THE MEASUREMENT OF INFORMATION FLOW EFFICIENCY IN SUPPLY CHAIN MANAGEMENT

by

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submitted in accordance with the requirements

for the degree

DOCTOR OF COMMERCE

in

BUSINESS MANAGEMENT

at the

UNIVERSITY OF SOUTH AFRICA

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NOVEMBER 2011

I, Claus Maurer, declare that the thesis, entitled “THE MEASUREMENT OF INFORMATION FLOW EFFICIENCY IN SUPPLY CHAIN MANAGEMENT”, 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.

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SUMMARY

Characteristics such as speed of reaction, order accuracy, operational flexibility and sustained quality have become fundamental in successful business today. The success of aligning a supply chain to attain these characteristics depends largely on the use of efficient communication and information technology. Communication between supply chain members requires that relevant information is transferred from its point of inception to the next point(s) of use. The transfer of information entails an efficient flow of information between systems, between systems and humans and between humans, which is directly associated with the effective interoperability between the various entities handling the relevant information. Accordingly, the realisation of interoperability will mean a faster information flow and, thus, an effective decision-making process. This research, therefore, will propose indicators and metrics for the assessment of the information flow efficiency of a business and, in particular, of a supply chain, examine the existing techniques of information flow measurement, and identify inherent weaknesses.

New information flow efficiency metricsare developed and categorised into different indicators, which are based on the quality of the information as it is applied in finance, information technology and the principles of business performance measurements. This research will illustrate that these quality characteristics drive an effective and efficient information flow which, in turn, enables them to be used both as indicators and as associated metrics of information flow efficiency. Explorative analysis and statistical cluster analysis identified the most important indicators and associated metrics based on the results of a survey instrument designed specifically for this purpose.

Scales were developed to facilitate the numeric assessment of the metrics and indicators. In order to prove the ability of the new indicators and associated metrics to differentiate between different levels of information flow efficiency, the new metrics were applied in sample organisations and the responses evaluated. This research lays an important foundation in terms of the ability to assess information flow efficiency which is, in turn, necessary in order to gain a better understanding of the performance of supