with requirements, design, and supplying and maintaining resources to support objectives, plans, and operations.' (This definition established in 1974 by the Society Of Logistics Engineers (SOLE), Huntsville, Ala., in Blanchard, 1992:4).*

v) **North Atlantic Treaty Organisation (NATO) - Consumer Logistics: '***the science of planning and carrying out the movement and maintenance of forces'. 'In its most comprehensive sense, the term refers to aspects of military operations, which deal with the following spheres:*

1) Design and development, acquisition, storage, transport, distribution, maintenance, evacuation and disposition of materiel.
2) Transport of personnel.
3) Acquisition, construction, maintenance, operation and disposition of facilities.
4) Acquisition or provision of services.
5) Medical and Health Service Support.' (NATO, 2002).

vi) **U.S. Air Force technical report:** 'The science of planning and carrying out the movement and maintenance of forces. In its most comprehensive sense, logistics pertains to those aspects of military operations which deal with

(a) design and development, acquisition, storage, movement, distribution, maintenance, evacuation, and disposition of material;
(b) movement, evacuation, and hospitalization of personnel;
(c) acquisition or construction, maintenance, operation, disposition of facilities; and
(d) acquisition or furnishing of services.' (U.S. Air Force technical report {Compendium of Authenticated Systems and Logistics Terms, Definitions, and Acronyms, 1981} in Blanchard, 1992:2).

vii) **Department of Defence Directive (DoDD) 5000.39:** 'In essence, logistics from a military view has primarily been oriented to distribution and system/product support and has included the elements of maintenance planning; personnel; supply support; support equipment; technical data; training and training devices; computer resources support; facilities; packaging, handling storage, and transportation; and the reliability and maintainability interface.' *(Department of Defence Directive 5000.39, Acquisition and Management of Integrated Logistic Support for Systems and Equipment, Department of Defense, Washington, D.C. 1983. In Blanchard, 1992:3).*

vii) **Jones, J. V. 1998. Integrated Logistics Support Handbook:** '… the applied science of defining supportable systems and of planning and implementing the acquisition and use of resources.' *(Jones, 1998:1.1);*

viii) **Jones, J. V. 2006. Integrated Logistics Support Handbook:** '… the applied science of planning and implementing the acquisition and use of resources. *(Jones, 2006:1-1).*

44) **Maintainability:** 'The probability that a failed item can be repaired in a specific amount of time using a specified set of resources.' (Source, Jones, 1995:3.1).

45) **Maintenance Planning:** 'This includes all planning and analysis associated with the establishment of requirements for the overall support of a system throughout its life cycle.' (Source: Blanchard, 1992:11).

46) **Manufactured exports:** '… defined according to the Standard International Trade classification to include exports of chemicals, basic manufactures, machinery and transport equipment and other miscellaneous manufactured goods.' (UNDP, 2004).

47) **Military expenditure:** '… all expenditures of the defence ministry and other ministries on recruiting and training military personnel as well as on construction and purchase of military supplies and equipment. Military assistance is included in the expenditures of the donor country.' (UNDP, 2004).

48) **Military expenditure:** As defined by the Stockholm International Peace Research Institute (SIPRI). 'Although the lack of sufficiently detailed data makes it difficult to apply a common definition of military expenditure on a worldwide basis, SIPRI has adopted a definition, based on the NATO definition, as a guideline. Where possible, SIPRI military expenditure data include all current and capital expenditure on:

(a) the armed forces, including peacekeeping forces;
(b) defence ministries and other government agencies engaged in defence projects;
(c) paramilitary forces, when judged to be trained and equipped for military operations; and
(d) military space activities.

Such expenditures should include:

(a) military and civil personnel, including retirement pensions of military personnel and social services for personnel;
(b) operations and maintenance;
(c) procurement;
(d) military research and development; and
(e) military aid (in the military expenditure of the donor country). Civil defence and current expenditures on previous military activities, such as veterans' benefits, demobilization, conversion and weapon destruction are excluded.

In practice it is not possible to apply this definition for all countries, since this would require much more detailed information than is available about what is included in military budgets and off-budget military expenditure items. In many cases SIPRI cannot make independent estimates but is confined to using the national data provided. Priority is then given to the choice of a uniform definition over time for each country in order to achieve consistency over time, rather than to adjusting the figures for single years according to a common definition. In cases where it is impossible to use the same source and definition for all years, the percentage change between years in the deviant source is applied to the existing series in order to make the trend as accurate as possible. In the light of these difficulties, military expenditure data are not suitable for close comparison between individual countries and are more appropriately used for comparisons over time.' (SIPRI, 2004c).

49) **Mobile Phone Subscriptions:** '… refer to the users of portable telephones who subscribe to an automatic public mobile telephone.' (EarthTrends, 2003). See note 1 of this appendix.

50) **Net enrolment ratio:** '… the number of students enrolled in a level of education who are of official school age for that level, as a percentage of the population of official school age for that level. See education levels.' (UNDP, 2004).

51) **Number of Internet hosts:** '… refer to the number of computers in the economy that are directly linked to the worldwide Internet network. One internet host can provide access to many internet users. Data are compiled by the Internet Software Consortium and RIPE (Réseaux IP Européens.) (EarthTrends, 2003).

52) **Packaging, handling, storage, and transportation:** 'This element of logistics includes all special provisions, containers (reusable and disposable), and supplies necessary to support packaging, preservation, storage, handling, and/or transportation of prime mission equipment, test and support equipment, spares and repair parts, personnel, technical data, and mobile facilities.' (Source: Blanchard, 1992:12).

53) **Patents granted to residents:** '… refers to documents issued by a government office that describe an invention and create a legal situation in which the patented invention can normally be exploited (made, used, sold, imported) only by or with the authorization of the patentee. The protection of inventions is generally limited to 20 years from the filing date of the application for the grant of a patent.' (UNDP, 2004).

54) **Personnel and training:** 'Personnel required for the installation, checkout, operation, handling, and sustaining maintenance of the system (or product) and its associated test and support equipment. Formal training includes both initial training for system/product familiarization and replenishment training to cover attrition and replacement personnel.' (Source: Blanchard, 1992:12).

55) **Phone Lines:** '… refer to telephone lines connecting a customer's equipment (e. g. telephone set, facsimile machine) to the Public Switched Telephone Network (PSTN) and which have a dedicated port on a telephone exchange. For most countries, main phone lines also include public payphones.' (EarthTrends, 2003). See note 1 of this annexure.

56) **Physicians:** '…includes graduates of a faculty or school of medicine who are working in any medical field (including teaching, research and practice).' (UNDP, 2004).

57) **Political (in)stability (Annett, 2001a):** 'The idea is that these factors capture different dimensions of political instability in the country. The following nine dimensions are employed: (1) genocidal incidents involving communal victims or mixed communal and political victims *(COMPO*L), measured as a dummy variable; (2) the occurrence of a civil war, measured as a dummy variable *(WARCN*); (3) the number of assassinations per thousand population *(ASSAS*S); (4) the number of extraconstitutional or forced changes in the top government elite and/or its effective control of the nation's power structure *(COUP*S); (5) the number of illegal or forced changes in the top government elite, any attempt at such change, or any successful or unsuccessful armed rebellion whose aim is independence from the central government *(REVOL*S); (6) violent demonstrations or clashes involving more than a hundred citizens involving the use of physical force *(RIOT*S); (7) the number of major government crises, where a crisis is defined as any rapidly developing situation threatening to bring the downfall of the present regime, excluding instances of revolt aimed at overthrow *(CRI*S); (8) the number of times in a year that a new premier is named and/or 50 percent of the cabinet posts are occupied by new ministers *(CABCH*G); and (9) the number of basic alterations in a state's constitutional structure, the extreme case being the adoption of a new constitution that significantly alters the prerogatives of the various branches of government *(CONSTCHG*).' (Easterly & Levine, 1997, in Annett, 2001a:576).

58) **Political Rights:** '… rates political rights on a scale of 1 to 7, with 1 representing the most free and 7 representing the least free. A rating of 1 indicates free and fair elections, political competition, and autonomy for all citizens, including minority groups. In countries with a ranking of 2, 3, 4, or 5, corruption, violence, political discrimination against minorities, and military influence on politics play a progressively larger role in political life. Countries and territories with political rights rated 6 are ruled by military juntas, one- party dictatorships, religious hierarchies, or autocrats. For countries with a rating of 7, political rights are basically nonexistent due to extremely oppresive [sic] regimes, civil war, extreme violence or warlord rule.' (Freedom House, cited in EarthTrends, 2003).

59) **Political Stability (Kaufmann, et al, 2003):** 'The Political Stability index measures perceptions of the likelihood that the government in power will be destabilized or overthrown by possibly unconstitutional and/or violent means, including terrorism. This index captures the idea that the quality of governance in a country is compromised by the likelihood of wrenching changes in government, which not only has a direct effect on the continuity of policies, but also at a deeper level undermines the ability of all citizens to peacefully select and replace those in power. The component indicators are aggregated using an unobserved components model that expresses the observed data in each cluster as a linear function of the unobserved common component of governance, plus a disturbance term capturing perception errors and/or sampling variation in each indicator. The choice of units for governance ensures that the estimates of governance have a mean of zero, a standard deviation of one, and range from around –2.5 to around 2.5. Higher or positive values indicate greater political stability.' (Kaufmann, et al, 2003:1).

60) **Polity IV Indices:** '… contain information on regime and authority characteristics for all independent states in the global state system. The Polity IV project consists of a group of international governance experts that assign index values (often numbers) to describe the nature of a country's system of government over time.' (EarthTrends, 2003).

61) **PPP (purchasing power parity):** '…A rate of exchange that accounts for price differences across countries, allowing international comparisons of real output and incomes. At the PPP US$ rate (as used in this Report), PPP US$1 has the same purchasing power in the domestic economy as $1 has in the United States.' (UNDP, 2004).

62) **Press Freedom:** '… "the degree to which each country permits the free flow of information." It is ranked on a scale of 1 to 100. Countries with a score between 1 and 30 are considered to have a "Free" media, 31 to 60, "Partly Free", and 61 to 100, "Not Free". The final index ranking incorporated a number of factors, including the influence of a country's laws and administrative decisions on the media; the degree of state censorship and intimidation; access to information within a country; and, the economic influences on the press from government funding, corruption, licensing bias, or quotas.' (Freedom House, cited in EarthTrends, 2003).

63) **Private health expenditure:** '… direct household (out of pocket) spending, private insurance, spending by non-profit institutions serving households and direct service payments by private corporations. Together with public health expenditure, it makes up total health expenditure. See health expenditure per capita (PPP US$) and health expenditure, public.' (UNDP, 2004).

64) **Public expenditure on education:** '… includes both capital expenditures (spending on construction, renovation, major repairs and purchase of heavy equipment or vehicles)and current expenditures (spending on goods and services that are consumed within the current year and would need to be renewed the following year). It covers such expenditures as staff salaries and benefits, contracted or purchased services, books and teaching materials, welfare services, furniture and equipment, minor repairs, fuel, insurance, rents, telecommunications and travel. See education levels.' (UNDP, 2004).

65) **Public health expenditure:** '… current and capital spending from government (central and local) budgets, external borrowings and grants (including donations from international agencies and non- governmental organizations) and social (or compulsory) health insurance funds. Together with private health expenditure, it makes up total health expenditure. See health expenditure per capita (PPP US$) and health expenditure, private.' (UNDP, 2004).

66) **Quality-of-life index:** '… unique methodology that links the results of subjective life-satisfaction surveys to the objective determinants of quality of life across countries.' (The Economist, 2005). See 'Determinants of quality of life'.

67) **Radar, (Radio detecting and ranging):** '… a method for detecting the position and velocity of a distant object, such as an aircraft. A narrow beam of extremely high-frequency radio pulses is transmitted and reflected by the object back to the transmitter, the signal being displayed on a radarscope. The direction of the reflected beam and the time between transmission and reception of a pulse determine the position of the object.' (Collins, 2004).

68) **Radios:** '… refer to radio receivers used for broadcast to the general public. Private sets installed in public places are also included as well as communal receivers.' (EarthTrends, 2003). See note 1 of this appendix.

69) **Reliability:** 'The probability that an item of equipment will perform its intended mission without failing, assuming that the item is used within the conditions for which it was designed.' (Source: Jones, 1995:2.1).

70) **Reliability Centered Maintenance (RCM):** 'Identify maintenance which can be done on a scheduled basis to avoid unwanted and untimely failures and improve overall system reliability and, therefore, system availability.' (Source: Jones, 1995:16.1).

71) **Research and development expenditures:** '… current and capital expenditures (including overhead)on creative, systematic activity intended to increase the stock of knowledge. Included are fundamental and applied research and experimental development work leading to new devices, products or processes.' (UNDP, 2004).

72) **Researchers in R&D:** '… people trained to work in any field of science who are engaged in professional research and development (R&D) activity. Most such jobs require the completion of tertiary education.' (UNDP, 2004).

73) **Secondary language.** Language endangerment is a serious concern to which linguists and language planners have turned their attention in the last decade. For a variety of reasons, speakers of some languages are motivated to stop using their language and to use another. Parents may begin to use only that second language with their children. Eventually there may be no speakers who use the language as their first or primary language and frequently the language ceases to be used altogether and the language becomes extinct—existing, perhaps, only in recordings or written records and transcriptions. (Gordon, 2005).

74) **Service arc:** 'The area in the GSO in which a satellite may be located and still serve it service area …' (Smith, 1990).

75) **Service area:** '… the portion of the coverage are in which earth stations are actually located and for which a service is actually provided." (Smith, 1990).

76) **Service:** 'The transmission, emission and/or reception of radio waves for specific telecommunication purposes.' (ITU, 1982 in Smith, 1990).

77) **Status of Freedom of Information:** 'Freedom of Information (FOI) laws require disclosure of government records to the public. A country's guarantee of public access to information in classified in one of 3 categories. 1) In Effect: countries that legally guarantee public access to government records, either by recently creating or updating constitutions, or passing FOI legislation. 2) Pending: countries that are considering adopting freedom of information acts. 3) No Data: marked by an 'X.' These are countries where no FOI legislation exists, or, in a few cases, no data is available concerning the status of FOI legislation.' (EarthTrends, 2003). See note 1 of this appendix.

78) **Supply support:** 'Supply support includes all spares (units, assemblies, modules, etc.), repair parts, consumables, special supplies, and related inventories needed to support prime mission-oriented equipment, software, test and support equipment, transportation and handling equipment, training equipment, and facilities.' (Source: Blanchard, 1992:11).

80) **Technology:** 'Technology is a general term for the processes by which human beings fashion tools and machines to increase their control and understanding of the material environment.' (Microsoft, 1995 cited in Cardullo 1996).

'The concept of technology is used in three contexts:

(1) Technology is a combination of means, such as hardware, software and skill, associated with a specific field of technical competence.
(2) Technology is a totality of means created by people to enhance human capability.
(3) Technology is a field of study.

Note the following concepts:

(1) Created - Technology is not a free gift of nature. To be available it first has to be brought into being.
(2) Means - Means are instrumentalities, not ends. In deciding whether one is dealing with ends or means, the function of the entity is the distinguishing feature.
(3) Entities - These are the depositories of capabilities. They may either be concrete or abstract in nature.
(4) Enhance - Mostly this means extending human capability. Sometimes it means replacing human capability.' (Source: R. J. Van Wyk)

81) **Telephone mainlines:** '… telephone lines connecting a customer 's equipment to the public switched telephone network.' (UNDP, 2004).

82) **Television Sets:** '… as used by both businesses and households.' (EarthTrends, 2003). See note 1 of this appendix.

83) **Tertiary students in science, math and engineering:** '… the share of tertiary students enrolled in natural sciences; engineering; mathematics and computer sciences; architecture and town planning; transport and communications; trade, craft and industrial programmes; and agriculture, forestry and fisheries. See education levels.' (UNDP, 2004).

84) **Test and Support Equipment:** 'This category includes all tools, special condition monitoring equipment, diagnostic and checkout equipment, metrology and calibration equipment, maintenance stands, and servicing and handling equipment required to support scheduled and unscheduled maintenance actions associated with the system or product.' (Source: Blanchard, 1992:12).

85) **The Technology Achievement Index (TAI):** '… aims to capture how well a country is creating and diffusing technology and building a human skill base–reflecting capacity to participate in the technological innovations of the network age. This composite index measures achievements, not potential, effort or inputs. It is not a measure of which country is leading in global technology development, but focuses on how well the country as a whole is participating in creating and using technology. (UNDP, Human Development Report, 2001).

86) **Tonne of oil equivalent (toe)**: There are differing definitions in the literature of a *tonne of oil equivalent* (toe). In OECD/IEA publications it is set equal to 10.0 kcal (IT) …, while in other publications it is set equal to 10.7 x 10^6 kcal (thermochemical) …. These choices correspond, respectively, to:
1 toe = 1.00 x 10^{10} cal (IT) = 41.868 GJ = 39.68 MBtu (IT)
and
1 toe = 1.07 x 10^{10} cal (thermochemical) = 44.769 GJ = 42.46 MBtu (thermochemical). (American Physical Society, 2008).

87) **Total armed forces:** '… strategic, land, naval, air, command, administrative and support forces. Also included are paramilitary forces such as the gendarmerie, customs service and border guard, if these are trained in military tactics.' (UNDP, 2004).

88) **Transparency International (TI):** '… is an international non- governmental organisation devoted to combating corruption through coalitions among civil society, business, and governments. As part of their mission, TI collects, analyses and disseminates information on the impact of corruption around the world.' (EarthTrends, 2003).

APPENDIX C: INTEGRATED LOGISTICS SUPPORT ELEMENT AND PLAN DEFINITIONS

C.1 Planned maintenance definition and the maintenance plan:

1) **<u>Planned maintenance:</u>** 'The philosophy, plan, and procedures related to the management, accomplishment, and quality control of preventive and corrective maintenance at each level to retain material in a serviceable condition or restore it to an operable condition once it has failed. Planned maintenance includes servicing, repair, inspection, corrosion control, testing, calibration, overhaul, modification, handling, and storage.' (DoDD 4100.35, cited in Carpenter; 1967:23).

2) **<u>Maintenance plan:</u>**
   - i) '… exactly how maintenance for the system will be accomplished.' (Jones, 1995:6.3);
   - ii) '… how the equipment will be maintained, at what level and depth, and at what overhaul periods the prescribed maintenance shall be undertaken to support the equipment post acceptance trials.' (UK MOD TLSD, [s.a.]);
   - iii) '… is a detailed plan specifying the methods and procedures to be followed for system support throughout the life cycle and during the consumer use period.' (Blanchard, 1992:19);
   - iv) '… is a detailed plan specifying the methods and procedures to be followed for system support throughout the life cycle and during the utilization phase.' (Blanchard, 2004:36); and
   - v) 'this plan provides the integrated planning and analysis process which addresses the requirement to assess the design as it relates to maintenance and the development of maintenance requirements.' (Palguta, Bradley and Stockton, 1987:73).

C.2 *Support and test equipment definitions, and the support and test equipment plan:*

1) **<u>Support equipment definitions:</u>**
   - i) '… all equipment required to support the operation and maintenance of the end item and includes the acquisition logistics support for the support equipment.' Biedenbender, et al (1993:280);
   - ii) '… special purpose vehicles, power units, maintenance stands, test equipment, special tools, and test benches used to facilitate or support maintenance actions, detect or diagnose malfunctions, or monitor the operational status of systems, subsystems, or equipments.' Carpenter (1967:23-24);
   - iii) '… all equipment required to support the operation of a system. It includes associated multi-use items, ground handling and maintenance equipment, tools, test and ATE. It also includes the logistic support for this equipment.' Galloway (1996:27);
   - iv) '… encompassing all equipment (manual and power-operated) and assistance devices used to support the operation and maintenance of the system or product.' Langford (1995:445);
   - v) '… the aggregate of all tools, monitoring equipment, diagnostic and checkout equipment, calibration devices, servicing and handling equipment and maintenance aids such as work benches that are used in the support of the product.' Hutchinson (1987:192); and
   - vi) '… all equipment (mobile or fixed) required to support the operation and maintenance of an equipment. This includes associated multi-use end items, tools, metrology, calibration equipment and test equipment. As part of

this discipline equipment specific Special Tools and Test Equipment (STTE) must be considered.' UK MOD TLSD ([s.a.])

2) Support and test equipment plan: '… identifies and provides common support equipment and software requirements necessary to accommodate organisational, intermediate, and depot level maintenance.' Palguta, et al (1987:76)

C.3 Supply support definitions and the supply support plan:

1) <u>Supply support definitions:</u>

- i) 'All management actions, procedures, and techniques used to determine requirements to acquire, catalog, receive, store, transfer, issue, and dispose of secondary items. This includes provisioning for initial support as well as replenishment supply support.' Palguta, et al (1987:82);
- ii) '… management actions necessary to determine the acquisition cataloguing, packaging, preservation, receiving, storage, transfer and issue and disposal of spare parts, repair parts, consumables and special parts needed to support both scheduled and unscheduled maintenance.' Finkelstein and Guertin (1988:117);
- iii) 'This encompasses all management procedures and techniques used to acquire, catalogue, receive, store, transfer, issue and dispose of all secondary items including provisioning for initial support.' Galloway (1996:27);
- iv) '… all management actions, procedures, and techniques used to determine requirements to acquire, catalog, receive, store, transfer, issue, and dispose of principal and secondary items. This includes provisioning for initial support as well as replenishment supply support.' According to Biedenbender, et al (1993:280);
- v) Supply support – 'spares/repair parts and associated inventories' '… all spares (repairable units, assemblies, modules, etc.), repair parts (nonrepairable components), consumables (liquids, lubricants, gases, disposable items), special supplies, and related inventories needed to maintain the prime mission related equipment, computers and software, test and support equipment, transportation and handling equipment, training equipment, communications equipment, and facilities/utilities. Spares/repair parts are required throughout the system operational (utilization) phase and in support of the retirement and recycling/disposal of system components.' Blanchard (2004:13); and
- vi) '… provisioning documentation, procurement functions, warehousing, distribution of material, and the personnel associated with the acquisition and maintenance of spare/repair part inventories at all support locations. Considerations include each maintenance level and geographical location where spare/repair parts are distributed and stocked; spares demand rates and inventory levels; the distances between stockage points; procurement lead times; and the methods of material distribution.' Blanchard (1992:11-12).

2) <u>Supply support plan:</u> '… the process for meeting the spare and repair parts requirements. This plan will specifically address provisioning procedures and requirements. Also, the plan will address the use of the LSA process and the maintenance plan in the development and definition of spare and repair parts requirements.' (Palguta, et al, 1987:76).

C.4 Packaging; handling; storage; and transportation definitions, and the packaging; handling; storage; and transportation plan:

1) <u>Packaging, handling, storage, and transportation definitions:</u>

- i) '… plan, develop, and manage the activities necessary to ensure that equipment is serviceable when it reaches the ultimate user and when it is moved by the user during its operational life.' (Jones, J. 1995:13.1); and

ii) '… the characteristics, actions, and requirements necessary to ensure the capability to transport, preserve, package, and handle all equipment and support items.' Biedenbender, et al, (1993:282).

2) **<u>'Packaging, handling, storage/warehousing, and transportation (distribution) definition:</u>** '… includes all materials, equipment, special provisions, containers (reusable and disposable), and supplies necessary to support the packaging, safety and preservation, storage, handling, and/or transportation of the prime mission-related elements of the system, personnel, spares and repair parts, test and support equipment, technical data, computer resources, and mobile facilities.' Blanchard (2004:14);

3) **<u>Transportation logistics:</u>** '…must include the firm, the suppliers of the firm, the market area served by the firm, the needs of the firm, and the transportation capabilities of available channels to properly assess and integrate transportation with the other logistic elements.' Hutchinson (1987:22); and

4) **<u>'Physical distribution and transportation' (PD&T)</u>** '… storage of raw materials and finished products, transportation of raw materials and assemblies needed for development of the product; materials handling; inventory control; warehousing; inbound, internal, and outbound flows of materials and service components; order processing and customer service; administration to include determining inventory carrying costs; transportation to wholesalers, retailers, and users; determining user satisfaction, waste disposal; and managing obsolescence in terms of materials, equipment, products and services.' Finkelstein and Guertin (1988:144).

5) **<u>Packaging, handling, storage, and transportation plan:</u>**

i) '… the procedures and resource requirements necessary to insure that all system equipment and support items are transported, preserved, packaged, stored and handled properly.' (Palguta, et al, 1987: 77); and

ii) '… applicable regulations, specifications and related documents that describe and define the packaging, handling and storage requirements. It will also provide identification and procedures for accomplishing transportation and handling in support of installation, transition and operation throughout the system and for the support during the entire life cycle.' (UK MOD TLSD, [s.a.]).

C.5 Technical data and documentation definitions:

1) **<u>Technical data and documentation definition:</u>** '… all recorded information, regardless of form or character, such as manuals, drawings, engineering studies or analyses, or even engineering notes that support the development of the specific design. … computer programs are not considered technical data; however, the documentation of the computer program and its related software are.' '… the recorded information used to define a design and to produce, support, maintain or operate the specific product.' (Finkelstein and Guertin, 1988:133-4).

2) **<u>Technical data definitions:</u>**

i) *'… all recorded data of a scientific/technical nature that are related to a program.' 'This includes drawings, operating and maintenance manuals, test and calibration procedures, and so on. Computer software and financial documentation are not generally considered to be technical data, although software documentation is.'* (Biedenbender, et al, 1993:281); and

ii) *'…all operating and maintenance procedures, special test procedures, installation instructions, checklists, change notices and change procedures and so on, for the prime equipment, support equipment, training equipment, software, transportation and handling equipment, and facilities.' (*Blanchard, 2004:367).

3) **<u>Technical documentation definition:</u>** technical documentation '… all recorded information, regardless of form or character of an instructive or technical nature; for example manuals, drawings and documentation to support both hardware and computer software.' (Galloway, 1996:27).

4) **<u>'Technical logistic data and information' definition:</u>** '… production and engineering data, prints and drawings; documents such as standards, specifications, technical manuals; changes and modifications; inspection and testing procedures; performance and failure data; or other forms of technical logistic data and information acquired from contractors, prepared by Military Departments, or obtained from other Government Departments and Agencies.' (Carpenter, 1967:23).

5) **<u>'Technical data, reports, and documentation' definition:</u>** 'Technical data may include system installation and checkout procedures, operating and maintenance instructions, inspection and calibration procedures, overhaul instructions, facilities data, system modification instructions, engineering design data (specifications, drawings, materials and parts lists, CAD/CAM/CAS data, special reports), logistics provisioning and procurement data, supplier data, system operational and maintenance data, and supporting databases. Included in this category is the ongoing and iterative process of data collection, analysis, and reporting covering the system throughout its life cycle (i.e. the maintenance data collection and assessment capability).' (Blanchard, 2004:13).

C.6 Facilities definitions and facilities planning:

1) **<u>Facilities definition:</u>** '… the planning, acquisition and management of permanent or semi-permanent real estate and property assets required to support the system.' (Galloway, 1996:27).

2) **<u>Facilities planning:</u>** '…includes the facilities and equipment required to support maintenance, training, storage, and installation and checkout.' (Palguta, et al, 1987:77).

C.7 Manpower and personnel plan

1) **<u>'logistics support personnel and training plan':</u>** '… qualitative and quantitative information for use by responsible management agencies to identify maintenance personnel requirements by numbers, skills, other qualifications, and training requirements.' Palguta, et al (1987:76)

C.8 Training and training devices plan:

1) **<u>Personnel and training plan:</u>** 'The specific requirements for maintenance and support personnel in terms of quantities, skill levels, and job classifications by location are determined through the SA process. These requirements are compared with the quantities, skills, and job classifications currently within the user's organisation, and the results lead to the development of a personnel training plan (i.e., the formal training necessary to bring the user personnel skills to he level specified for the system). Although maintenance training is emphasized here, system operator training is sometimes included. This plan should cover the following:

   i) *The training of system operators – type of training, length, basic entry requirements, brief program/course outline, and output expectations. System operator requirements are often determined through system engineering and/or human factors program requirements.*

   ii) *The training of maintenance personnel for all levels – type of training, length, basic entry requirements, brief program/course outline, and output expectations.*

   iii) *Training equipment, devices, aids, simulators, computer resources. Facilities, and data required to support operator and maintenance personnel training.*

   iv) *Proposed schedule for initial operator and maintenance personnel training and for replenishment training throughout the system life cycle (for replacement personnel).'* (Blanchard, 2004:384-5).

C.9 Computer resources definition and computer resources plan:

1) **<u>'Logistics Information System Plan' definition:</u>** '… addresses those data elements, files, reports, and associated hardware and software that provide for status, historical data, trends, management visibility, accountability, performance evaluation, control and allocation of logistics resources.' (Palguta, et al, 1987:77).

2) **<u>Computer resources plan:</u>** 'A detailed listing of maintenance software programs, and the procedures for modifying such programs.' (Blanchard and Fabrycky, 1990:468).

C.10 Reliability, availability, and maintainability:

1) **<u>Reliability definitions:</u>**

i) '… the probability that a system (or product) will perform in a satisfactory manner for a given period of time, or in the accomplishment of a mission, when used under specified operating conditions.' (Blanchard, 2004:47); and

ii) '… the probability that a device will satisfactorily perform a specified function for a specified period of time under given operating conditions.' (Smith and Hinchcliffe, 2004:40).

2) **<u>Inherent availability (A_i) definitions:</u>**

i) '… to determine the net percentage of the time that the system should theoretically be available for its intended use.' (Jones, J. 1995:5.2);

ii) '… the readiness of a system when evaluated under the conditions of an ideal environment.' (Langford, 1995:72); and

iii) '… the probability that a system or equipment, when used under stated conditions in an ideal support environment (i.e., readily available tools, spares, maintenance personnel, etc.), will operate satisfactorily at any point in time a required. It excludes preventive or scheduled maintenance actions, logistics delay time, and administrative delay time …' (Blanchard, 2004:72).

3) **<u>Achieved availability (A_a) definitions:</u>**

i) 'This prediction includes the factor mean time between maintenance (MTBM) rather than MTTR. MTBM makes allowance for periods when the system will not be available because of preventive maintenance activities or when maintenance will not be performed but a failure may of occurred.' (Jones, J. 1995:5.2);

ii) '… defines system readiness under the same ideal environment prescribed for inherent availability …'. '… Applicable for use in system test and evaluation.' (Langford, 1995:81); and

iii) '… the probability that a system or equipment, when used under stated conditions in an ideal support environment (i.e., readily available tools, spares, personnel, etc.), will operate satisfactorily at any point in time.' (Blanchard, 2004:73).

4) **<u>Operational availability (A_o):</u>**

i) 'The actual gauge of the availability of a system is what percentage of the time it is available to perform its mission under actual operating conditions.' (Jones, J. 1995:5.3);

ii) '… the readiness of a system in its actual operational environment.' (Langford, 1995:82); and

iii) '… the probability that a system or equipment, when used under stated conditions in an actual operational environment, will operate satisfactorily when called upon.' (Blanchard, 2004:73).

APPENDIX D: LIST OF TECHNICAL ABBREVIATIONS AND ACRONYMS

ACC	Accident
A_i	Inherent Availability
ALA	Approach and Landing Accidents.
B	Breadth.
BIT	Built In Test
BITE	Built In Test Equipment.
C	Casualties.
CAA	Civil Aviation Authority.
CFIT	Controlled Flight Into Terrain.
CI	Configuration Item.
CM	Configuration Management
COTS	Commercially Off The Shelf
DH	Decision Height.
D-level	Depot level
DME	Distance Measuring Equipment.
DVOR	Doppler VOR.
ERP	Enterprise Resource Planning
ESD	Electrostatic Discharge.
FMECA	Failure Modes, Effects, and Criticality Analysis.
FRACAS	Failure Reporting, Analysis, and Corrective Action System
GPS	Global Positioning System.
GSM	Global System for Mobile Communications.
Hz	Hertz.
I-level	Intermediate level
IOS	Integrated Operational Support
LLCSC	Low Level Computer Software Configuration item.
LORA	Level Of Repair Analysis
LRU	Line Replaceable Unit
LSA	Logistics Support Analysis
LSAR	Logistics Support Analysis Record
MIS	Management Information System.
MRB	Material Review Board
MRI	Master Record Index
O-level	Organisational level
PBS	Physical Breakdown Structure
PEC	Printed Electronic Circuit.
PHS&T	Packaging, Handling, Storage and Transportation
R&D	Research and Development
Radar	Radio Detection (Detecting) And Ranging
RAM	Reliability, Availability, and Maintainability
RCM	Reliability Centred Miantennace
RF	Radio Frequency.
rps	Revolutions per second.
STTE	Special to Type Test Equipment
Tacan	TACtical Air Navigation.
TAT	Turn Around Time.
TLCSC	Top Level Computer Software Configuration item.

UPS	Un-interruptible Power Supply.
UV	Ultra Violet.
VHF	Very High Frequency.
VOR	VHF Omnidirectional Range.
VORTAC	VOR-Tacan.

APPENDIX E: ILS PILOT STUDY QUESTIONNAIRE

INTEGRATED LOGISTICS SUPPORT (ILS) PILOT STUDY QUESTIONNAIRE

Please answer the questions below, either mark them with a cross "×" or a tick "✓", or circle the appropriate option, or highlight the appropriate option, or write/complete the appropriate answer.

SECTION A: DEMOGRAPHIC/GENERAL INFORMATION – FOR STATISTICAL PURPOSES ONLY

Although the following optional questions within this section may be personal, please be so kind as to complete the optional questions, the information will be kept strictly confidential. The information will be used for statistical demographic purposes.

1)	**Gender?**	Female		Male	
2)	**Race?**	Black	Coloured	Indian	White
3)	**Home language?**	Afrikaans	English	Ndebele	Northern Sotho
		Southern Sotho	Swazi	Tsonga	Tswana
		Venda	Xhosa	Zulu	Other:
4)	**In which direction is your basic training?**	Engineering	Financial	Management	
		Other:			
5)	**In which direction is your highest qualification?**	Engineering	Financial	Management	
		Other:			
6)	**Age?**				
7)	**Job title?**				

Please be so kind as to complete the following compulsory questions.

8)	**Organisation name?**			
9)	**Current system involved with?**			
10)	**Other previous systems involved with?**			
11)	**Job orientation?**	Engineering	Maintenance	Management

SECTION B: INFORMATION TECHNOLOGY & KNOWLEDGE MANAGEMENT

You can select more than one appropriate option.

12)	**Which of the following do you have access to?**	Company software, e.g. SAP, eB, Teamcenter, Baan, etc.	Standalone PC	Networked PC – Intranet or Internet	None
13)	**Which of the following do you regularly (5 times a week) use?**	Company software, e.g. SAP, eB, Teamcenter, Baan, etc.	Commercial software, e.g. MS-Office	Networked PC – Intranet or Internet	None

In your opinion rate the following questions with the applicable rating scales given.

Most important = “1”, and “4” = least important.

14)	**Factors which could be used in your company in a better way than you see them being used at the moment (1 to 4)**	Best Practices		Skills	
		Competencies		Knowledge	

Most important = “1”, and “6” = least important.

15)	**Qualities that make information valuable to an organisation in order of importance (1 to 6)**	Accessibility		Timely	
		Assurance		Use	
		Accuracy		Rarity	

SECTION C: INTEGRATED LOGISTICS SUPPORT – HIGH TECHNOLOGY SYSTEM RELATED

Please rate the following questions as they relate to your high-technology system on a scale of 1 to 5, where “1” is least important and “5” is most important

16)	**Necessity to write operator & maintenance documentation in such a manner that operating & maintenance personnel are capable of understanding the contents thereof?**	5	4	3	2	1
17)	**Necessity to include personal warning notices within manuals where personnel safety or/and health is a concern?**	5	4	3	2	1
18)	**Importance of applying configuration management principles with respect to documentation?**	5	4	3	2	1
19)	**Importance of attracting & retaining the applicable skilled personnel to maintain & operate the system**	5	4	3	2	1
20)	**Necessity to define skill levels at each level of maintenance to ensure compatibility with the complexity of maintenance and operator tasks**	5	4	3	2	1
21)	**Necessity of defining the maintenance & operational personnel requirements**	5	4	3	2	1
22)	**Importance of defining human factors engineering/ behavioural research requirements**	5	4	3	2	1
23)	**Necessity for establishing baselines?**	5	4	3	2	1
24)	**Necessity for conducting periodic audits?**	5	4	3	2	1
25)	**Necessity of applying configuration management?**	5	4	3	2	1
26)	**Importance of maintaining a complete physical (product) breakdown structure (PBS) of your system including part numbers and serial numbers?**	5	4	3	2	1

Please answer the following questions either “yes” or “no”.

27)	**Which of the following support and test equipment (S&TE) issues are applicable to your system? (yes or no)**	Supporting/ maintaining the S&TE		Standardization of S&TE	
		Availability of S&TE, & personnel		Periodic audits/ calibration of S&TE	

28)	**Which of the following Plans do you currently use for your system? (yes or no)**	Maintenance Plan		Risk Management Plan	
		Obsolescence Plan		Logistic Support Plan (LSP)	
		Resource Development Plan		Skills Acquisition & Development Plan	
		Disposal/System Retirement Plan		Manpower & Personnel (including Training) Plan	

In your opinion please rate the following questions according to the rating scales given, where "1" is most important and "3" is least important.

29)	**In you opinion rate the following typical disposal costs in order of importance (1 to 3)**	Dismantling/ disassembly costs		Environmental & safety concerns	
		Redesign for alternative use (e.g. demilitarization)			

In your opinion please rate the following questions as they relate to your high-technology system in order of importance, where "1" is most important and "4" is least important.

30)	**Maintenance issues**	Strategic, e.g. maintenance concept, maintenance responsibilities.			
		Analysis, e.g. logistic support analysis (LSA), level of repair analysis (LORA), resource availability, maintenance task analysis, support deficiencies.			
		How to do, e.g. schedule maintenance tasks, preventive maintenance.			
		Cost, e.g. managing total cost of ownership/budget adherence			
31)	**Storage facility requirements**	Impact on reliability of product		Product technological essence/substance	
		Additional repair & spare parts replacement time		Product quantity distributed	
32)	**Packaging requirements**	Withstand environmental conditions		Transportation constraints	
		Protection of equipment		Labelling & identification	
33)	**Training factors**	Personnel skill level related training programs		Ability of training instructors	
		Adequacy of training material		Availability of training devices	
34)	**Effectively manage obsolescence**	Replace complete system		Manage obsolescence under risk	
		Overhaul complete system		Redesign complete or part of system	

In your opinion please rate the following questions as they relate to your high-technology system in order of importance, where “1” is most important and “5” is least important.

35)	**Factors influencing the effectiveness of a maintenance facility**	Failure generation rate		Turnaround time	
		Repair restoration rate		Condition of facility	
		Procurement and administrative lead time			
36)	**Reliability, availability & maintainability (dependability) issues**	Identifying parts with excessive failure rates		Defining the operational availability (A_O)	
		Defining MTTR (mean time to repair) of items		Defining MTBF (mean time between failure) of items	
		Conducting reliability, availability & maintainability (RAM) analyses			

In your opinion please rate the following questions as they relate to your high-technology system in order of importance, where “1” is most important and “6” is least important.

37)	**Common maintenance problems**	Strategic guidelines, philosophy & objectives		Poorly defined & implemented maintenance practices	
		Non-existent maintenance practices		Faulty maintenance work	
		Repeated problems		Proactive maintenence	
38)	**Material handling principles**	Size & dimensions of handled material		Shortest distances to move items	
		Quantity handled		Minimum handling	
		Use automatic and mechanical handling		Standardize handling equipment	
39)	**Possible causes of maintenance personnel error**	Inadequate work space or work layout		Poor environmental conditions	
		Poor supervision		Poor training & procedures	
		Inadequate human factors design, e.g. facilities, equipment, & control panels		Lack of training aids, e.g. test equipment	
40)	**Possible causes of logistics delay time**	Administrative activities		Repair response time	
		Technical data research		Reviews & decisions time	
		Necessary skill allocation		Ordering & shipping time (lead time)	
41)	**System operational requirements**	Basic characteristics		Mission	
		Utilization requirements		Expected life cycle	
		Operational condition of deployments		Number of systems per site	

42)	**Determinants of obsolescence**	Failures		New technology	
		Reliability		Manufacturing/design problem	
		Supportability		Cost to support	

In your opinion please rate the following questions as they relate to your high-technology system in order of importance, where "1' is most important and "7" is least important.

43)	**Types of failures/ defects**	Damage-induced failures		Wear-out failures	
		Operator-induced failures		Vulnerable failures (immature/reliant)	
		Manufacturing defects		First failures	
		Maintenance induced failures			

In your opinion please rate the following questions as they relate to your high-technology system in order of importance, where "1" is most important and "8" is least important.

44)	**Economical decisions as they relate to supply support (spares & repair parts)**	Operational environment		Spare & repair parts lead time	
		Failure probability		Location of system	
		Spare & repair part cost		Consequence of failure	
		Spare & repair part reliability		Spare & repair parts stock levels leading to stock outs	
45)	**Transportation factors**	Obtaining best possible price rate structures		Meeting regulations & regulations	
		Selecting transportation methods		Transportation time	
		Transportation route (national & international)		Service provider (carrier) selection	
		Transportation capability or capacity		Transportation cost	

COMMENTS:

Please be so kind as to provide constructive feedback below concerning this pilot study questionnaire with respect to the following questions, (please write legibly), (should you have additional comments please feel free to add additional paper):

1) Any questions, which are ambiguous, difficult to understand, or which need improvement. Please state possible improvements.

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2) Any questions that are irrelevant or that some questions need to be added to the questionnaire.

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3) Length of questionnaire (number of questions, number of pages, duration to complete).

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APPENDIX F: ILS FINAL STUDY QUESTIONNAIRE – SAAF

sa air force
Department:
Defence
REPUBLIC OF SOUTH AFRICA

UNISA university of south africa

SBL
GRADUATE SCHOOL OF
BUSINESS LEADERSHIP
UNISA

Dear Respondent

31 July 2007

REQUEST TO COMPLETE ATTACHED QUESTIONNAIRE

I am currently an enrolled student for the Doctor of Business Leadership (DBL) Degree at the University of South Africa's (UNISA's) School of Business Leadership (SBL). I am conducting empirical research for my thesis via the attached questionnaire. This is in partial fulfilment of the requirements for this Degree.

I would be extremely grateful if you would take some of your valuable time to respond and complete the attached questionnaire in order that I may obtain data for the empirical research. The empirical research being conducted concerns Integrated Logistics Support in a high-technology industry in a developing country. The questionnaire should not take more than 30 minutes of your time to complete.

My research concerns high-technology systems that require support and maintenance beyond their expected and/or extended life cycles. Where spare parts are not always readily available and encounter the challenges of a developing country.

Regrettably no further explanatory information concerning the research has been included in this letter or the questionnaire, and no explanatory information concerning the questions is or will be made available. The purpose thereof is to receive unbiased responses as far as is reasonably possible.

Please answer all the questions to the best of your ability, using your current experience within your current high-technology system as well as previous experience gained on other high-technology systems. Instructions on completing the questionnaire are provided.

It would be deeply appreciated if you could complete the attached questionnaire and contact me to arrange collection or return it to me before or on the 31 August 2007 by means of one of the following contact or delivery methods:

1) Phone me to collect or arrange collection via courier, my Cell phone number is: 'Cell phine number withheld' (preferred method); or
2) 'Postal address withheld'

Thanking you in advance for your patience, co-operation and assistance in this endeavour.

Yours Sincerely

Keith R. Lambert

INTEGRATED LOGISTICS SUPPORT (ILS) RESEARCH QUESTIONNAIRE

Please answer the questions below, either mark them with a cross "×" or a tick "✓", or circle the appropriate option, or highlight the appropriate option, or write/complete the appropriate answer. Please only complete the questionnaire once.

SECTION A: DEMOGRAPHIC/GENERAL INFORMATION – FOR STATISTICAL PURPOSES ONLY

Although the following questions within this section may be personal, please be so kind as to complete the questions, the information will be kept strictly confidential. The information will strictly be used for statistical demographic purposes only.

1)	**Gender?**	Female		Male	
2)	**Race?**	Black	Coloured	Indian	White
3)	**Home language?**	Afrikaans	English	Ndebele	Northern Sotho
		Southern Sotho	Swazi	Tsonga	Tswana
		Venda	Xhosa	Zulu	Other:
4)	**In which direction is your basic training?**	Engineering	Financial	Management	
5)	**Age?**				
6)	**Organisation name?**				
7)	**Current main system /project involved with?**				
8)	**Job orientation?**	Engineering	Maintenance	Management	

SECTION B: INFORMATION TECHNOLOGY & KNOWLEDGE MANAGEMENT

In your opinion please sort (1 to 3) the options to the following statements, where: Most important = "1", and "3" = Least important. An example is given below.

e.g.	**Important elements of reliability? (1 to 3)**	Satisfactory Performance			3
		Probability	2	Time	1

9)	**Factors which could improve your organisations efficiency (delivery system)**	Best Practices			
		Knowledge		Skills	

10)	**Qualities that make information valuable to an organisation**	Accessibility			
		Accuracy		Timely	

SECTION C: INTEGRATED LOGISTICS SUPPORT – HIGH TECHNOLOGY SYSTEM RELATED

In order to understand the context with which you are answering the remainder of the questionnaire, please indicate your experience & knowledge base below in question 11:

11)	**Design of new system**		**Maintenance (relatively new system, less than five years old)**		**Maintenance (system older than five years)**	

Please rate the necessity of the following questions as they relate to your high-technology system on a scale of 1 to 5, where "1" is most necessary and "5" is least necessary.

12)	**Writing operator & maintenance documentation in such a manner that operating & maintenance personnel are capable of understanding the contents thereof?**	1	2	3	4	5
13)	**Defining the maintenance & operational personnel requirements**	1	2	3	4	5
14)	**Conduct periodic audits?**	1	2	3	4	5
15)	**Applying configuration management?**	1	2	3	4	5

Please rate the importance of the following questions as they relate to your high-technology system on a scale of 1 to 5, where "1" is most important and "5" is least important.

16)	**Applying configuration management principles with respect to documentation?**	1	2	3	4	5
17)	**Attracting & retaining the applicable skilled personnel to maintain & operate the system**	1	2	3	4	5

In your opinion rate (on a scale of 1 to 3) each of the options to the following statements as they relate to your high-technology system, where: Most important = "1", and "3" = Least important. An example is given below.

e.g.	**Important elements of reliability? (1 to 3)**	Satisfactory Performance			3
		Probability	1	Time	3

18)	**Support and Test Equipment (S&TE) factors used on your system that require improvement**	Availability of S&TE, & personnel	
		S&TE standardization	
		S&TE support/maintenance	

In your opinion please sort (1 to 3) the options to the following statements as they relate to your high-technology system, where: Most important = "1", and "3" = Least important. An example is given below.

e.g.	**Important elements of reliability? (1 to 3)**	Satisfactory Performance			3
		Probability	2	Time	1

19)	**Maintenance issues**	Analysis, e.g. Logistic Support Analysis, Level Of Repair Analysis, resource availability, maintenance task analysis.	
		Cost, e.g. managing total cost of ownership/budget adherence	
		Strategic, e.g. maintenance concept & responsibilities	

20)	**Reliability, availability & maintainability (RAM) - (dependability) issues**	Conducting RAM analyses	
		Defining the operational availability (A_O)	
		Identifying parts with excessive failure rates	

21)	**Common maintenance problems**	Faulty maintenance work	
		Poorly defined & implemented maintenance practices	
		Strategic guidelines, philosophy & objectives	

22)	**Material handling principles**	Minimum handling	
		Size & dimensions of handled material	
		Standardize handling equipment	

23)	**System operational requirements (beyond life cycle)**	Expected life cycle	
		Operational condition of deployments	
		Utilization requirements	

Please rate the importance of the following statement with respect to **determinants of obsolescence** as they relate to your high-technology system on a scale of 1 to 5, where "1" is most important and "5" is least important.

24a)	Cost to support	1	2	3	4	5
24b)	New technology	1	2	3	4	5
24c)	Reliability	1	2	3	4	5
24d)	Supplier (Original Equipment Manufacturer – OEM) supportability	1	2	3	4	5

Please rate the importance of the following statement with respect to **economical decisions as they relate to supply support** as they relate to your high-technology system on a scale of 1 to 5, where "1" is most important and "5" is least important.

25a)	Consequence of failure	1	2	3	4	5
25b)	Cost to repair	1	2	3	4	5
25c)	Distance to support	1	2	3	4	5
25d)	Failure probability	1	2	3	4	5
25e)	Lead-time to repair	1	2	3	4	5
25f)	Operational environment	1	2	3	4	5
25g)	Reliability of repaired system	1	2	3	4	5

APPENDIX G: ILS FINAL STUDY QUESTIONNAIRE – INDUSTRIAL ORGANISATIONS – E-MAILED

Dear Respondent

28 August 2007

REQUEST TO COMPLETE ATTACHED QUESTIONNAIRE

I am currently an enrolled student for the Doctor of Business Leadership (DBL) Degree at the University of South Africa's (UNISA's) School of Business Leadership (SBL). I am conducting empirical research for my thesis via the attached questionnaire. This is in partial fulfilment of the requirements for this Degree.

I would be extremely grateful if you would take some of your valuable time to respond and complete the attached questionnaire in order that I may obtain data for the empirical research. The empirical research being conducted concerns Integrated Logistics Support in a high-technology industry in a developing country. The questionnaire should not take more than 30 minutes of your time to complete.

My research concerns high-technology systems that require support and maintenance beyond their expected and/or extended life cycles. Where spare parts are not always readily available and encounter the challenges of a developing country.

Regrettably no further explanatory information concerning the research has been included in this letter or the questionnaire, and no explanatory information concerning the questions is or will be made available. The purpose thereof is to receive unbiased responses as far as is reasonably possible.

Please answer all the questions to the best of your ability, using your current experience within your current high-technology system as well as previous experience gained on other high-technology systems. Instructions on completing the questionnaire are provided.

It would be deeply appreciated if you could complete the attached questionnaire and contact me to arrange collection or return it to me before or on the 14 September 2007 by means of one of the following contact or delivery methods:

1) E-mail the questionnaire back to me at: 'e-mail address withheld' (preferred method); or
2) Phone me to collect, my Cell phone number is: 'Cell phone number withheld'.

Thanking you in advance for your patience, co-operation and assistance in this endeavour.

Yours Sincerely

Keith R. Lambert

INTEGRATED LOGISTICS SUPPORT (ILS) RESEARCH QUESTIONNAIRE

This questionnaire is also available at the following URL: <http://www.sbleds.ac.za/sbldbs/SBLSurve.nsf/SurveyILSResearch.html>. Please only complete the questionnaire once.

Please answer the questions below, either mark them with a cross "×" or a tick "✓", or circle the appropriate option, or highlight the appropriate option, or write/complete the appropriate answer.

SECTION A: DEMOGRAPHIC/GENERAL INFORMATION – FOR STATISTICAL PURPOSES ONLY

Although the following questions within this section may be personal, please be so kind as to complete the questions, the information will be kept strictly confidential. The information will strictly be used for statistical demographic purposes only.

1)	**Gender?**	Female	Male		
2)	**Race?**	Black	Coloured	Indian	White
3)	**Home language?**	Afrikaans	English	Ndebele	Northern Sotho
		Southern Sotho	Swazi	Tsonga	Tswana
		Venda	Xhosa	Zulu	Other:
4)	**In which direction is your basic training?**	Engineering	Financial	Management	
5)	**Age?**				
6)	**Organisation name?**				
7)	**Current main system /project involved with?**				
8)	**Job orientation?**	Engineering	Maintenance	Management	

SECTION B: INFORMATION TECHNOLOGY & KNOWLEDGE MANAGEMENT

In your opinion please sort (1 to 3) the options to the following statements, where: Most important = "1", and "3" = Least important. An example is given below.

e.g.	**Important elements of reliability? (1 to 3)**	Satisfactory Performance			3
		Probability	2	Time	1

9)	Factors which could improve your organisations efficiency (delivery system)	Best Practices			
		Knowledge		Skills	

10)	**Qualities that make information valuable to an organisation**	Accessibility			
		Accuracy		Timely	

SECTION C: INTEGRATED LOGISTICS SUPPORT – HIGH TECHNOLOGY SYSTEM RELATED

In order to understand the context with which you are answering the remainder of the questionnaire, please indicate your experience & knowledge base below in question 11:

11)	Design of new system		Maintenance (relatively new system, less than five years old)		Maintenance (system older than five years)	

Please rate the necessity of the following questions as they relate to your high-technology system on a scale of 1 to 5, where "1" is most necessary and "5" is least necessary.

12)	**Writing operator & maintenance documentation in such a manner that operating & maintenance personnel are capable of understanding the contents thereof?**	1	2	3	4	5
13)	**Defining the maintenance & operational personnel requirements**	1	2	3	4	5
14)	**Conduct periodic audits?**	1	2	3	4	5
15)	**Applying configuration management?**	1	2	3	4	5

Please rate the importance of the following questions as they relate to your high-technology system on a scale of 1 to 5, where "1" is most important and "5" is least important.

16)	**Applying configuration management principles with respect to documentation?**	1	2	3	4	5
17)	**Attracting & retaining the applicable skilled personnel to maintain & operate the system**	1	2	3	4	5

In your opinion rate (on a scale of 1 to 3) each of the options to the following statements as they relate to your high-technology system, where: Most important = "1", and "3" = Least important. An example is given below.

e.g.	**Important elements of reliability? (1 to 3)**	Satisfactory Performance			3
		Probability	1	Time	3

18)	**Support and Test Equipment (S&TE) factors used on your system that require improvement**	Availability of S&TE, & personnel	
		S&TE standardization	
		S&TE support/maintenance	

In your opinion please sort (1 to 3) the options to the following statements as they relate to your high-technology system, where: Most important = "1", and "3" = Least important. An example is given below.

e.g.	**Important elements of reliability? (1 to 3)**	Satisfactory Performance			3
		Probability	2	Time	1

19)	**Maintenance issues**	Analysis, e.g. Logistic Support Analysis, Level Of Repair Analysis, resource availability, maintenance task analysis.	
		Cost, e.g. managing total cost of ownership/budget adherence	
		Strategic, e.g. maintenance concept & responsibilities	

20)	**Reliability, availability & maintainability (RAM) - (dependability) issues**	Conducting RAM analyses	
		Defining the operational availability (A_O)	
		Identifying parts with excessive failure rates	

21)	**Common maintenance problems**	Faulty maintenance work	
		Poorly defined & implemented maintenance practices	
		Strategic guidelines, philosophy & objectives	

22)	**Material handling principles**	Minimum handling	
		Size & dimensions of handled material	
		Standardize handling equipment	

23)	**System operational requirements (beyond life cycle)**	Expected life cycle	
		Operational condition of deployments	
		Utilization requirements	

Please rate the importance of the following statement with respect to **determinants of obsolescence** as they relate to your high-technology system on a scale of 1 to 5, where "1" is most important and "5" is least important.

24a)	**Cost to support**	1	2	3	4	5
24b)	**New technology**	1	2	3	4	5
24c)	**Reliability**	1	2	3	4	5
24d)	**Supplier (Original Equipment Manufacturer – OEM) supportability**	1	2	3	4	5

Please rate the importance of the following statement with respect to **economical decisions as they relate to supply support** as they relate to your high-technology system on a scale of 1 to 5, where "1" is most important and "5" is least important.

25a)	**Consequence of failure**	1	2	3	4	5
25b)	**Cost to repair**	1	2	3	4	5
25c)	**Distance to support**	1	2	3	4	5
25d)	**Failure probability**	1	2	3	4	5
25e)	**Lead-time to repair**	1	2	3	4	5
25f)	**Operational environment**	1	2	3	4	5
25g)	**Reliability of repaired system**	1	2	3	4	5

In your opinion rate (on a scale of 1 to 3) each of the options to the following statement as they relate to your high-technology system, where: Most important = "1", and "3" = Least important. An example is given below.

e.g.	**Important elements of reliability? (1 to 3)**	Satisfactory Performance			3
		Probability	1	Time	3

26)	**Using the following plans to improve your systems performance**	Disposal/System Retirement Plan		Risk Management Plan	
		Maintenance Plan		Manpower & Personnel (including Training) Plan	
		Obsolescence Plan			

In your opinion please sort (1 to 3) the options to the following statements as they relate to your high-technology system, where: Most important = "1", and "3" = Least important. An example is given below.

e.g.	**Important elements of reliability? (1 to 3)**	Satisfactory Performance			3
		Probability	2	Time	1

27)	**Typical disposal costs**	Dismantling/ disassembly costs		Environmental & safety concerns	
		Redesign for alternative use (e.g. demilitarization)			

28)	**Storage facility requirements**	Additional repair & spare parts lead time	
		Impact on reliability of product	
		Product quantity distributed	

29)	**Packaging requirements**	Labelling & identification	
		Protection of equipment during transportation	
		Transportation constraints	

30)	**Training factors**	Ability of training instructors	
		Adequacy of training material	
		Personnel skill level related training programs	

31)	**Effectively manage obsolescence**	Manage obsolescence under risk	
		Redesign complete or part of system	
		Replace complete system	

32)	**Possible causes of maintenance personnel error**	Inadequate work space or work layout	
		Poor supervision	
		Poor training & procedures	

33)	**Possible causes of logistics delay time**	Administrative & approval activities	
		Ordering & shipping time (lead time)	
		Technical knowledge & specification	

34)	**Types of failures/ defects**	Maintenance induced failures	
		Operator-induced failures	
		Wear-out (predictable) failures	

APPENDIX H: DESCRIPTIVE STATISTICS OF THE FINAL QUESTIONNAIRE DATA

MIL/IND				
MIL_IND	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Military	122	65.24	122	65.24
Industrial	65	34.76	187	100.00

Gender				
Q1	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Female	17	9.19	17	9.19
Male	168	90.81	185	100.00

Not defined = 2

Race				
Q2	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Black	31	17.03	31	17.03
Coloured	4	2.20	35	19.23
Indian	3	1.65	38	20.88
White	143	78.57	181	99.45
Other	1	0.55	182	100.00

Not defined = 5

Home language				
Q3	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Afrikaans	115	62.16	115	62.16
English	37	20.00	152	82.16
Northern Sotho	7	3.78	159	85.95
Southern Sotho	3	1.62	162	87.57
Tsonga	1	0.54	163	88.11
Tswana	10	5.41	173	93.51
Venda	1	0.54	174	94.05
Xhosa	7	3.78	181	97.84
Zulu	2	1.08	183	98.92
German	1	0.54	184	99.46
Kiswahili	1	0.54	185	100.00

Not defined = 2

In which direction is your basic training				
Q4	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Engineering	145	78.80	145	78.80
Financial	2	1.09	147	79.89
Management	37	20.11	184	100.00

Not defined = 3

Age?				
age1	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
20-30	34	18.48	34	18.48
31-40	62	33.70	96	52.17
41-50	56	30.43	152	82.61
51-67	32	17.39	184	100.00

Not defined = 3

Age?				
age2	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
20-24	6	3.26	6	3.26
25-34	50	27.17	56	30.43
35-44	64	34.78	120	65.22
45-54	50	27.17	170	92.39
55-64	13	7.07	183	99.46
65-74	1	0.54	184	100.00

Not defined = 3

Organisation Name /Institution Name				
Q6	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Military and assoc	131	70.43	131	70.43
Industrial - Existing	21	11.29	152	81.72
Industrial - Planned	34	18.28	186	100.00

Not defined = 1

Current Main system/ project involved with				
Q7	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Ground systems	52	33.77	52	33.77
Aircraft	42	27.27	94	61.04
Support	33	21.43	127	82.47
Mechanical	27	17.53	154	100.00

Not defined = 33

Job orientation				
Q8	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Engineering	68	37.16	68	37.16
Maintenance	44	24.04	112	61.20
Management	71	38.8	183	100.00

Not defined = 4

Factors which could improve your organisations efficiency (delivery system). Best practices				
Q9A	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	69	38.55	69	38.55
Neutral	36	20.11	105	58.66
Least important	74	41.34	179	100.00

Frequency Missing = 8

Factors which could improve your organisations efficiency (delivery system). Knowledge				
Q9B	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	67	37.64	67	37.64
Neutral	67	37.64	134	75.28
Least important	44	24.72	178	100.00

Frequency Missing = 9

Factors which could improve your organisations efficiency (delivery system). Skills				
Q9C	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	67	37.64	67	37.64
Neutral	70	39.33	137	76.97
Least important	41	23.03	178	100.00

Frequency Missing = 9

Qualities that make information valuable to an organisation. Accessibility				
Q10A	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	58	32.22	58	32.22
Neutral	63	35.00	121	67.22
Least important	59	32.78	180	100.00

Frequency Missing = 7

Qualities that make information valuable to an organisation. Accuracy				
Q10B	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	99	55.31	99	55.31
Neutral	50	27.93	149	83.24
Least important	30	16.76	179	100.00

Frequency Missing = 8

Qualities that make information valuable to an organisation. Timely				
Q10C	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	37	20.79	37	20.79
Neutral	69	38.76	106	59.55
Least important	72	40.45	178	100.00

Frequency Missing = 9

Indicate the option which best applies to you				
Q11	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Design of new system	59	31.55	59	31.55
Maintenance (relatively new system, less than five years old)	43	23.00	102	54.55
Maintenance (system older than five years)	85	45.45	187	100.00

Writing operator & maintenance documentation in such a manner that operating & maintenance personnel are capable of understanding the contents thereof				
Q12	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most necessary	128	68.45	128	68.45
Necessary	36	19.25	164	87.70
Neutral	15	8.02	179	95.72
Less necessary	6	3.21	185	98.93
Least necessary	2	1.07	187	100.00

Defining the maintenance & operational personnel requirements				
Q13	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most necessary	61	32.62	61	32.62
Necessary	80	42.78	141	75.40
Neutral	32	17.11	173	92.51
Less necessary	11	5.88	184	98.40
Least necessary	3	1.60	187	100.00

Conduct periodic audits				
Q14	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most necessary	39	20.97	39	20.97
Necessary	62	33.33	101	54.30
Neutral	53	28.49	154	82.80
Less necessary	24	12.90	178	95.70
Least necessary	8	4.30	186	100.00

Frequency Missing = 1

Applying configuration management				
Q15	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most necessary	88	47.06	88	47.06
Necessary	54	28.88	142	75.94
Neutral	31	16.58	173	92.51
Less necessary	13	6.95	186	99.47
Least necessary	1	0.53	187	100.00

Applying configuration management principles with respect to documentation				
Q16	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	93	50.00	93	50.00
important	66	35.48	159	85.48
Neutral	17	9.14	176	94.62
Less important	5	2.69	181	97.31
Least important	5	2.69	186	100.00

Frequency Missing = 1

Attracting & retaining the applicable skilled personnel to maintain & operate the system				
Q17	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	111	59.36	111	59.36
Important	48	25.67	159	85.03
Neutral	17	9.09	176	94.12
Less important	9	4.81	185	98.93
Least important	2	1.07	187	100.00

Support and Test Equipment (S&TE) factors used on your system that require improvement. Availability of S&TE and personnel				
Q18A	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	125	68.68	125	68.68
Neutral	34	18.68	159	87.36
Least important	23	12.64	182	100.00

Frequency Missing = 5

Support and Test Equipment (S&TE) factors used on your system that require improvement. S&TE standardisation				
Q18B	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	39	21.55	39	21.55
Neutral	53	29.28	92	50.83
Least important	89	49.17	181	100.00

Frequency Missing = 6

Support and Test Equipment (S&TE) factors used on your system that require improvement. S&TE support/maintenance				
Q18C	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	50	27.47	50	27.47
Neutral	90	49.45	140	76.92
Least important	42	23.08	182	100.00

Frequency Missing = 5

Maintenance issues. Analysis, e.g. Logistic Support Analysis, Level Of Repair Analysis, resource availability, maintenance task analysis				
Q19A	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	91	50.00	91	50.00
Neutral	56	30.77	147	80.77
Least important	35	19.23	182	100.00

Frequency Missing = 6

Maintenance issues. Cost, e.g. managing total cost of ownership/budget adherence				
Q19B	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	50	27.62	50	27.62
Neutral	61	33.70	111	61.33
Least important	70	38.67	181	100.00

Frequency Missing = 6

Maintenance issues. Strategic, e.g. maintenance concept & responsibilities				
Q19C	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	54	29.51	54	29.51
Neutral	80	43.72	134	73.22
Least important	49	26.78	183	100.00

Frequency Missing = 4

Reliability, availability & maintainability (RAM) - (dependability) issues. Conducting RAM analyses				
Q20A	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	67	36.81	67	36.81
Neutral	62	34.07	129	70.88
Least important	53	29.12	182	100.00

Frequency Missing = 5

Reliability, availability & maintainability (RAM) - (dependability) issues. Defining the operational availability				
Q20B	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	54	29.83	54	29.83
Neutral	72	39.78	126	69.61
Least important	55	30.39	181	100.00

Frequency Missing = 6

Reliability, availability & maintainability (RAM) - (dependability) issues. Identifying parts with excessive failure rates				
Q20C	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	92	50.55	92	50.55
Neutral	52	28.57	144	79.12
Least important	38	20.88	182	100.00

Frequency Missing = 5

Common Maintenance Problems. Faulty maintenance work				
Q21A	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	56	30.60	56	30.60
Neutral	68	37.16	124	67.76
Least important	59	32.24	183	100.00

Frequency Missing = 4

Common Maintenance Problems. Poorly defined & implemented maintenance practices				
Q21B	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	76	41.53	76	41.53
Neutral	76	41.53	152	83.06
Least important	31	16.94	183	100.00

Frequency Missing = 4

Common Maintenance Problems. Strategic guidelines, philosophy & objectives				
Q21C	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	61	33.33	61	33.33
Neutral	51	27.87	112	61.20
Least important	71	38.80	183	100.00

Frequency Missing = 4

Material handling principles. Minimum handling				
Q22A	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	75	40.98	75	40.98
Neutral	60	32.79	135	73.77
Least important	48	26.23	183	100.00

Frequency Missing = 4

Material handling principles. Size and dimensions of handled material				
Q22B	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	40	21.86	40	21.86
Neutral	79	43.17	119	65.03
Least important	64	34.97	183	100.00

Frequency Missing = 4

Material handling principles. Standardise handling equipment				
Q22C	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	67	36.61	67	36.61
Neutral	72	39.34	139	75.96
Least important	44	24.04	183	100.00

Frequency Missing = 4

System operational requirements (beyond life cycle). Expected life cycle				
Q23A	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	60	33.15	60	33.15
Neutral	44	24.31	104	57.46
Least important	77	42.54	181	100.00

Frequency Missing = 6

System operational requirements (beyond life cycle). Operational condition of deployments				
Q23B	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	73	40.33	73	40.33
Neutral	66	36.46	139	76.80
Least important	42	23.20	181	100.00

Frequency Missing = 6

System operational requirements (beyond life cycle). Utilisation requirements				
Q23C	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	67	37.02	67	37.02
Neutral	74	40.88	141	77.90
Least important	40	22.10	181	100.00

Frequency Missing = 6

Determinants of obsolescence. Cost of support				
Q24A	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	62	33.88	62	33.88
Important	61	33.33	123	67.21
Neutral	37	20.22	160	87.43
Less important	14	7.65	174	95.08
Least important	9	4.92	183	100.00

Frequency Missing = 4

Determinants of obsolescence. New technology				
Q24B	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	55	29.89	55	29.89
Important	58	31.52	113	61.41
Neutral	46	25.00	159	86.41
Less important	18	9.78	177	96.20
Least important	7	3.80	184	100.00

Frequency Missing = 3

Determinants of obsolescence. Reliability				
Q24C	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	118	64.48	118	64.48
Important	42	22.95	160	87.43
Neutral	18	9.84	178	97.27
Less important	3	1.64	181	98.91
Least important	2	1.09	183	100.00

Frequency Missing = 5

Determinants of obsolescence. Supplier supportability				
Q24D	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	71	38.80	71	38.80
Important	62	33.88	133	72.68
Neutral	32	17.49	165	90.16
Less important	13	7.10	178	97.27
Least important	5	2.73	183	100.00

Frequency Missing = 4

Economical decisions as they relate to supply support. Consequence of failure				
Q25A	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	92	49.73	92	49.73
Important	62	33.51	154	83.24
Neutral	19	10.27	173	93.51
Less important	2	1.08	175	94.59
Least important	10	5.41	185	100.00

Frequency Missing = 2

Economical decisions as they relate to supply support. Cost to repair				
Q25B	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	55	29.57	55	29.57
Important	72	38.71	127	68.28
Neutral	41	22.04	168	90.32
Less important	15	8.06	183	98.39
Least important	3	1.61	186	100.00

Frequency Missing = 1

Economical decisions as they relate to supply support. Distance to support				
Q25C	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	40	21.62	40	21.62
Important	44	23.78	84	45.41
Neutral	60	32.43	144	77.84
Less important	31	16.76	175	94.59
Least important	10	5.41	185	100.00

Frequency Missing = 2

Economical decisions as they relate to supply support. Failure probability				
Q25D	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	41	22.16	41	22.16
Important	68	36.76	109	58.92
Neutral	57	30.81	166	89.73
Less important	15	8.11	181	97.84
Least important	4	2.16	185	100.00

Frequency Missing = 2

Economical decisions as they relate to supply support. Lead time to repair				
Q25E	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	64	34.59	64	34.59
Important	68	36.76	132	71.35
Neutral	38	20.54	170	91.89
Less important	11	5.95	181	97.84
Least important	4	2.16	185	100.00

Frequency Missing = 2

Economical decisions as they relate to supply support. Operational environment				
Q25F	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	63	34.43	63	34.43
Important	59	32.24	122	66.67
Neutral	48	26.23	170	92.90
Less important	12	6.56	182	99.45
Least important	1	0.55	183	100.00

Frequency Missing = 4

Economical decisions as they relate to supply support. Reliability of repaired system				
Q25G	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	103	55.38	103	55.38
Important	55	29.57	158	84.95
Neutral	19	10.22	177	95.16
Less important	7	3.76	184	98.92
Least important	2	1.08	186	100.00

Frequency Missing = 1

Industrial Questionnaires only 65 Responses

Using the following plans to improve your systems performance. Disposal plan				
Q26A	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	4	6.45	4	6.45
Neutral	18	29.03	22	35.48
Least important	40	64.52	62	100.00

Not defined = 3

Using the following plans to improve your systems performance. Maintenance plan				
Q26B	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	43	66.15	43	66.15
Neutral	20	30.77	63	96.92
Least important	2	3.08	65	100.00

Using the following plans to improve your systems performance. Manpower plan				
Q26C	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	29	45.31	29	45.31
Neutral	28	43.75	57	89.06
Least important	7	10.94	64	100.00

Not defined = 1

Using the following plans to improve your systems performance. Obsolescence Plan				
Q26D	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	13	20.63	13	20.63
Neutral	34	53.97	47	74.60
Least important	16	25.40	63	100.00

Not defined = 2

Using the following plans to improve your systems performance. Risk management plan				
Q26E	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Most important	31	47.69	31	47.69
Neutral	29	44.62	60	92.31
Least important	5	7.69	65	100.00

Typical disposal costs. Dismantling/disassembly costs				
Q27A	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Most important	15	23.08	15	23.08
Neutral	28	43.08	43	66.15
Least important	22	33.85	65	100.00

Typical disposal costs. Environmental & safety concerns				
Q27B	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Most important	38	58.46	38	58.46
Neutral	14	21.54	52	80.00
Least important	13	20.00	65	100.00

Typical disposal costs. Redesign for alternative use (e.g. demilitarization)				
Q27C	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Most important	12	18.46	12	18.46
Neutral	23	35.38	35	53.85
Least important	30	46.15	65	100.00

Storage facility requirements. Additional repair & spare parts lead time				
Q28A	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Most important	20	30.77	20	30.77
Neutral	27	41.54	47	72.31
Least important	18	27.69	65	100.00

Storage facility requirements. Impact on reliability of product				
Q28B	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Most important	34	52.31	34	52.31
Neutral	22	33.85	56	86.15
Least important	9	13.85	65	100.00

Storage facility requirements. Product quantity distributed				
Q28C	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Most important	11	16.92	11	16.92
Neutral	16	24.62	27	41.54
Least important	38	58.46	65	100.00

Packaging requirements. Labeling & identification				
Q29A	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Most important	21	32.31	21	32.31
Neutral	20	30.77	41	63.08
Least important	24	36.92	65	100.00

Packaging requirements. Protection of equipment during transportation				
Q29B	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Most important	34	52.31	34	52.31
Neutral	25	38.46	59	90.77
Least important	6	9.23	65	100.00

Packaging requirements. Transportation constraints				
Q29C	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Most important	10	15.38	10	15.38
Neutral	20	30.77	30	46.15
Least important	35	53.85	65	100.00

Training factors. Ability of training instructors				
Q30A	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	29	44.62	29	44.62
Neutral	21	32.31	50	76.92
Least important	15	23.08	65	100.00

Training factors. Adequacy of training material				
Q30B	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	13	20.00	13	20.00
Neutral	28	43.08	41	63.08
Least important	24	36.92	65	100.00

Training factors. Personnel skill level related training programs				
Q30C	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	23	35.38	23	35.38
Neutral	16	24.62	39	60.00
Least important	26	40.00	65	100.00

Effectively manage obsolescence. Manage obsolescence under risk				
Q31A	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	38	58.46	38	58.46
Neutral	12	18.46	50	76.92
Least important	15	23.08	65	100.00

Effectively manage obsolescence. Redesign complete or part of system				
Q31B	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	19	29.23	19	29.23
Neutral	33	50.77	52	80.00
Least important	13	20.00	65	100.00

Effectively manage obsolescence. Replace complete system				
Q31C	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	8	12.31	8	12.31
Important	20	30.77	28	43.08
Least important	37	56.92	65	100.00

Possible causes of maintenance personnel error. Inadequate work space or work layout				
Q32A	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	4	6.15	4	6.15
Neutral	25	38.46	29	44.62
Least important	36	55.38	65	100.00

Possible causes of maintenance personnel error. Poor supervision				
Q32B	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	10	15.38	10	15.38
Neutral	32	49.23	42	64.62
Least important	23	35.38	65	100.00

Possible causes of maintenance personnel error. Poor training & procedures				
Q32C	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	51	78.46	51	78.46
Neutral	8	12.31	59	90.77
Least important	6	9.23	65	100.00

Possible causes of logistics delay time. Administrative and approval activities				
Q33A	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	26	40.00	26	40.00
Neutral	25	38.46	51	78.46
Least important	14	21.54	65	100.00

Possible causes of logistics delay time. Ordering & Shipping time (lead time)				
Q33B	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	26	40.00	26	40.00
Neutral	24	36.92	50	76.92
Least important	15	23.08	65	100.00

Possible causes of logistics delay time. Technical knowledge & specification				
Q33C	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	13	20.00	13	20.00
Neutral	16	24.62	29	44.62
Least important	36	55.38	65	100.00

Types of failures/ defects. Maintenance induced failures				
Q34A	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	15	23.08	15	23.08
Neutral	29	44.62	44	67.69
Least important	21	32.31	65	100.00

Types of failures/ defects. Operator induced failures				
Q34B	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	23	35.38	23	35.38
Neutral	24	36.92	47	72.31
Least important	18	27.69	65	100.00

Types of failures/ defects. Wear-out (predictable) failures				
Q34C	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Most important	27	41.54	27	41.54
Neutral	12	18.46	39	60.00
Least important	26	40.00	65	100.00

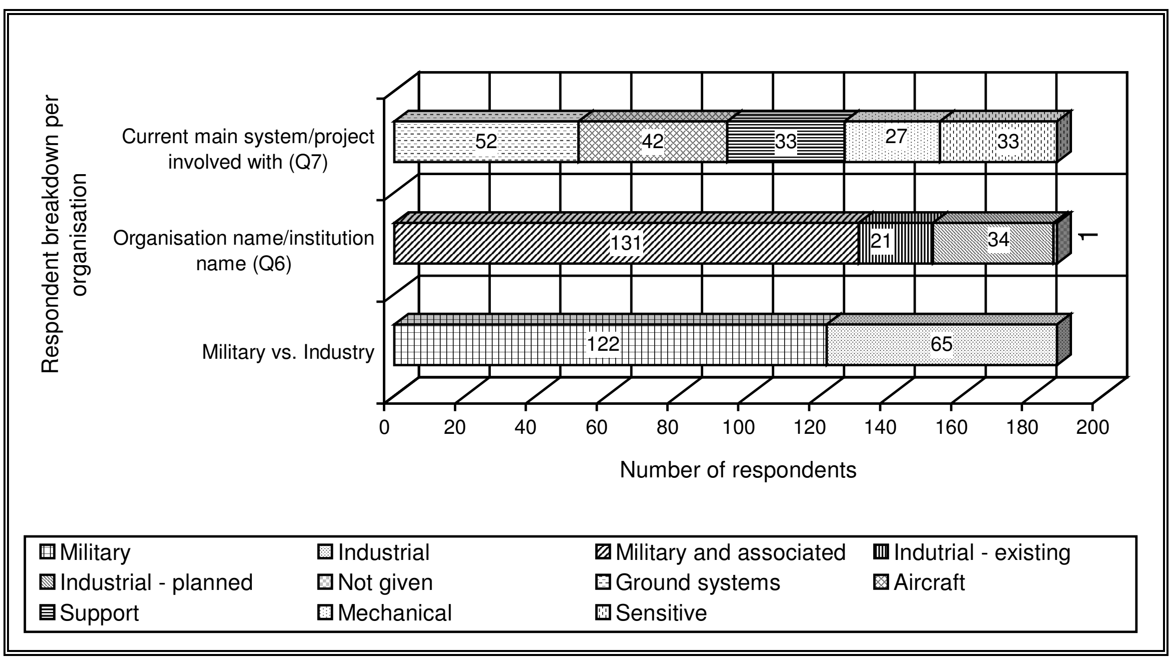

Figure H–1: Respondent breakdown per organisation

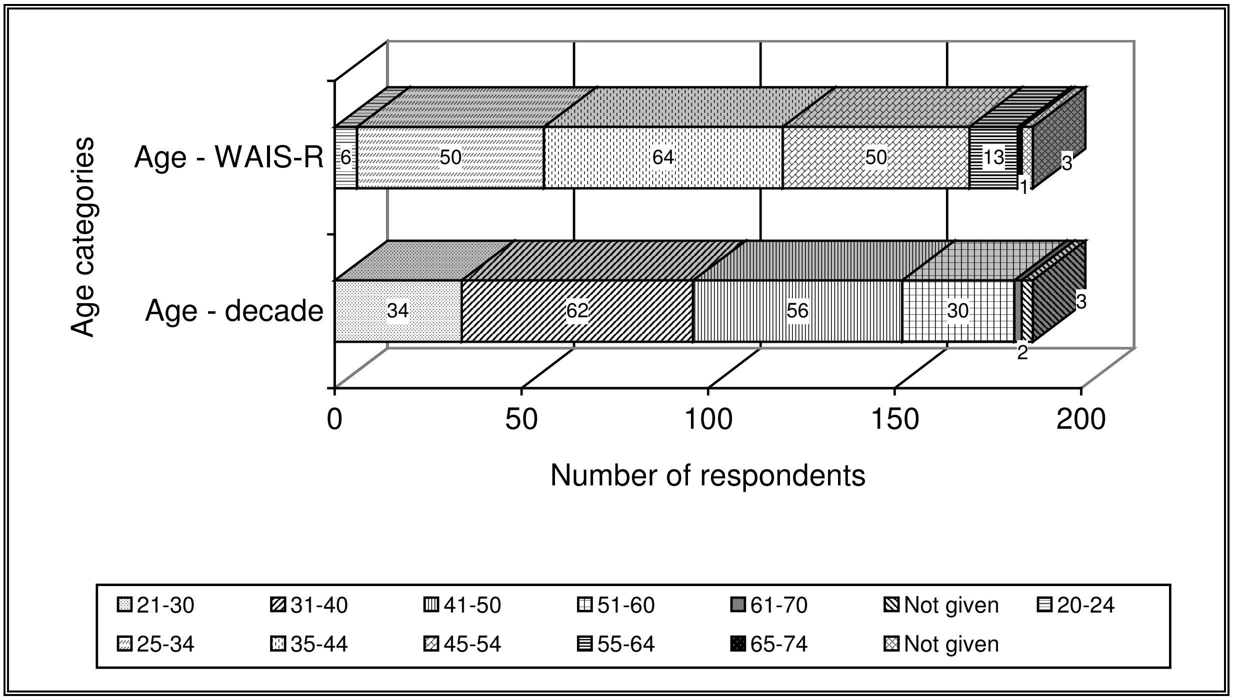

Figure H–2: Question 5 – Respondent age

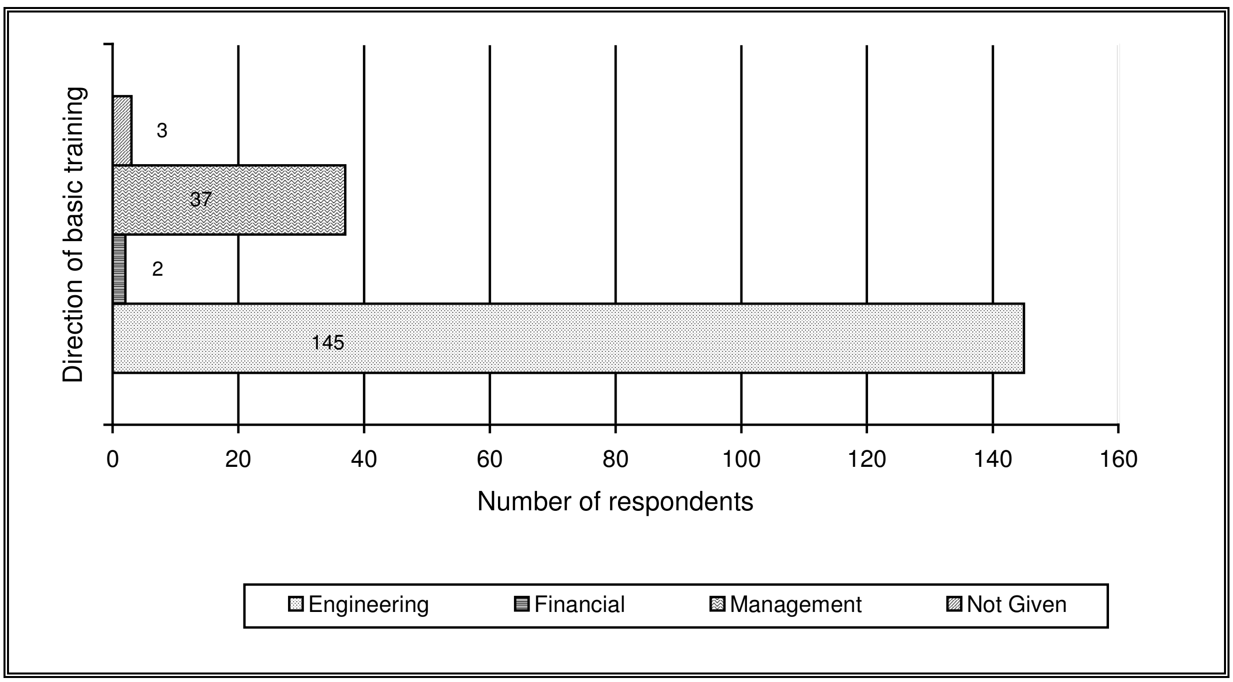

Figure H–3: Question 4 – In which direction is your basic training?

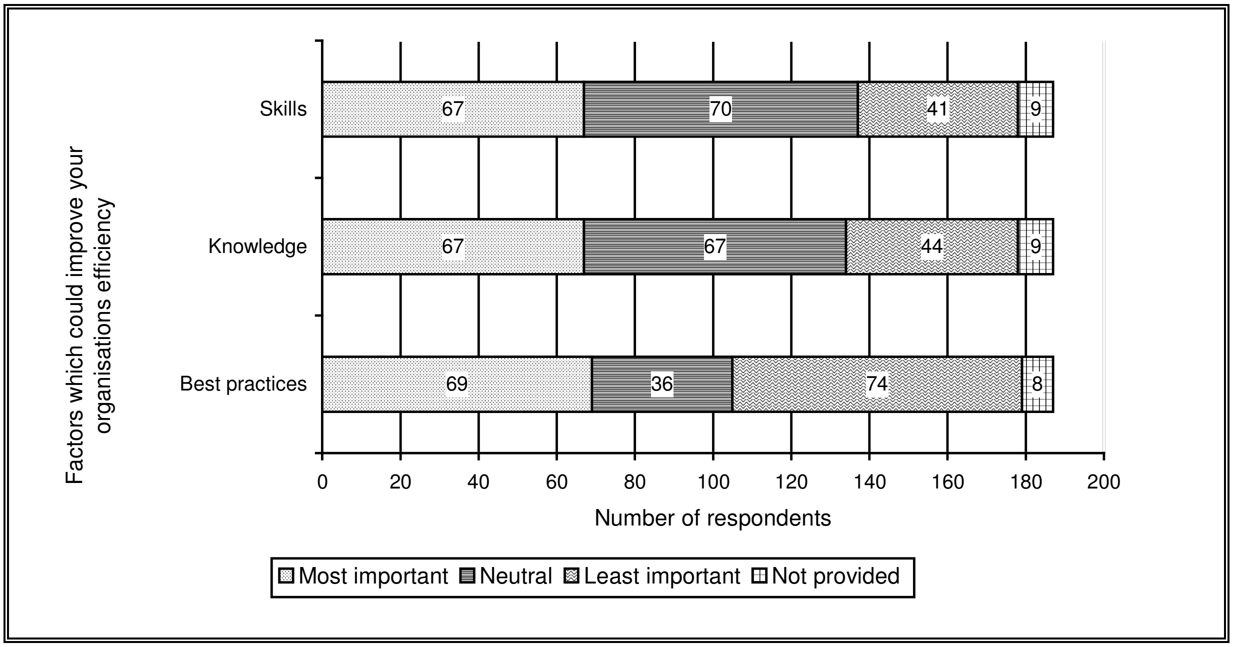

Figure H–4: Question 9 – Factors which could improve your organisation efficiency

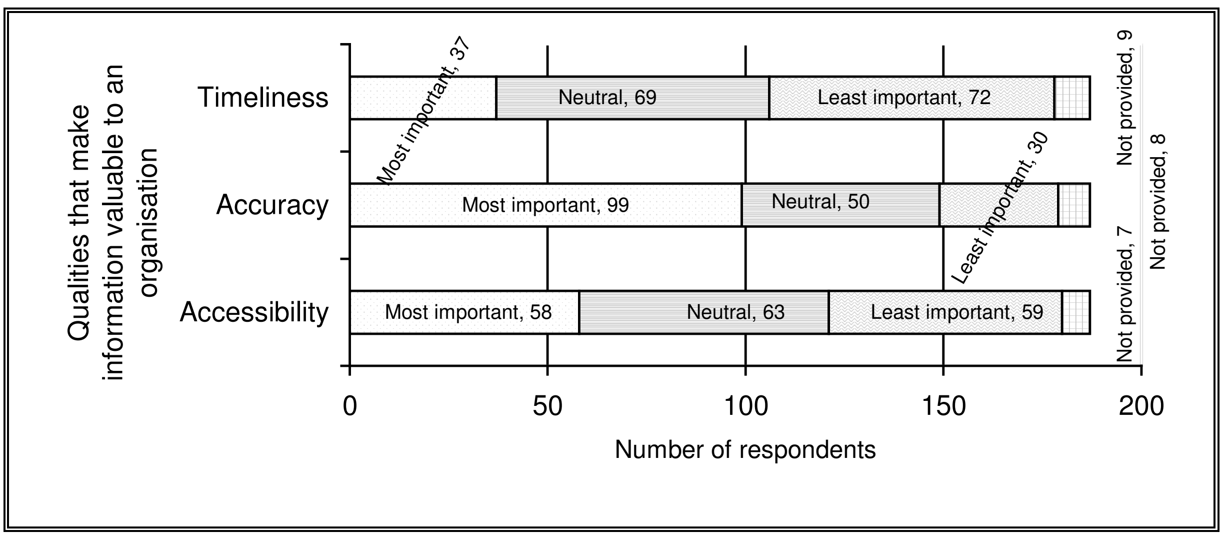

Figure H–5: Question 10 – Qualities that make information valuable to an organisation

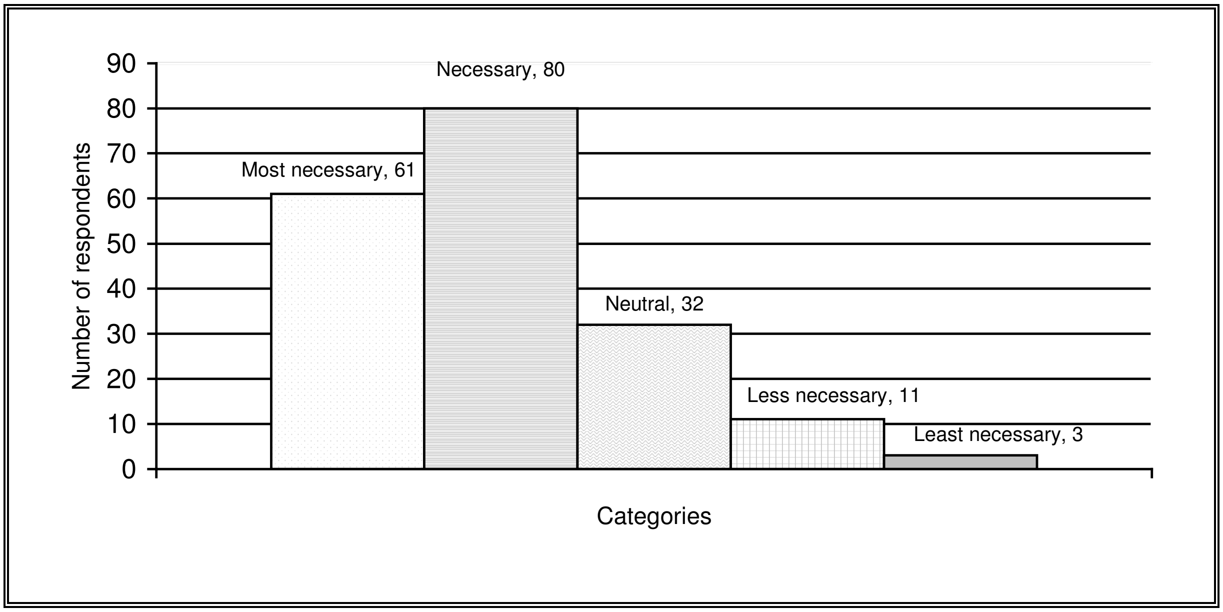

Figure H–6: Question 13 – Defining the maintenance and operational personnel requirements

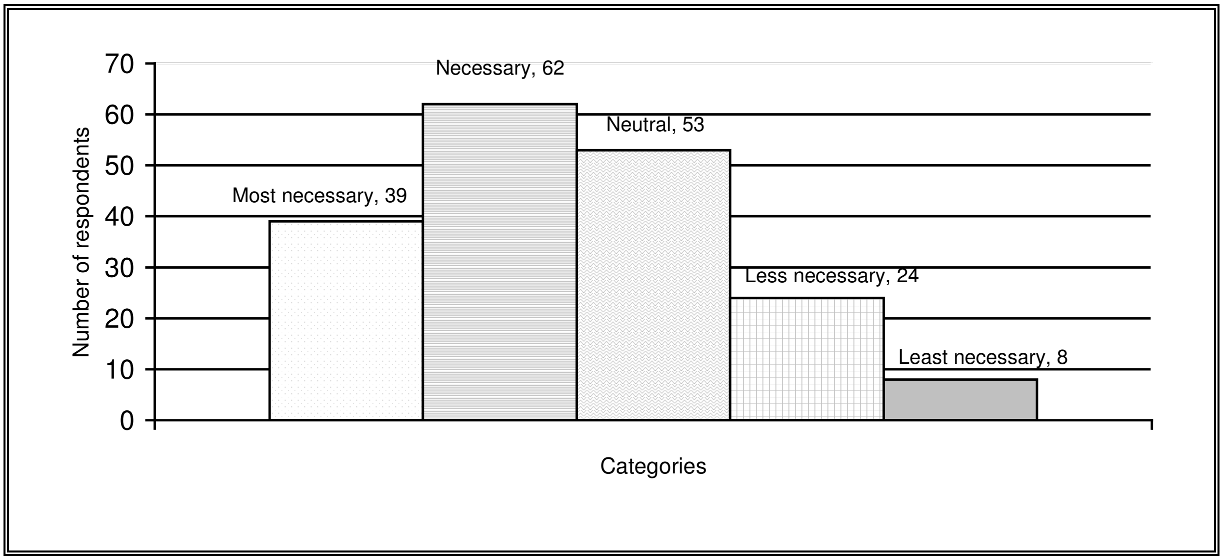

Figure H–7: Question 14 – Conduct periodic audits

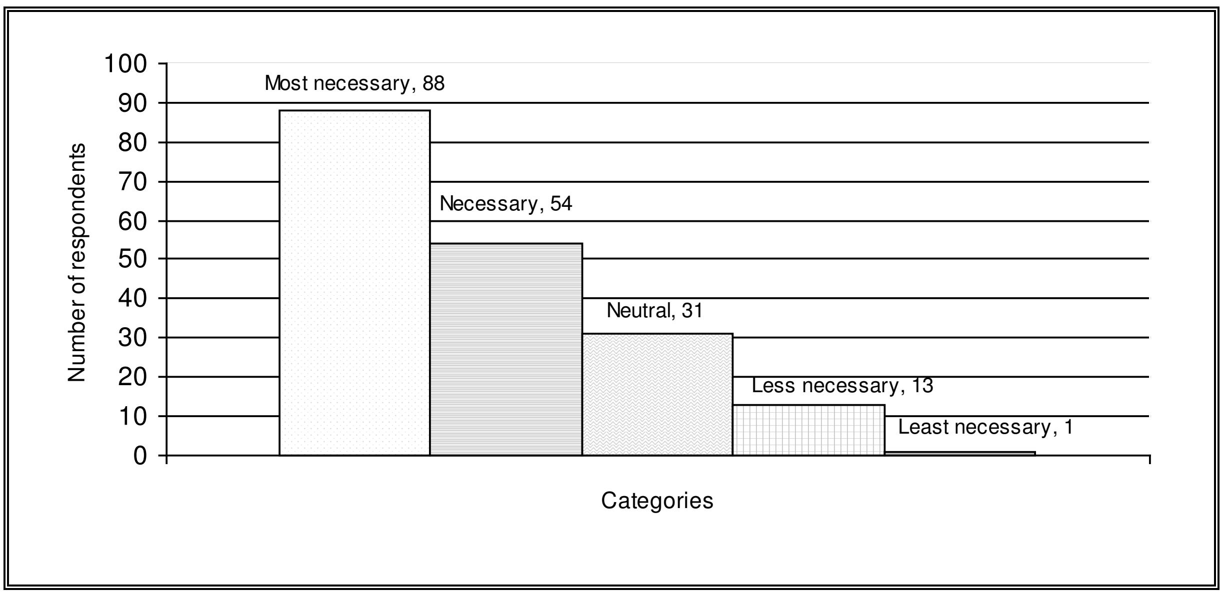

Figure H–8: Question 15 – Applying configuration management

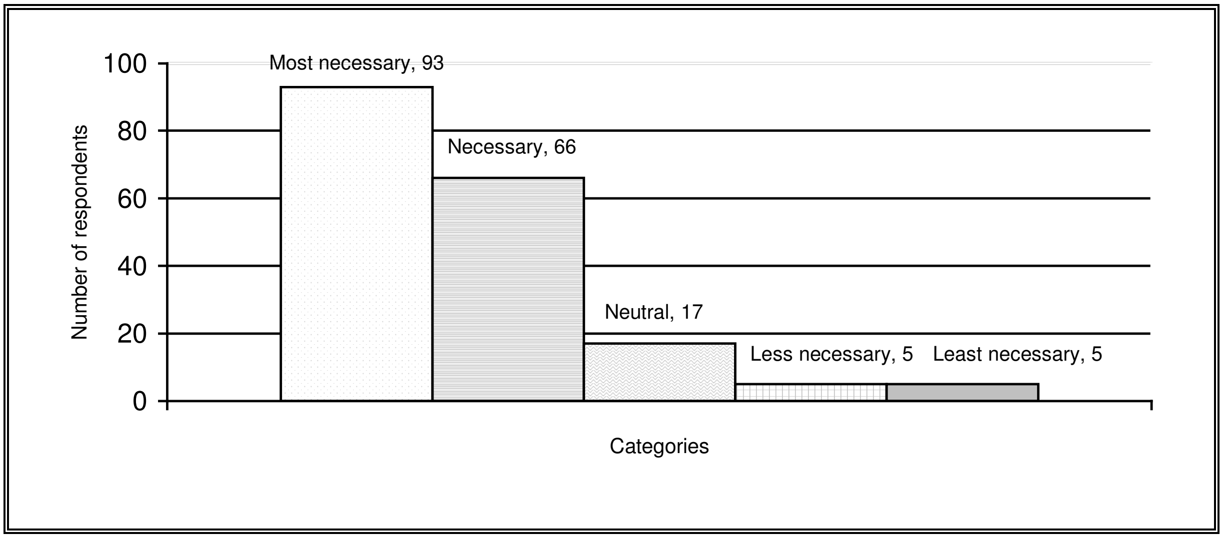

Figure H–9: Question 16 – Applying configuration management principles with respect to documentation

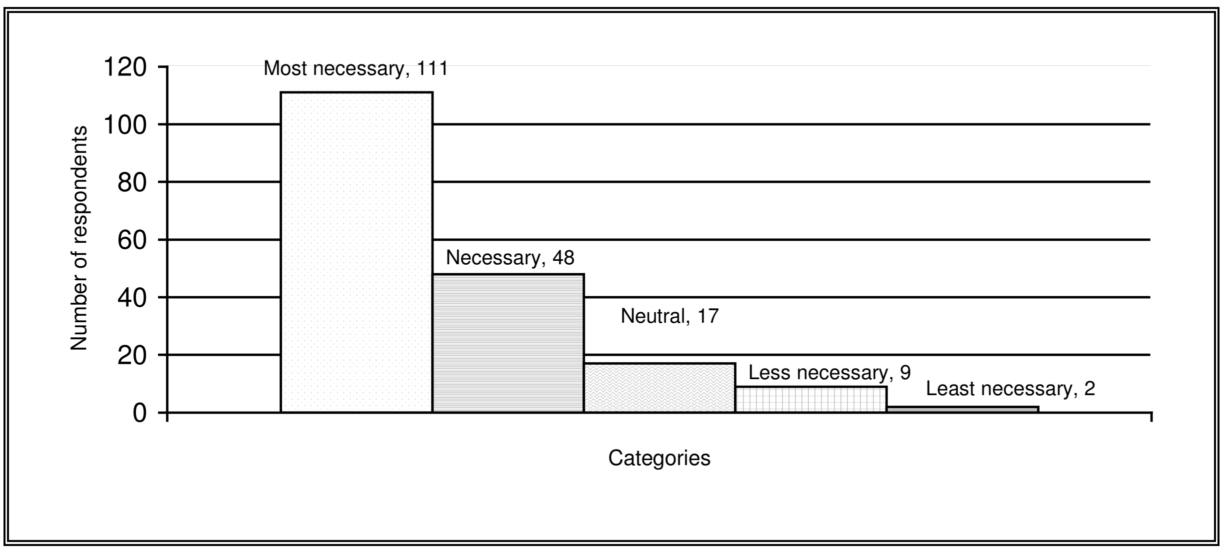

Figure H–10: Question 17 – Attracting and retaining applicably skilled personnel to maintain and operate the system

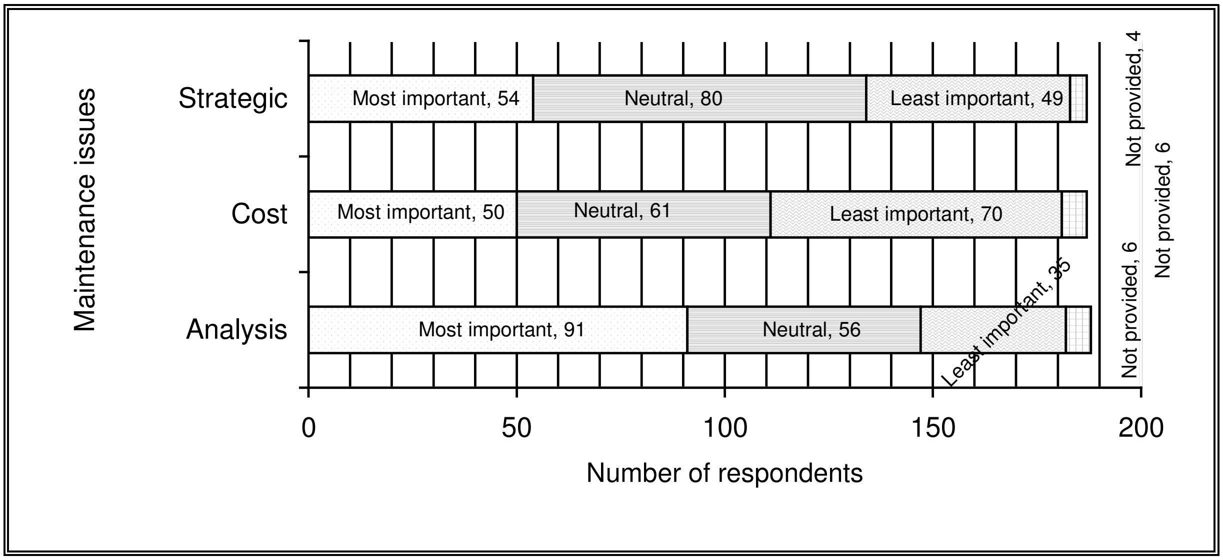

Figure H–11: Question 19 – Maintenance issues

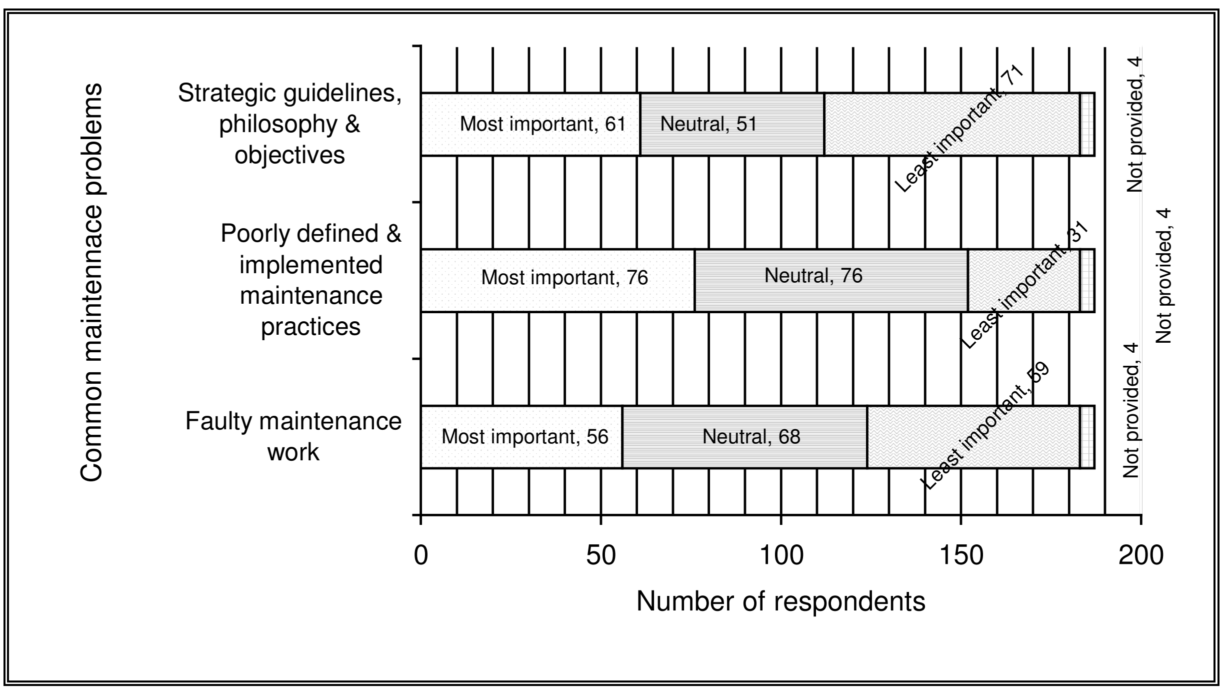

Figure H–12: Question 21 – Common maintenance problems

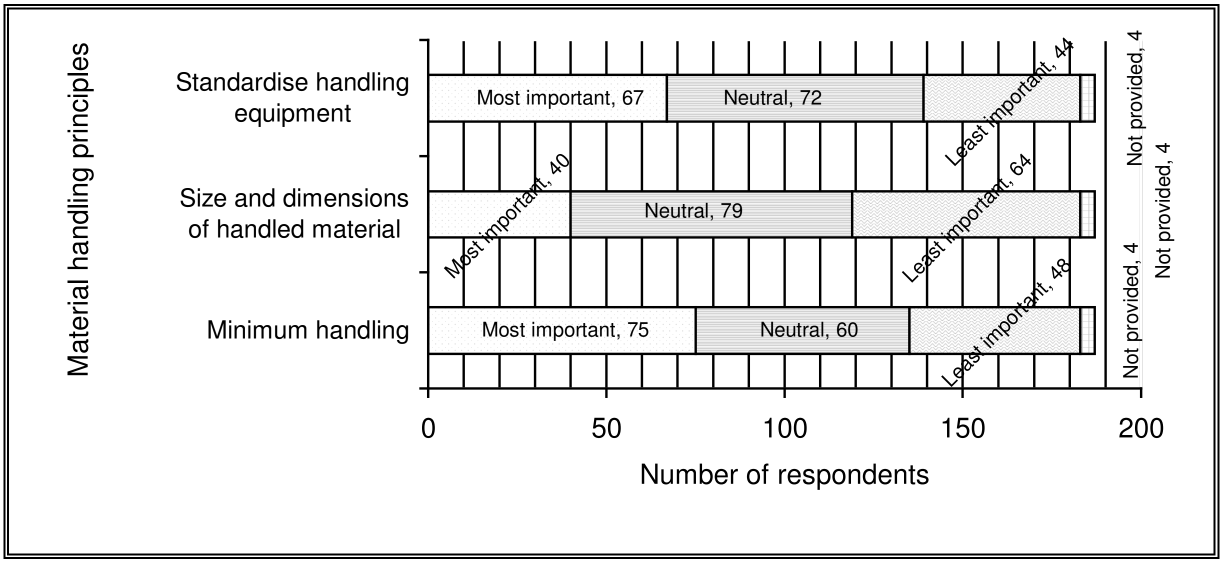

Figure H–13: Question 22 – Material handling principles

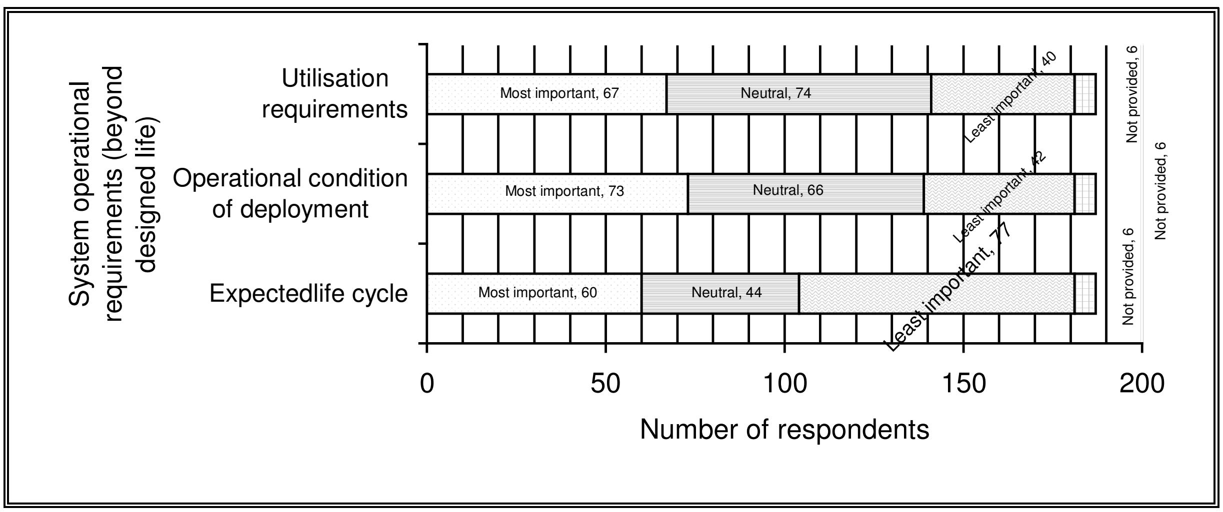

Figure H–14: Question 23 – System operational requirements (beyond life cycles)

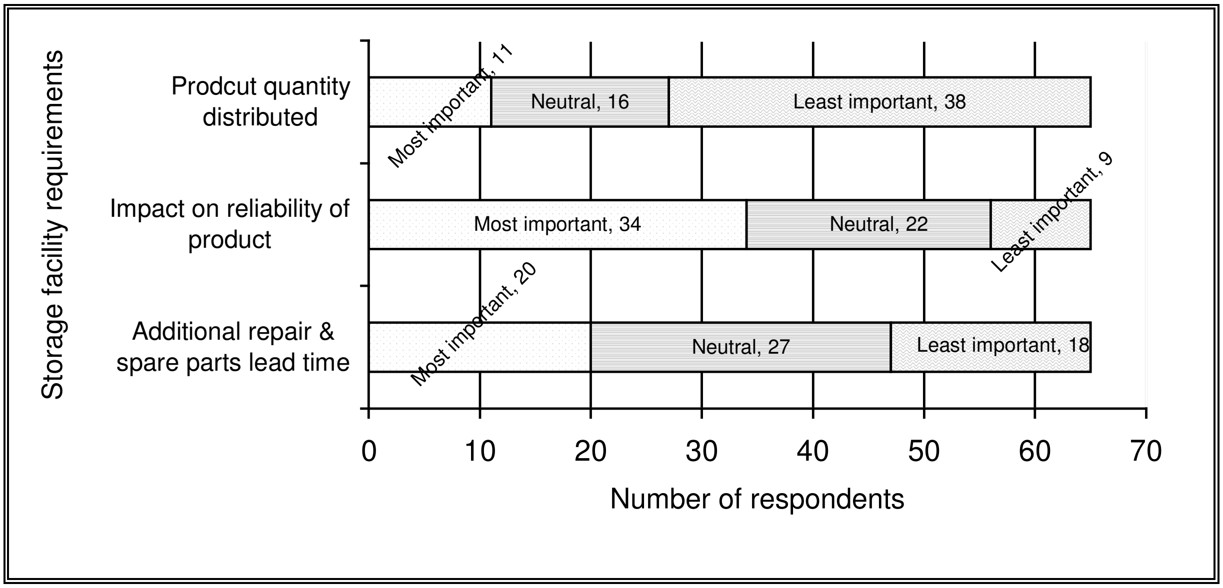

Figure H–15: Question 28 – Storage facility requirements

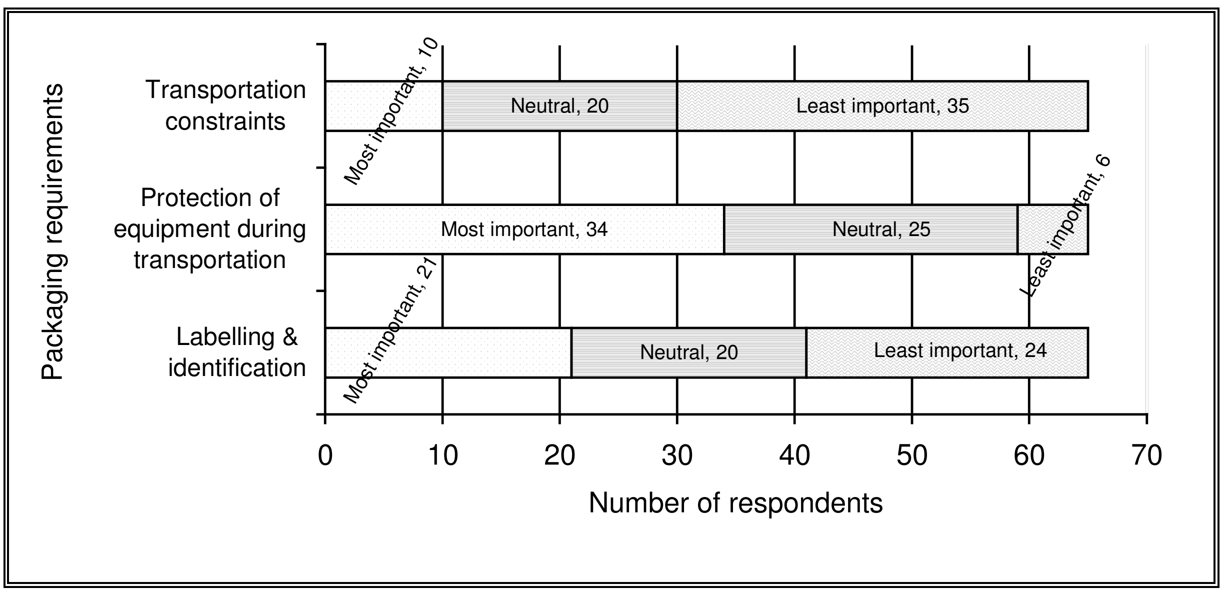

Figure H–16: Question 29 – Packaging requirements

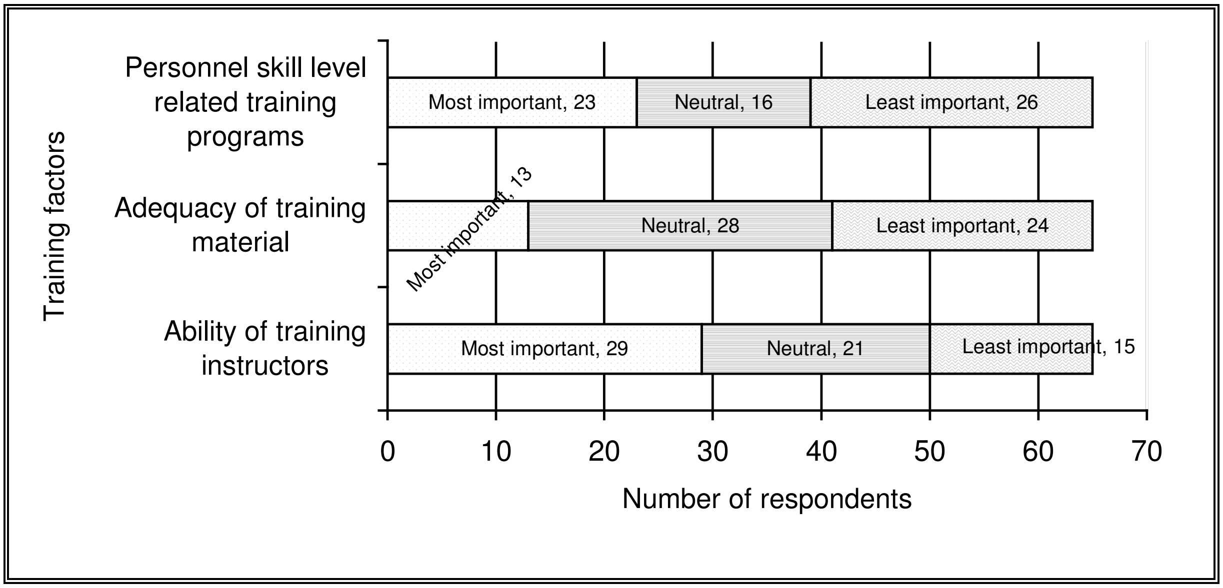

Figure H–17: Question 30 – Training factors

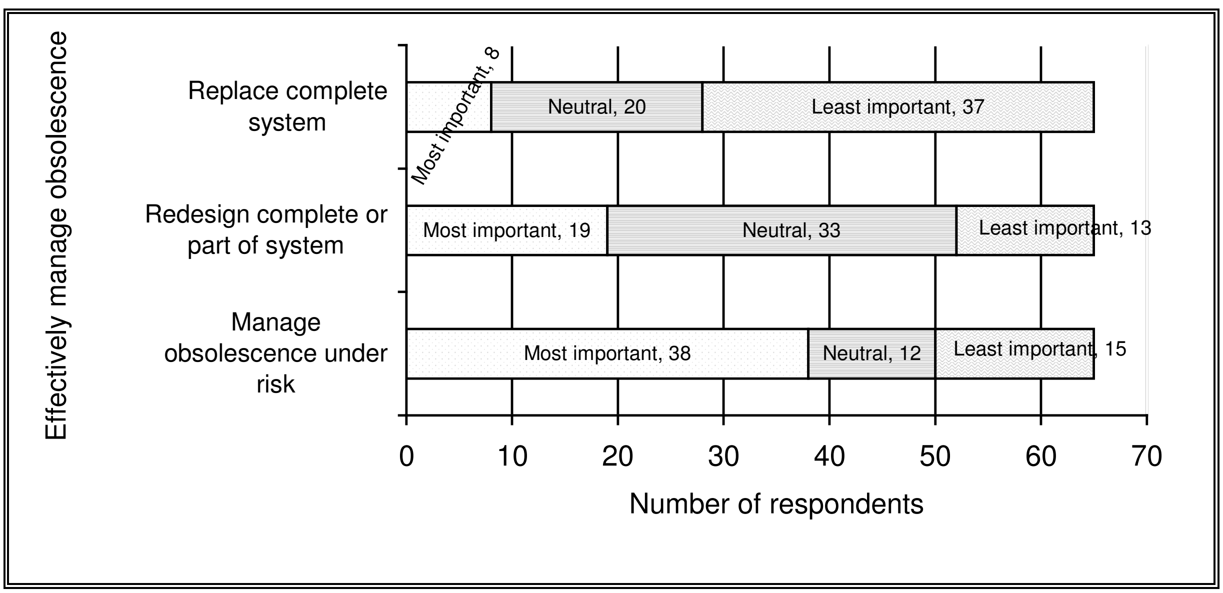

Figure H–18: Question 31 – Effectively manage obsolescence

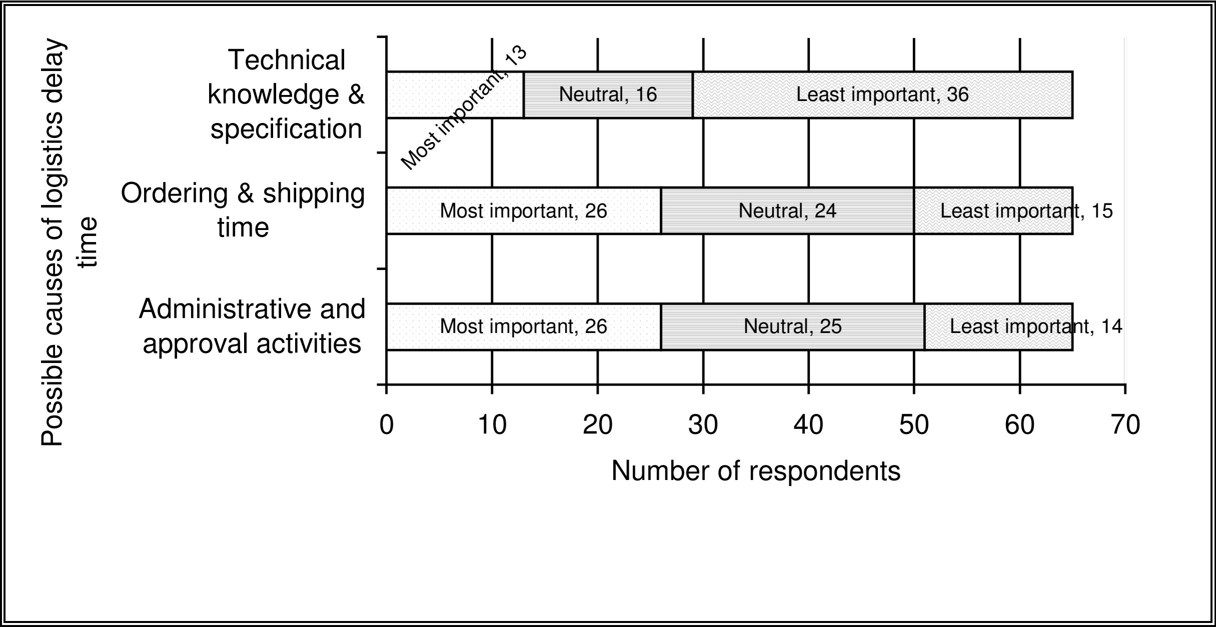

Figure H–19: Question 33 – Possible causes of logistics delay time

APPENDIX I: COMBINATION OF DECONSTRUCTION OF INTEGRATED LOGISTICS SUPPORT LITERATURE AND DECONSTRUCTION OF CASE STUDIES

In order to assess the deconstructed literature and deconstructed case studies they have been combined in Table I–4.

Table I–4: Combination of deconstructed literature and deconstructed case studies

AUTHOR /CASE STUDY THEME	DODD 4100.35 IN CARPENTER	PALGUTA, BRADLEY AND STOCKTON	MIL-STD-1369-A	ARMY REGULATION 700-127	BLANCHARD	JONES	HUTCHINSON	FINKELSTEIN AND GUERTIN	NASA	LANGFORD	SYSTEM ALPHA	SYSTEM BRAVO	SYSTEM CHARLIE	SYSTEM DELTA	SYSTEM ECHO	SYSTEM FOXTROT
MAINTENANCE	Philosophy. Plan. Procedures. Quality control. Preventive and corrective maintenance at each level. Serviceable condition, operable condition. Operable condition. Planned maintenance. Contract	Integrated planning. Maintenance requirements.	Evaluation of projected requirements. Maintenance concepts. Maintenance philosophies. Integrated contractor support or contractor logistic support. Maintenance actions. Maintenance capabilities. Maintenance planning. Testing & evaluation criteria. Performing activity for each level of maintenance. Maintenance program. Specified requirement. Maintenance concept. Planned maintenance tasks. All levels of maintenance. Maintenance concepts. Maintenance parameters. Maintenance constrictions. Maintenance actions. Maintenance functions. Systematic application of analysis. LORA. Qualitative and quantitative constraints. Update maintenance concepts. Maintenance planning integrated with LSA & LSAR. Maintenance plans. Maintenance engineering analysis: LSA, frequency, location, MTTR, design trade-off analysis.	System actions & support to attain system objectives. Specific criteria for repair. Maintenance levels. Interservice maintenance requirements. Contractor mix. Extent, duration and use of interim contractor support. Actions and support required for material fielding. Warranty considerations. Maintenance concepts. Maintenance requirements. Maintenance development. Maintenance planning. LORA. Minimize use of hazardous materials and the generation of waste.	Maintenance Planning. Levels of maintenance. Maintenance functions for each level. Level of repair policies. Criteria for the level of repair decisions. Criteria for test and support equipment at each level of maintenance. Criteria for personnel quantities and/or skills for maintenance. Responsibilities for maintenance. Effectiveness factors. Maintenance categories: Corrective & Preventive. Maintainability factors. Maintenance concept. RCM. LSA. Maintenance requirements	Maintenance planning. Concept for the maintenance program. Detailed maintenance actions. Maintenance plan. Levels of maintenance. O-level, I-level, D-level. FMECA maintainability information. Maintainability analysis. Maintainability allocations. Maintenance tasks/analysis. Maintenance types: Corrective & Preventive. LORA. RCM. LSA.	LORA. Maintenance plan. Maintenance concept. Levels of maintenance Preventive, scheduled, unscheduled, corrective	Concept or plan of product maintenance. Define the repair philosophy. Maintenance concept is developed to be consistent with the operational requirement. Maintenance support. R&M, & diagnostics defined. Assembly, module, part or component repair per level. LORA. Testing categories: no testing, internal testing, external testing, automated testing, semi-automated testing, manual testing. Physical considerations. Maintenance concept, then diagnostics routines and appropriate test points then location of test equipment. Levels of maintenance support. General overall repair policies and/or constraints. Maintainability analysis. Maintainability predictions. LSA	Maintenance planning. Maintenance concepts. Maintenance plan requirements. Maintenance plan. Maintenance engineering analysis.	Corrective, preventive maintenance. Organizational, Intermediate, Depot maintenance. Maintenance concept: levels of maintenance, governing philosophy (repair, remove-and-replace), responsibilities for each level, effectiveness factors (R&M), maintenance environment. Reparability (able to be repaired, recovered, or remedied) of components: Design influences - nonreparable, partially, fully), Economic influences - repair, next higher maintenance level, discard. Maintenance activity indicators: System supportability indicators (MTBM, MTBR, etc.) and Facility effectiveness indicators (TAT, Logistics pipeline time, etc.) Screening for repair or discard. Factors favoring repair: economic (inventory, transportation), noneconomic (reliability database, market responsiveness, weight, volume). Factors favoring discard: Economic (design, engineering, unit production cost), noneconomic (modification, skills, facilities). Maintenance reporting	Logistic support concept. Maintenance contract with end user's representative. Time-and-material contract. Maintenance concept: O- and D-level on various technical areas of system. Maintenance responsibility: O-level performed by end user. D-level performed by contractor. Engineering support: design expertise, product/system expertise provided by contractor to customer. Procurement responsibilities for spares. Electro-mechanical and mechanical end user responsibility. System specific and electronic spares via maintenance contract. Delivery from suppliers, and to and from contractor. Safety hazard information. Maintenance schedules (maintenance tasks & frequency). Major assemblies have periodic maintenance/ servicing tasks. Maintenance plan. Data analysis and reporting.	Logistic support concept. Maintenance levels: O-, I-, and D-level. D-Level performed by overseas contractor. -	Maintenance concept. Maintenance philosophy. Four lines of maintenance. Predictive, preventive, and corrective maintenance. -	System mission requirements. Support concept. Repair policy. Maintenance organisations and environment. Support organisation. Maintenance plan. Maintenance matrix, O-, I-, and D-level per week. Failed unit at O-level site is repaired remotely, if not repairable then I-level responsibility for removal of faulty LRUs, Maintenance concept five tiers split into three levels. Physical breakdown structure of system including software breakdown is documented. -	Maintenance matrix (Customer/contractor), for five areas of maintenance responsibility. Maintenance volumes requirements, operating hours, systems, life expectancy. Maintenance concept: O-, I-and D level. Support organisation, maintenance process flow, data flow and responsibilities, data analysis and reports, corrective action. -	Levels of repair, User, Support & Factory level. Maintenance activities, and responsibilities. Support Structure. Maintenance process flow. Data flow and responsibilities. Data analysis and reports. Preventive maintenance schedules -

AUTHOR /CASE STUDY THEME	DODD 4100.35 IN CARPENTER	PALGUTA, BRADLEY AND STOCKTON	MIL-STD-1369-A	ARMY REGULATION 700-127	BLANCHARD	JONES	HUTCHINSON	FINKELSTEIN AND GUERTIN	NASA	LANGFORD	SYSTEM ALPHA	SYSTEM BRAVO	SYSTEM CHARLIE	SYSTEM DELTA	SYSTEM ECHO	SYSTEM FOXTROT
SUPPORT AND TEST EQUIPMENT (S&TE)	Facilitate or support maintenance actions.	Identifies and provides common support equipment and software requirements .	Plan, develop & identify all support equipment. Trade-off analysis. Support equipment constraints. Support equipment standardization. Support equipment interoperability. Reliability identification of S&TE. Requirements to perform scheduled and unscheduled maintenance. Logistic support requirements of S&TE. LSA requirements. Initial support and test equipment planning. Integrated S&TE plans. Availability.	All S&TE (mobile & fixed). SE for on-and off-equipment maintenance. Special inspection equipment/depot maintenance plant equipment. Planning and acquisition of logistic support for equipment. Environmental considerations influencing SE design and selection.	Support scheduled and unscheduled maintenance. Support and test equipment requirements for each level of maintenance. Support and test equipment items compatibility with the main equipment Reliability and maintainability features in the support and test equipment compatibility with those equivalent features in the main equipment? Logistic support requirements for the selected support and test equipment.	SE-special item (*special to type*), common, Operational SE. SE can be classified by its use for testing or actual maintenance or availability, application, complexity, or cost. Common support equipment. Special support equipment.	Unique requirements. Expected operating environment of the product. Capabilities of operating and maintenance personnel. Test equipment derived from LSA. S&TE must be designed or selected to complement the product, operating environment, and limitations of product support personnel. Test and support quantities. Common or general. Special or peculiar. S&TE Requirements: Levels of maintenance, corrective and preventive maintenance. Types of product failures. Selection Process: Need, elimination-design changes, simpler items, environmental, inside or outside, mobile-how frequent, scope & complexity, measurement parameters, accuracies & tolerances, existing S&TE at same location, COTS. Quantity determination per level of maintenance.	Scheduled and unscheduled maintenance. Support equipment planned & developed at same time as the product. Verification and validation of main equipment. Support the support equipment. State-of-the-art technology. Simplicity of design. Life cycle planning of support equipment. SE: some requirements, modified, developed, developed as peculiar to the end item, BIT and diagnostic SE in the end item, automated or semi-auto SE. SE trade-offs. Revisions to SE requirements. Calibration requirements. Special test equipment. Special training programmes. Special test equipment requires support. Develop test equipment so that prime item can be tested during production phase. BIT & diagnostic capabilities replaces special test equipment. Special test equipment adds a level of complexity to the support. Test equipment selection: Maintenance technician, physical factors, R&M, Logistics, Application.	Perform S&TE trade-off. Establish SE concept. SE Plan requirements. SE plan evaluation criteria, Approve SE Plan. Update SE requirements, design SE, Verify availability of SE. Identify SE deficiencies. Procure additional SE. Modify SE.	All equipment (manual and power-operated) and assistance devices. S&TE evaluated for three levels of maintenance. Standard equipment availability and consideration instead of newly deisgned equipment. S&TE compatible with prime, host equipment. R&M of S&TE equivalent to those of prime equipment. Logistics support requirements for S&TE must be defined. Test and maintenance software requirements must be clearly defined. S&TE allocation should be based on the minimum, essential capability necessary to support the prime system. Automatic self-test provisions should be incorporated in the prime equipment where cost-effective and technologically feasible. Direct fault signals (visible or audible) should be incorporated in the system to provide indications of malfunctions. Continuous performance-monitoring features should be incorporated in the prime system, where appropriate. System test points should be incorporated in the system design to enable fault isolation beyond the limitations of the self-test features. Test points in the system must be accessible and must accommodate the level of maintenance being accomplished. System test points should be functionally grouped to facilitate sequential testing steps, signal flow, testing of similar functions, or frequency of use, in the case of limited access. Test points should be provided for direct test of reparable items in the system. Test points should be adequately identified, labeled, and illuminated (where possible). At the system level, every malfunction should be detectable by means of a simple "no-go" indication. This feature validates the thoroughness of testing the system. The maintenance software must be designed so as to provide accurate diagnostic data.	S&TE requirements for levels of maintenance. Standard test equipment. Special to type test equipment. Automatic test equipment. S&TE compatibility with main equipment. Calibration. All items that require calibration are sent periodically for calibration, calibration certificates are held on file indefinitely, calibration at D-level has single point of responsibility. Firmware. Archived on CDs, under configuration management, baselines kept and audited. Embedded special test equipment. Notebooks for each system, under configuration control. Ground support equipment. Cabin ladders, platforms, hydraulic jacks, chairs, first aid kits, and fire extinguishers checked for completeness and serviceability before system is transported as well as on regular periodic time intervals.	Requirements for support and test equipment. Commercial off the shelf, special support equipment. S&TE periodic calibration. S&TE compatibility with main equipment. -	Special tools and equipment. Equipment handling system. Commercial off the shelf equipment. Periodic calibration of S&TE. -	Support equipment. Test equipment (asset) register. Special tools. Standard test equipment. Special test equipment. Special to type test equipment. (Flight calibration). Software. Calibration of system and S&TE. - -	Support equipment, special tools, standard test equipment, special to type test equipment, software. Support equipment list per system O-, I- and D- level. Test equipment evaluation. Asset register, audited annually. Test equipment calibration, periodically, test equipment register, calibration procedures, records, and calibration status identification. -	Support equipment, special tools, standard tools, standard test equipment, and software. Support equipment list per system maintenance level. Test equipment evaluation. Test equipment calibration, periodically, test equipment register, calibration procedures, records, calibration status identification, asset register. -

AUTHOR /CASE STUDY THEME	DODD 4100.35 IN CARPENTER	PALGUTA, BRADLEY AND STOCKTON	MIL-STD-1369-A	ARMY REGULATION 700-127	BLANCHARD	JONES	HUTCHINSON	FINKELSTEIN AND GUERTIN	NASA	LANGFORD	SYSTEM ALPHA	SYSTEM BRAVO	SYSTEM CHARLIE	SYSTEM DELTA	SYSTEM ECHO	SYSTEM FOXTROT
SUPPLY SUPPORT	Spares. Repair parts.	Spare and repair parts requirements. Provisioning procedures and requirements. LSA process and the maintenance plan in the development and definition of spare and repair parts requirements.	Plan, develop projected supply levels, replacement rate & storage site. Life cycle support. Initial provisioning. Ordnance, safety, security, surety & facility requirements. Timely provisioning distribution & inventory replenishment of spares, repair parts & supplies. How supply support and provisioning program shall be conducted. Specified requirements. Identification of planning inputs. Identification of utilization rates, maintenance level or category, operating hours, failure rates and repairable program planning. Identification of provisioning requirements, technical documentation and maintenance planning inputs, such as Source Maintenance and Recoverability (SMR) codes. Identification of the relationship of supply support to the outfitting and fitting out of the system/equipment and its supporting resources. Identification of appropriate LSA requirements.	Acquire. Catalogue. Receive. Store. Transfer. Issue. Dispose of secondary items. Provide for initial support. Acquire, distribute, and replenish inventory. Impact of human-factor engineering. Availability of principal and secondary items. Special disposal or demilitarization information or instructions.	Spare/repair part requirements for each level of repair. Types and quantity of spare/repair parts compatibility with the LORA Types of spare/repair parts that are appropriate for the estimated demand of a given location. Spare/repair part requirements optimized to the maximum extent possible? Test and acceptance procedures for spare/repair part/units. Risk of stock-out in terms of mission requirements and cost. Inventory safety stock levels. Provisioning cycle. (Order frequency). Supply availability requirement.	Operation and maintenance actions. Spare and repair parts. Identification and acquisition of the materials necessary to support the operation and maintenance. Scheduled and unscheduled maintenance. Correct parts available when and where required in the quantities necessary to support maintenance. Range and depth, or scale. Past experience or statistical projections. Repairable items. Nonrepairable items. Initial spares. Correct amount of spares in the appropriate locations to support maintenance. Inventory cycle. Economic Order Quantity.	Spares decisions: probability of failure, consequences of failure. Inventory: forms (material for production & spare and repair parts). Functions of inventory: geographic specialization, decoupling, balancing supply and demand, and safety stock. Inventory risk: manufacturing risk, wholesale risk, retail risk. Inventory cycle. Elements of inventory cost: transport, storage, obsolescence, opportunity, order. Production and inventory control: monitoring inventory levels, EOQ's, order point, discrete lot sizing. MRP. JIT. Kanban. Probability of failure & the consequences. Availability of replacement items. Decision to spare also influenced product location and operating environment. Spares from LSA. SMR (source, maintenance and recoverability) codes. Spares quantities determinants: LSA data, MTBD (demand), budget constraints.	Scheduled and unscheduled maintenance. LSA: Reliability predictions and modelling techniques. Maintenance concept: needs of the supply or spare parts requirements. Piece-part or modular replacement. Cost and feasibility of increased realiability versus reduced quantities of repair parts. Effect of human engineering design on maintainability. Corrective and preventive maintenance. Repairable and non-repairable items. Stock levels of spares compensate for repairable items undergoing maintenance. Added stock levels of spare and repair compensate for the pipeline and procurement lead time for item acquisition. An additional stock level of spares compensates for condemning or scrapping repairable items. Range or variety of spares. Optimum quantity for each line item. Evaluation of the impact of item selection and quantities on the effectiveness of the product. Demand prediction and identifying the consequences of not leaving the spare or repair part in stock. Criticality of an item. Identify replacements. Replacement and repair frequencies, repair and resupply cycle times, condemnation factors and unit cost. Stock-out promotes cannibalisation. Preparation of stock lists and procurement	Perform supply support trade-offs, establish supply support concepts, develop supply support requirements. Provisioning requirement criteria, evaluate provisioning and support proposals, approve provisioning plan, prepare provisioning documents. Procure spares, repair parts, and special supplies for testing, training, and to support operations. Verify suitability of spares and repair parts, validate/update provisioning plan, identify SS deficiencies, update provisioning plan. Procure spares and repair parts identified by change/modifications decisions.	On-hand stocks, safety stock, in-transit assets, speculative stocks, dead stocks. Inventory management under certainty and uncertainty. Inventory levels, make-or-buy decisions, LIFO/FIFO. Items with - high rates of sale, high values per unit, costly storage requirements, high strategic value to customers. Production inventory control - master schedules, production sequencing, production smoothing. Production resources planning - MRP I (Materials Requirements Planning), MRP II (Manufacturing Resources Planning), JIT (Just-In-Time), Kanban. Quantitative Applications to Inventory Management - Total inventory cost, Economic order quantity. Inventory costs - order placement or setup costs, inventory investment, warehousing costs, inventory risks, stock-out costs.	System support at levels of maintenance. Depending on the system configuration, deployment, and utilisation. O-level dependent on operational requirement/mission. Special storage requirements. Items that require power up, recharge, or service while not in operational use, while stored in a special storage area and have a limited shelf life. Long lead & high cost spares. Items requiring long manufacturing times from local or international suppliers (lead time of three months), items with a high unit cost, due to design, research and development. System critical spares. LRUs and/or items of equipment which when they fail, render the whole system unserviceable. Risk of stock-out. Provisioning cycle Inventory safety stock levels. Stores management. End user stores in a storeroom in building, controlled by an MIS. Larger store area for incoming inspection, non-conformance, work in progress.	System support at all levels of maintenance. Spare and repair parts are partly in stock. Obtain spares from suppliers when needed. Repairable LRUs sent to contractor for repair, spares used are invoiced. -	System under development, supply support requirements will be determined after logistic support analysis has been conducted. -	Spares list for systems and per site. Recommended spares for O-, I- and D-level. Spares (LRUs) and repair parts (components). O-, I- and D-level spares storage area. End user stores instructions and package system. Labels identification, non-conformance, disposal, and selling. Acquisition procedure for LRUs and repair parts and consumables. Reprovisioning strategy. Inventory management procedure. Material review board. Beyond economical repair. -	Types, replacement policy, and period of supply: Standard items, peculiar supply support items, long lead items, and single source items. Spares flow diagram, sites maintained by customer and contractor. Supply support for sites. Contact list for spares. Acquisition of supply support items, I-, D-level and ad-hoc. Recommended spares for each maintenance responsibility area. Turn around times of LRUs. Items installed under project and D-level maintenance Container consumables. Preventative maintenance material and equipment requirements per system per I-, and D-level. Reprovisioning strategy, reorder cycle, order point, safety stock, safety level. Inventory management procedure, Material Review Board (MRB). Stock control. -	Types: Standard items, peculiar supply support items, long lead items, single source items. Acquisition of standard supply support items, user, factory level and ad-hoc. Stock items for user, support and factory levels. Recommended spares list. Acquisition of peculiar supply support items. Reprovisioning strategy, (order point, reorder cycle, safety stock), Inventory management procedure. -

AUTHOR /CASE STUDY THEME	DODD 4100.35 IN CARPENTER	PALGUTA, BRADLEY AND STOCKTON	MIL-STD-1369-A	ARMY REGULATION 700-127	BLANCHARD	JONES	HUTCHINSON	FINKELSTEIN AND GUERTIN	NASA	LANGFORD	SYSTEM ALPHA	SYSTEM BRAVO	SYSTEM CHARLIE	SYSTEM DELTA	SYSTEM ECHO	SYSTEM FOXTROT
PACKAGING, HANDLING, STORAGE AND TRANSPORTATION (PHS&T)	-	Procedures and resource requirements.	Identify actions and requirements necessary to establish capability. Functional requirements analysis & actions. How the PHS&T program shall be conduted. Description of how each specified PHS&T requirement shall be complied with and performed. Documentation defining all PHST. Environmental considerations and system/equipment impacts. Cost considertaions, location, duration of transport, and general PHST. LSA requirements.	Resources and procedures of short- and long-term requirements PHS&T resources, techniques, and methods for both short- and long-term storage. Planning and programming the details associated with movement of the system. Establishment of critical parameters and constraints. Special security requirements. Geographic and environmental restrictions. Special handling equipment and procedures. Impact on spare or repair parts and basic issue item storage requirements. PHS&T technologies and resource-intensive PHS&T procedures. Environmental impacts and constraints.	Special provisions. Transportation and handling requirements for both operational and maintenance functions. Transportation and handling environments. Modes of transportation. Requirements for re-usable containers. Packing requirements and procedures. Storage and shelf space requirements for spare/repair parts. Storage environments.	PHS&T not to reduce its effectiveness Plan, develop, and manage the activities necessary to ensure that equipment is serviceable when it reaches the ultimate user and when it is moved by the user during its operational life. Packaging Levels - level a (maximum), level B (intermediate), level C (minimum). Preservation. Packing- common, selective, and special. Reusable containers. Packaging data. Marking. Handling: Distance, weight, Dimensions, Material handling equipment. Storage. The short- or long-term storage of items. Temporary or permanent facilities. Warehouses, covered in open areas, uncovered in open areas, in a controlled environment, or in special facilities. Transportability - Physical limits, Dynamic limitations, Environmental limitations, Hazardous effects. Modes of Transportation.	Transportation - to & from firm. Transport may influence the location for a firm. Transportation logistics: the firm, suppliers, the market, the needs, transportation capabilities of available logistics channels. Storage: type of facility, stored quantity. Size of storage facility: quantity of product distributed, technological content of the product, product reliability, replacement time for additional spare and repair parts. Transport modes: road, rail, water, air, pipeline. Grouping of carriers: Common, contract, exempt, private carriers. Transportation rate structures.	Develop and support an effective transportation strategy. PHS&T complexities: carrier to choose, selecting optional modes, requirements within regulatory structure, best rates, objectives for profitability and sustainable growth against the requirements for quality, excellence and customer service. Transportation costs are the largest component of any commercial firm's total outlay. Nature of PHS&T. Information systems. PD&T managers issues: finished good inventory positioning (where to stock): forward or backward. Transportation mode selection. Scheduling, routing and selecting a carrier. Inventory control.	Transportation and handling concepts, provide transportation and handling input to support plan requirements.	Packaged to withstand most severe climatological conditions, and impacts and shock levels. Economic significance of packaging. Conditions of austere operational facilities, shelf-life constraints, climatic extremes. Packaging objectives - Protection, labeling and identification, sales promotion, consumer security, storability, transportability, environmental factors, communication to the consumer. Packaging design - Production, purchasing, engineering, materials handling, storage, marketing, traffic management, legal counsel. Packaging design interface with pallet configurations. Packaging design - Protection against rough handling and resulting shocks, dirt, dust, moisture, and other contaminants. Relationship to environment in terms of disposability and multipurpose use. Facilitation of production, marketing, and logistics functions. Packaging design - Prevention of pilferage and tampering. Safeguarding of hazardous materials. Simplification and more efficient piling, warehousing, and inventory control through use of standard shipping units. Packaging design - Definition of unit of sale. Provision of product identity and definition of quality, quantity, size, color, etc. Assistance to marketing by means of "miniature billboards" which are provided by attractive shipping containers. Building of customer goodwill through convenient, reusable containers.nMaterials handling - principles: minimum handling, short distances, material routes on same level to avoid lifting and lowering, once in motion materials should be kept moving, use mechanical and automatic means of materials handling, standardize materials handling equipment, gravity flow, maximum investment in movement rather than in stationary equipment, minimize ratio of dead weight to payload.nMaterial handling methods: Manual systems, mechanized systems, automated systems, combination systems. Principles of pallet utility.nWarehousing and storage - Legal status of warehouse: public or private warehouse. Field or bonded warehouse.nWarehousing operations: Role in logistics system, commodities handled, public vis-à-vis private warehousing. Warehouse design, economics of warehousing, functional warehouse cost standards - warehouse volume, warehouse dispersion. Transportation - Legal forms of transportation: common carriers, contract carriers, exempt carriers, private carriers. Operational modes of transportation - rail, highway, water, air and pipeline. Intermodal. Transfer facilities - packaged freight terminals, container terminals, bulk commodity terminals, carrier equipment transfer facilities. Transportation regulatory agencies and their jurisdiction. Transportation rate structure.	Transportation and handling requirements for operational and maintenance functions. Transportation and handling environments (rail, air, sea, and road). Transportation responsibilities, modes of transport, personnel, equipment, frequency of transportation. Requirements for re-usable containers, bubble plastic bags, antistatic bags, cardboard boxes, wooden crates. Packing requirements and procedures, condition of packaging, materials and item types , environmental factors, identification on packaging. PHS&T procedures and responsibilities. Handling requirements and identification (static sensitive devices, mechanical damage).	Transportation from end user to contractor is per air. From airport to end user site is per vehicle or public transport. Cardboard boxes and wooden crates used as packaging for equipment. Re-usable boxes and crates are used. -	System under development, PHS&T requirements will be determined after logistic support analysis has been conducted. Special containers are used to package and store equipment. Equipment requires cranes, forklifts, trolleys, etc. to transport the equipment. -	End user stores instructions and package system. Labels identification, non-conformance, and handling of static sensitive equipment. Transportation - Modes (Road - prime, air). Frequency when required, urgency. Packaging - Responsibilities, correct packaging, supporting documentation and labels. Equipment or packaging not damaged, if damaged investigate. Test documentation, failure forms, and applicable labels. Handling/storage - static sensitive, special storage areas. -	PHS&T requirements and system modules for each system. Spares flow, for sites maintained by customer and sites maintained by contractor. Transportation: responsibilities, modes of transport, frequency, and delivery address. Packaging: responsibilities, condition of packaging, material and item types, identification of packaging, OEM instructions. Handling: Responsibilities, handling requirements for identified item types, handling requirement identification. Storage: Protection from rain, excessive dust, temperature range, humidity considerations. -	PHS&T requirements. Transportation: responsibilities, frequency, delivery addresses. Packaging: responsibilities, condition of packaging, materials and item types, environmental factors, identification of packaging. Handling: responsibilities, handling requirements for identified item types, handling requirement identification. Storage: Requirements, Protection from rain, excessive dust, temperature range, humidity considerations.

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DATA & DOCUMENTATION	Production, engineering data, prints and drawings. Standards, specifications, technical manuals. Changes and modifications. Inspection and testing procedures. Performance and failure data. Other forms of technical logistic data and information.	Technical data and the documentation planning.	Data requirements (software and firmware) plan & compile. Technical data planning, development & delivery. Technical publication plan and delivery. Establish recordable information required, generated by, planning performance cycles. Specific description of how the technical data program shall be conducted. A detailed description of how each specified technical data requirement shall be complied with and performed. Technical data support requirements, breadth of information required. LSA requirements. Identification of computer resource support requirements. Update requirements and operations, support and maintenance task requirements.	Scientific or technical information necessary to translate materiel system requirements into discrete engineering and logistic support documentation.	Operating and maintenance documentation requirements. Maintenance documentation compatible with the levels of activity performed at the location where these documents are used. Operating and maintenance documentation written to the skill levels of the individual accomplishing the functions covered by all procedures. Operating and maintenance documentation specifies the correct support and test equipment, spare / repair parts, transportation and handling equipment and facilities. Documentation includes special warning notices in areas where safety is a concern.	Technical publications. The technical manual: Operator's manual, maintenance manual, parts manual.	Well-documented library of technical publications. Technical publications department - all printed, & media (microfilm, video tape, computer displays & so forth). Technical writers need to write for the reader, not themselves. Writing (technical or nontechnical) is judged on two levels: level of literacy & level of competence. Intended audience: "evaluate" readers' educational level. Scope of the publication. Job analysis: facilitates the writing task, provides a task listing and task analysis. Identifying parts upon which maintenance can be performed. Identification of tools & test equipment, personnel requirements. Specific activity data.	All recorded information. Accurate determination of the requirements for the acquisition and timely utilisation of adequate technical data. Engineering technical data: design data, R&M, human factors, LSA. Verification & validation. Equipment publications, manuals, discs storage. Any mistakes or inaccuracies in the documentation could represent a major fault in the operation and use of the product.	Performtechnical data trade-offs. Establish technical data concepts. Establish technical data concepts. Identify technicall data deficiencies.	Specifications: research, development and engineering, product, functional, product fabrication (military application), process, material specifications. Engineering drawings: level 1 conceptual design drawings, level 2 developmental design drawings, level 3 production drawings, parts lists. Installation drawings. Technical manuals: equipment and component manuals, system-level manuals, consumer manuals.	Technical and technical training documentation. Software documentation. List Of Applicable Publications (LOAP). Automatic and special to type test equipment documentation. Configuration of documentation using ERP system. Documentation audits. Maintenance documentation. Correct technical and maintenance information. Documentation written at skill level of person using the manual. Documentation inventories. Correct issue levels, configuration management.	Technical and technical training documentation. Documentation written at skill level of person using the manual. -	System under development, data and documentation requirements will be determined after logistic support analysis has been conducted. Operator and maintenance manuals. Illustrated parts breakdown, spare parts lists, procedures, and processes. -	Technical documentation, standard operating procedures, Inspection/test/repair standards and procedures. General standards and specifications, technical manuals, test equipment documentation. Acceptance of documents - reviewed internally, under configuration control following acceptance of documentation, forms part of system MRI. -	Documentation requirements and list of documentation. Acceptance of documents. Updating process. Distribution process. Document format and layout. Document numbering. Language. -	Documentation requirements and list of proposed documentation. Acceptance of documents, updating, distribution. -

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FACILITIES	Physical plants.	Facilities planning	Long lead time for military facility approval. Facility requirements on operational and maintenance analyses, system/equipment design, specifications. Facilities required: support system testing, training, operations, storage & maintenance. Facilities requirements for all levels of maintenance. Facility requirements and constraints. Specific description of how the facilities program shall be conducted, managed and implemented to meet all contract requirements. A detailed description of how each specified requirement shall be complied with and performed. Facilities planning based on operational, training, supply and maintenance analysis and planning, identification of new construction requirements, identification of rehabilitation requirements, identification of support and test requirements. Define types of facilities, locations, space needs, environmental factors, fixed and mobile requirements, existing facilities. Identification of appropriate LSA requirements.	Required permanent or semi-permanent operating and support facilities. Comprehensive planning. Studies to define & establish impacts on LCC, facility locations and improvements, space requirements, environmental impacts, duration or frequency of use, safety and health standards requirements, and security restrictions. Utility requirements, for both fixed and mobile facilities, with emphasis on limiting requirements of scarce or unique utilities. Human-factor engineering.	Performance of maintenance functions at each level. Facility requirements necessary to support the system. Facility requirements necessary for maintenance at each level. Operational and maintenance facility requirements minimized to the greatest extent. Equipment environmental requirements associated with operational and maintenance facilities.	Land and buildings, structures, or utilities built on or in the land. Fixed or mobile. Permanent facilities. Mobile facilities. Maintenance facilities. Supply facilities. Training facilities. Special facilities.	Warehousing, training, spare & repair parts, size & location. Maintenance facility: Size, expected repair actions, workload determinants, personnel requirements. Sizing maintenance facility, office space that may be required in meeting personnel needs, alternative functions such as training. Expected repair actions: O, I & D level. Operational scenario assumption, 6 hour per day 7days per week, etc. Number of times corrective action is expected considers the total number of all maintenance actions. Workload determinants. Personnel requirements: function of the tasks that must be performed and the time required for their performance. Warehouse facility.	Commercial & military. Overseas operations, facility acquisition takes much longer. Implemeting change to an existing facility will require a review of its present status. Then an analysis of new product requirements. Training facility - computer aided instruction.	Evaluate requirements and define facilities support capability. Perform facility trade-offs. Establish facilities concept. Provide facilities plan requirements, establish facility plan. Facilities constructions or modification, approval and start and completion thereof, activate operational support facilities, validate/update facilities plan, identify facilities deficiencies, initiate action to modify facilities. Identify facilities deficiencies, initiate action to modify facilities.	Facility decision considerations: Purpose, or mission, of the facility; principle of locational gravitation, economic factors, sociopolitical criteria. Purpose of facility: production facilities, distribution centers, service centers, inventory storage points. Principle of locational gravitation: Transfer-production trade-offs, (close to source of input or output). Effects of economic factors on location: costs of transfer of raw materials and working stocks from the sources to the production plant, costs of transfer of finished products from the plant to market centers, production cost (labor, taxes, utilities, facility costs, etc.) at the plant site. Economic factors: impact of logistics on commercial locations (quantitative and graphic analysis techniques) - isotims and isodapanes. Sociopolitical criteria: quality of life, workforce dynamics, community attitudes, political indicators, environment and ecology, absorptive capacity of local infrastructure.	Facility requirements for maintenance levels (O- and D-level). Equipment environmental requirements. Operational cabins radio frequency (RF) screened, antistatic precautions. Storage environments: technical stores, library, transito, other stores under roof, well ventilated, cement floor, access control, fire protection. Test equipment store. Tool stores. Software storage. Site for system. Parking space for vehicles, equipment, offices for staff, logistic support area. -	Facility requirements for maintenance levels. Operational cabins RF screened. -	System under development, data and documentation requirements will be determined after logistic support analysis has been conducted. Decontamination facilities. Laboratories. Clean rooms. Containment building. -	Existing facilities and new facilities used, maintenance, storage, calibration, and training. O- and I-level are end-user responsibility. D-level facilities are contractor responsibility. O level maintenance activities performed by remote maintenance software, O-level facilities are not required, except that in which the equipment is situated. I- and D-level maintenance requirements for Electro-mechanical, general, radionavigation workshops. Calibration - No facilities are required at O-, I- or D-level as test equipment calibration is outsourced under contract. Training facility - classroom and furniture for students and lecturer, power outlets, temperature limits, lighting. Equipment for practical aspects of course. Software - controlled store, issued on demand, fire proof safe. Storage - Holding areas for documentation, spares, test equipment. Containers on site for storage of LRUs and hardware items. Technical library in a container at the base workshop, end user documentation depot holds one complete set. Transito - receive & dispatch areas, secure area, admin, packaging facilities, racks, and secure. Test equipment store - access control, racks, ventilated, under roof, cement floor, temperature	Existing sites for O-, I- and D level. Contractor facilities. Containers. Training facilities. -	Facility requirement for user level: storage, maintenance support, and site facilities. Facility requirements for support level: storage, maintenance support, engineering support, administration, and training. Facility requirements for factory level: storage (work in progress, incoming goods receiving & inspection, dispatch, quarantine storage area, computerised stores control), maintenance support, engineering support, administration, and training. Security: access control for customer and contractor facilities. Facility requirements. -

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MANPOWER & PERSONNEL	Logistic Support Personnel - Manpower & Personnel & Training. Qualitative and quantitative skill, performance requirements, and standards. Training requirements, standards, curricula and devices. Human factors engineering requirements. Personnel protection.	Qualitative and quantitative information to identify maintenance personnel requirements by numbers, skills other qualifications and training requirements.	Qualitative & quantitative personnel requirements & constrictions. Manpower & training objectives. Number, type & skills of personnel (maintenance and operational). Task frequencies times & steps manhour planning & operating hours for all personnel specially skill & accuracy standards. Requirements, restrictions, constraints, parameters - manpower & personnel integration. Manpower & personnel goals, objectives & constraints to generate specific manning plans, establish design drivers & influence design of emerging system/equipment. Establish program defining requirements for fully trained operation & maintenance personnel. Constraints & requirements. Human dimensions. Specific description of how manpower and personnel program shall be conducted, managed and implemented to meet all contract requirements. A detailed description of how each specific requirement shall be complied with and performed. Identification of manning determination, restrictions and incentives, and their derivation from system/equipment design activities. Identification of specified manning criteria categories.Identification of variables of personnel performance factors or constraints affecting quality, psychological considerations,	Identification and acquisition of military and civilian personnel with skills and grades. Manpower requirements are developed and personnel assignments are made to meet mission support demands throughout the life cycle. Manpower requirements are predicted on accomplishing the logistics support mission in the most efficient and economical way. Requirements to optimize numbers, skills, and grades.	Maintenance of the system (or product) and its associated test and support equipment. Operational & maintenance personnel requirement. Pre-requisites for personnel expertise levels. Operational and maintenance personnel requirements minimized to the greatest extent possible. Personnel skill levels defined at each location and compatability with the complexity of operational and maintenance tasks. Personnel effectiveness factors. Client personnel involvement in the various levels of maintenance.	Military and civilian personnel needed to support operations and maintenance and the skills they require. Personnel in the military services are classified in two ways, grade (rank) and skill specialty. Commercial skill specialty. By position title rather by an identification number. In some cases assignment to a position is based on experience, and in others it may be based on some combination of training and experience.	-	Appropriate skills to operate any new piece of equipment or product, which skill levels. Complexity of system. Replaceable or repairable and will a duly described, accepted or certified technician be capable of repairing the device as prescribed by the documentation. Skills & skill levels. How much additional training is needed? Determine the tools which could be designed into the equipment to simplify the work to be performed. Number and type of maintenance personnel. Skill levels of individuals. Type of new skills level requirements needed and how much additional training is required. Time they are alloted to work on problems, the more problems they experience, or the worse the reliability of the product becomes, the harder it is to ensure that the equipment will be properly maintained and kept in operation. The impetus for personnel and manpower becomes reliability, maintenance concept and designs of the diagnostic routines as part of the maintenance concept. Lower the skill level more complex device becomes. Train people properly, have the right skill levels at the right place, at the right time, doing the appropriate job, as this has a direct impact on the corporation.	Estimate of skill requirements. Establish personnel and training concept. Personnel and training requirements, personnel and training plans, determine personnel availability. Prepare training package, instructor training, operations and maintenance personnel training. Verify required skill levels, verify availability of trained personnel for operations and maintenance. Identify personnel & training deficiencies. Update training package, conduct additional operations and maintenance training.	Definition and understanding of the corporation's mission, its products, and its organization as a goal-oriented activity. Logistics mission: factors governing role of logistics - type of business transacted, importance of logistics costs, need for trade-offs among logistics cost categories, complexity of the logistics network, nature of corporate strategy, capabilities of logistics managers; Definition of logistics functions; organization of logistics - project organization, matrix organization, centralized/decentralized logistics management function, organization for logistics services. Development of Logistics Human Resources: Logistics HR qualifications - experience, education, professional certification, technical skills, human characteristics. Development of position descriptions; recrutment and training. Management of HR: employee motivation; optimizing HR productivity - productivity indicators, performance appraisal, rewards and recognition. Personnel performance profiles. Interrelationship of logistics disciplines and job categories.	Operational and maintenance personnel requirement. Deploy service and maintain the system. D-level is outsourced to a contractor, O-level performed by end user. Pre-requisites for personnel expertise levels. Qualified in relevant trades, apprentices undergo training as per apprentice training curriculum. Advanced systems training, cross training, retention of trained personnel and expertise is of prime importance. Personnel competencies for each level of maintenance. O-level competence is application, while D level competence is application/analysis. Depending per system, site, allocated per rank, discipline needed. Personnel skill levels. Competencies per level depend per technical discipline. Technical assistance at O-level by contractor. Ad-hoc basis, sub-system repairs, setting up & calibration of sub-systems, software changes, maintenance tasks that are not O-level related, training of O-level personnel. Apprentices follow a three-year apprenticeship; qualified personnel need one to three years experience in specific discipline before attending other training courses/cross training on other disciplines.	Operational and maintenance personnel requirement. Deploy service and maintain the system. D-level is outsourced to a contractor, O-level performed by end user. I- level is split between end user and contractor. Pre-requisites for personnel expertise levels. Personnel competencies for each level of maintenance. Personnel skill levels. Competencies per level depend per technical discipline -	System under development, manpower and personnel requirements will be determined after logistic support analysis has been conducted. Requirement for operators, maintainers, management personnel. Prerequisites to be ascertained after logistic support analysis. -	Manpower profiles for O-, I- and D-level, qualifications and experience. Engineering support personnel – quality assurance (QA), configuration management, logistic engineering. Personnel requirements - number of personnel per discipline. Personnel certification - new personnel required to undergo training on system. -	Manpower profiles: O-, I- and D-level, administrative and engineering support personnel. Qualifications, experience, specific training prerequisites. Personnel requirements for O-, I- and D level. Personnel utilisation for support level, job title, location, minimum quantity, utilisation (full or part time). Personnel certification. -	Manpower profiles including quantity, qualification and experience per level of maintenance, administrative, engineering personnel (QA, configuration management, logistics engineering). Personnel requirements: Job title, quantity, and utilisation. Personnel certification: new personnel, certified for competency. -

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TRAINING AND TRAINING DEVICES	Logistic Support Personnel - Manpower & Personnel & Training. Qualitative and quantitative skill, performance requirements, and standards. Training requirements, standards, curricula and devices. Human factors engineering requirements. Personnel protection, including safety, survival, clothing, escape and rescue and sterss pertaining to the system or equipment.	Qualitative and quantitative information to identify maintenance personnel requirements by numbers, skills other qualifications and training requirements.	Qualitative & quantitative personnel requirements & constrictions. Manpower & training objectives. Contractor incentives. Develop & plan training and training devices & training requirements. Quantity, skill levels & all training requirements. Identify operator & maintenance training equipment locations, training devices. Requirement, constraints, & parameters. Training programs, training aids & devices & support, training equipment, aids or devices and its requisite support. Establish need for training & training devices to support instruction or support simulator settings. Formal training program. Specific description of how the training program shall be conducted, managed, implemented, and supported to meet all contract requirements. A detailed description of how each specific requirement or training tasks shall be complied with and performed. Determinations of training aids, devices or training equipment requirements and their logistic support. Determinations of training aids, devices or training equipment requirements and their logistic support. Identification of specifc training requirements Identification of specific aids or device or simulator requirement. Identification of training constraints for the program.	Processes, procedures, techniques, training devices, and equipment used to train civilian and military personnel to operate and support a materiel system. Qualitative and quantitative requirements for the training of operating and support personnel throughout the life cycle of the system. The design, development, delivery, installation, and logistic support of required embedded training features, mockups, simulators, and training aids are also included. Assess the training burden associated with competing materiel designs Develop an effective training program. Design training devices that effectively replicate the end item and minimize the training burden.	Formal training includes both initial training for system/product familiarization and replenishment training to cover attrition and replacement personnel. Training requirements. Training programs. Training programs compatibility with the personnel skill level requirements and specified for the optimum performance of the operational and maintenance tasks. Training aid equipment requirements.	Trained and qualified operators and maintenance personnel. Necessary devices and equipment to support training are also developed by this group. Training objectives. Operator training. Maintenance training. Supervisor training. Instructor training. Initial training. Sustainment training. The overall concept of how training of personnel who will operate and maintain a new item of equipment will be conducted. The concept may consist of a curriculum. Training development. Training presentation. The training program: training plan, training requirements, training methods. Training methods. Lectures. Performance. On-the-job training. Self-study. Training materials: Instructor guide. Student guide. OJT handbook. Training aids. Testing. Training Support includes: Instructors. Facilities. Training equipment. Equipment types being as follows: Actual equipment. Audiovisual equipment. Mock-ups.	Training must be specifically designed and developed to be consistent with the product that is being produced, the applicable technical publications, the maintenance instructions, and the test and support equipment. Scheduled to assure the availability of operators and repair technicians as needed to support the product. Prerequisites to training: Types of training (O, I, D), student population prior skills, knowledge & education. Training philosophy. Training requirements analysis. Training program. Supporting course materials.	Operator, maintenance and supervisory personnel. Levels of maintenance have been defined. Skill levels possessed by people already employed, matching the education requirements with the skill levels. If knowledge base is not known the depth and breadth of training will be very difficult to establish. Training devices. Levels of training. Interface between man and machine must be kept as simple as possible. Training will be required at all levels of maintenance. On the equipment and support equipment Training split between theory and practical. Determining how much training is required: type, depth & breadth, i.e. number of hours. Field service personnel also be training personnel. Training plan, course outline, instructors guide, technical manuals, other presentation material. Training consists of processes, procedures techniques, training devices and equipment. Crew training, new equipment training, initial, formal and OJT and logistics support training.			Training requirements for each artisan trade and level. Qualified in specific trade, practical qualification on system, high level of analytical capability with respect to technical field. Training programs: classroom based training and self paced training. Qualification of competency: required elements for technical training. Theoretical and practical training, per discipline. Training aids. Overhead projector/Transparencies, Digital projector, stationery, exam papers and answer sheets, course progress reports, student course feedback, facility well ventilated which sits required number of students. Training course pre-requisites. Background knowledge of technical field. Training curricula. Discipline, duration, venue, pass mark, pre-requisites of qualified students. - -	Training requirements for each artisan trade and level. Qualified in specific trade, practical qualification on system, and high level of analytical capability with respect to technical field. Training courses provided by a contractor who is responsible for D-level repairs. - -	System under development, training and training devices requirements will be determined after logistic support analysis has been conducted. Training needs analysis. -	Personnel certification - new personnel required to undergo training on system. Training resources - manpower, facilities, hardware, support and test equipment required to successfully train technician to be capable of performing all the maintenance activities of the system at specific levels of maintenance. Training philosophy - classroom and practical training followed by a period of on-the-job training under supervision of a qualified mentor. Instructors & mentors – D-level system engineer or field engineer. In-depth knowledge of system, test equipment and fault finding techniques. Facilities – end user or contractor responsibility depending whose premises, training facilities - air conditioned, overhead projector, stationery. Hardware - Test benches, test equipment. Training documentation - Student training manuals, instructor handbook, also placed under configuration control. Technical training course descriptions - Aspects covered during course, duration. Continuation training - unsatisfactory work results, major system upgrades or modifications. -	Training resources: manpower, facilities, and hardware. Training philosophy: Classroom, On the job (OJT) training. System engineer is instructor. Facilities: formal training- furniture, tools, stationery, hardware for practical- functional units, test benches, test equipment. Number of students, lecture hours, length of courses. Technical training: training manuals for students, instructor manual. Also placed under configuration control. Manpower prerequisites: maintenance technician, qualification, experience and additional experience. Technical training course descriptions (theory, practical), and duration, test and evaluation, competency. Student performance. Course evaluation. On the job training: after course at site under mentor. Re-training: new personnel, existing - unsatisfactory work results, system upgrades or modifications. Informal training at sites.	Candidate requirements: existing customer personnel. Training strategy for theoretical, practical and hands on training: operation and maintenance of equipment, number of students, student requirements. Training courses: in depth training, training manuals, course curriculum and schedule. -

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COMPUTER RESOURCES	-	Logistics Information System Plan.	Plan and develop computer requirements (firmware and software). Computer resource constraints, considerations or criteria & define associated support concepts to include Interim Contract Support (ICS), Contract Logistic Support (CLS), standardization & other such requirements. Computer data records required and equipment needed to support information & contract systems to meet technical support management needs. Document recordable information. Description of how the program shall be conducted, managed and implemented to meet all contract requirements. A detailed description of how each specified requirement shall be complied with and performed. Determination of data needs, equipment and resources and their requisite support. Identification of requirements for data formats, substance and methods of processing. Identification of validation requirements, verification and delivery of data on time to meet needs. Communications identification and points of contact for people involved in the management process. Identification of system/equipment computer resource criteria, restrictions and requirements. Identification of LSA requirements.	Facilities, hardware, software, documentation, manpower, and personnel needed to operate and support computer systems. Computer resources include both stand-alone and embedded systems. Planned, developed, implemented and monitored by a computer reources working group. Computer reources support is available where and when needed. Computer resource requirements do not exceed available or achievable manpower resources and personnel capabilities.	Computer resources. Computer equipment and accessories at each level. Document processes addressing computer and software resources. Computer software configuration management system. Computer software and data management security system. Software reliability.	Computer resources support (software and firmware).		Changes associated with computer programs are properly documented and maintained. Change properly coordinated and implemented. Audit trail is always maintained. Computer software being generated will be properly identified, annotated and documented. Specific diagnostic routines designed to help check all of the software applications being used in the product. Diagnostic programmes are fully evaluated and deficiencies are corrected prior to future deployment. Software configuration baseline exists. Know where all of the operating products are and what the configuration baseline of each product is. Periodic audits need to take place. Control over computer software. Plan highlighting documentation training, support equipment and facilities required for the software.		Computer facilities, equipment, software, firmware, associated documentation, skilled personnel, and supplies needed to operate an embedded computerized subsystem. Influences of computer resources on Logistics Engineering: Computer programs and software identified; computer language requirements; specifications; requirements for compatibility with other programs; software configuration management procedures and quality control provisions; Influences of computer resources on Logistics Engineering: System software requirements for operating and maintenance functions identified and developed; software complete in terms of scope and depth of coverage; supporting software compatibility with equipment interfacing with host system; Influences of computer resources on Logistics Engineering: operating software compatibility with maintenance software; computer language requirements compatibility for operating and maintenance software; software clearly described; software tested, validated, and verified with respect to reliability, maintainability, and performance. Organization of computer software: Hardware Configuration Item (HWCI), Software Configuration Item (CSCI) - Top Level Computer Software Component (TLCSC) - which consist of Lower-Level Computer Software Components (LLCSC) - consisting of other LLCSC or units. Software development cycle: Software life-cycle phases - software requirements analysis, preliminary design, detailed design, coding and unit testing, Computer Software Component (CSC) integration and testing, CSCI testing. Reliability of computer resources prospective of software reliability, software reliability considerations, software failure sources - specification faults, design faults, code generation, computer program errors. Hardware and software interaction.	Procedure for operational software control (configuration control). All version baselines of operational software archived in fireproof safe, placed under configuration control. Auditing and verification processes for all operational software management. Software changes per engineering change proposal (ECP). Six monthly audits performed on operational software Interfaceability to other systems. System software deployment preparation, transportation and storage procedures. System operational software change procedures, using ECP and configuration control board (CCB).	Procedure for operational software control (configuration control). Auditing and verification processes for all operational software management. -	System under development, computer resources requirements will be determined after logistic support analysis has been conducted. Failure reporting and recording system. Continuous control and instrumentation measurement capturing. -	Computer resources and software support. Auditing and verification processes for all operational software management. -	Management organisation and software team and responsibilities. System and hardware description and configuration per FIR. System software and description and functionality. Standards and procedures: documentation, magnetic media, configuration, test procedures, software change requests, system trouble reports, corrective action, testing/acceptance testing. Software: Source items, software support items, buildstate. Quality activity, audit reviews and inspections, supplier control.	Computer resources and software support. Auditing and verification processes for all operational software management. -

AUTHOR /CASE STUDY THEME	DODD 4100.35 IN CARPENTER	PALGUTA, BRADLEY AND STOCKTON	MIL-STD-1369-A	ARMY REGULATION 700-127	BLANCHARD	JONES	HUTCHINSON	FINKELSTEIN AND GUERTIN	NASA	LANGFORD	SYSTEM ALPHA	SYSTEM BRAVO	SYSTEM CHARLIE	SYSTEM DELTA	SYSTEM ECHO	SYSTEM FOXTROT
RELIABILITY, AVAILABILITY AND MAINTAINABILITY (RAM)	-	-	Reliability apportionment and predictions. Reliability - Redundancy used in design. Contribution of planned preventive maintenance procedures to increase reliability. Effects of PHS&T, shelf life, and maintenance on reliability. FMECA data . LRU's with a failure rate greater than a certain percentage. Components with a known useful operating life and their frequency of replacement. Maintainability - System Mean Time To Repair (MTTR). Maintainability - System Mean Active Maintenance Downtime (MAMDT). Maintainability - System Mean Time Between Maintenance Actions (MTBMA). Maintenance or turnaround tasks with a MAMDT greater than a certain period.	RAM are key design parameters that influence both the performance (mission effectiveness and system availability) and economics (support requirements and LCC) of the materiel system	R&M Interfaces. R&M factors. System R&M. R&M allocation. Reliability testing. R&M Plan. Maintainability demonstration. Reliability block diagram. RCM. System wear-out period. Failure modes and effects. Item failure rates. Parts with excessive failure rates. Mean life. Adequate derating factors. Minimize equipment design complexity. Protection against secondary failures. Minimal adjustable components. Avoidance of friction or pressure contacts in mechanical equipment. Elimination of critical-useful-life items. Component cooling provisions. Effectiveness factors.	R&M. Operate without failure and how long it will take to fix an item when it fails.. Reliability. The probability that an item of equipment will perform its intended mission without failing, assuming that the item is used within the conditions for which it was designed. Maintainability. The probability that a failed item can be repaired in a specified amount of time using a specified set of resources. (statistical prediction). MTBF, MTTR Availability, or the ability to use a system when required, Inherent, Achieved, Operational.	Reliability, probability, performance as expected, time, specified conditions. MTBF. Tools of reliability: redundancy, simplification of design, high reliable parts, derating of parts, environmental constraints. Failure rate curve, bathtub. MTTR.	Trade-off of reliability against other desired qualities. Reliability vs total system cost. MTBF = Reliability. Reliability activities: Selection and application of components, Reliability analysis, FMECA, Reliability prediction, Critical useful life analysis, design review, reliability test and evaluation. Maintainability: Maintainability analysis, Maintainability predictions, LSA, Design reviews.	R&M logistics support capability. R&M Trade-off study. Gross R&M Requirements. R&M Evaluation criteria. R&M evaluation. R&M design guidelines. R&M design goals. Demonstrate attainment of R&M goals.	Reliability: Operating cycle, average operating intervals, failure frequency. System Life-Cycle Reliability: Phases of system reliability, bathtub curve. Maintainability: mean corrective maintenance time, mean preventive maintenance time. Corrective maintenance: mean corrective maintenance time, MTBF, failure rate-lambda; preventive maintenance: mean preventive maintenance time, MTBM (preventive), preventive maintenance frequency. Logistics/admin dealy: mean logistics delay time, MTBL (logistics delays), logistics delay frequency. General maintenance: mean active maintenance time, MTBM, MDT (downtime). Availability: inherent, achieved, and operational	Effectiveness factors. Reliability growth programme. Other contractor involvement in product. Sub systems within main system are not main contractor responsibility. Other products/systems attached to main product. External agencies affecting the system. Evaluation process and corrective action formats for R&M.	Other contractor involvement in product. Sub systems within main system are not main contractor responsibility. Other products/systems attached to main product. External agencies affecting the system. -	System under development RAM requirements will be determined after logistic support analysis has been conducted. FRACAS implementation. -	Collection and processing of failure/maintenance data. Evaluation of logistic system and equipment performance. Measuring model. Data analysis. Failure reporting. RAM analysis. Corrective Action Board. FRACAS process. Maintenance requirements per system.	Inherent availability objectives per system. Measuring model reports, failure reporting, RAM analysis outputs. Fracas process. Maintainability: characteristics, requirements, hardware responsibility matrix, support requirements, levels of repair -	Evaluation of logistic system and equipment performance. Reliability programme. Failure data, build states, shipping & dispatch information, engineering change proposals, cost drivers, FMECA, failure reporting, Maintenance analysis and reports. Availability: Inherent, achieved, operational. FRACAS process, measuring model, RAM process. -

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CONFIGURATION MANAGEMENT	-	-	MIL-STD-483. Configuration management policies, responsibilities, authority, relationship and interfacing activity with overall management organization. Integrated logistic support representation on CCB, integrated logistic support authority in design approval, ECP, trade-off studies. Configuration documentation.	ECP	Configuration management process where equipment, documentation, supply support, support and test equipment and facilities relate to each other in such a way that equipment/project performance goes ahead unhindered. Numbering system that addresses all aspects of the system. Business processes available, approved and audited. Engineering Change Proposal (ECP) process. Items, documents and support equipment traceability.	CCB &ECP	-	Elements of configuration man: configuration identification, configuration control, configuration status accounting, configuration auditing. Selection of prime and lower level configuration items (CI). Configuration control: CCB's, Class I, II or III, ECN's/ECP's, Configuration Control Process. Config status accounting is a MIS that provides traceability of configuration baselines and changes thereto and facilitates the effective implementations of changes. Configuration audits: Validate that the development requirements have been achieved and that the product's config is identified. FCA & PCA Physical nature of parts, assemblies, equipment or products, or any combination of these.	-	Configuration identification: Configuration items - functional configuration item, product configuration item; establishing configuration baselines - functional, product baselines. Configuration control: Engineering Change Proposals (ECP's) - Class I & II; Deviations and waivers; Specification Change Notes (SCN); Notes Of Revision (NOR). Configuration Status Accounting (CSA) - Engineering management information system: Configuration item drawings, CSA database, Configuration Identification Manual (CIM), Engineering release and correlation of manufactured products, Engineering release record. Configuration Audits: Functional Configuration Audit (FCA), Physical Configuration Audit (PCA). Configuration Management Process; Configuration Control Board.	Configuration management. Evaluation, coordination and approval of all changes to equipment configuration, Information database, status accounting, responsibilities, technical configuration of system, and documentation. Functional, mechanical, electrical and software requirements. Item identification and codification of system. Engineering change proposals (ECPs). Configuration Control Board (CCB). Master Record Index (MRI). Physical Breakdown Structure (PBS) of system. Audits. System technical configurations. Build history record. Baseline/product configuration and record on information system. History of configuration changes. Audits, hardware configuration & PBS, software version record, technical documentation, ECP records, MIS. Configuration items archived. Control of non-conforming products. Database. Control of purchased material and consumption.	Configuration management. -	Configuration management. Evaluation, coordination and approval of all changes to equipment configuration, Information database, status accounting, responsibilities, technical configuration of system, and documentation. Item identification and codification of system. History of configuration changes. Audits, hardware configuration & PBS, software version record, technical documentation, ECP records, MIS. -	Configuration identification. Control (CCB, ECP), status accounting & audits. Documentation management. Configuration responsibilities of system. Configuration management organisation. Deviations/concessions. Functional Configuration Baseline (FCB) to Allocated Configuration Baseline (ACB) to Product Configuration Baseline (PCB). Modification Information. Configuration Management Data System. Build State Record and build history. Subcontractor/vendor control. Configuration audits. Physical Configuration Audit, PCA procedure and requirements, Post audit action.	Configuration identification, control, status accounting and audits. Configuration management responsibilities and organisation. Configuration management data system. CCB, configuration control, documentation management, Design Change Proposal (DCP), classification of changes. Configuration baselines - FCB, ACB, PCB. Build State Record and build history. Deviations/Concessions. Configuration Status Accounting (CSA). Modification information. Configuration audits (Physical Configuration Audit), responsibilities, records kept. Post audit action. MRI.	Configuration identification, control, status accounting and audits. Configuration management responsibilities. Configuration management data system. CCB, ECP, DCP, classification of changes. Configuration baselines - FCB, ACB, PCB. Build State Record and build history. Documentation management. Modification information. Change procedure. Configuration Status Accounting (CSA). Configuration audits (Physical Configuration Audit), responsibilities, records kept. Post audit action. MRI.

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OBSOLESCENCE	-	-	-	-	System phase-out and disposal costs. System/equipment retirement and material phaseout plan.	Disposal costs: Inventory closeout, PHS&T, data management, refurbishment, demilitarization, waste management.	Obsolescence cost.	Designed-in Obsolescence. Obsolescence plan. Disposal categories: surplus material, scrap, obsolete material and equipment, waste, rejected products and services,safety stock. Disposal strategic options: Use as is, reclamation for intra-plant use, sale to anotherfirm, return to vendor, sale to dealer or through a broker, dumping.			Suffering from obsolescence. Obsolescence plan.	Suffering from obsolescence.	System under development, obsolescence not considered as yet.	No obsolescence plan in place, not suffering from obsolescence.	No obsolescence plan in place, not suffering from obsolescence.	No obsolescence plan in place, not suffering from obsolescence.
DISPOSAL	-	-	-	Minimum hazardous materials. Recycleability. Reuse of product. Environmentally preferable products. Waste prevention. Ultimate disposal Use of recovered materials Pollution prevention.	Environmental qualification	Disposal	-	-	-	Corporate safety policies and procedures. Design Safety. Hazards Analysis.	Disposal plan for system. Disposal of hardware, software media and firmware. Disposal of documentation.	Disposal of hardware, software media and firmware. Disposal of documentation.	Disposal plan for LRU's must still be developed. Radioactive waste disposal.	Procedure for disposal of LRU's -	Procedure for disposal of LRU's -	Procedure for disposal of LRU's -

Source: Blanchard (1986; 1991; 1992; 1998; and 2004), Jones, J. (1995 and 2006), Finkelstein and Guertin (1988), United States Army Regulation AR-700-127 (1999 and 2005), Carpenter (1967), Palguta; Bradley and Stockton (1987), Hutchinson (1987), United States DoD MIL-STD-1369-A (1988), and NASA (1974).

APPENDIX J: ADDITIONAL ACKNOWLEDGEMENTS

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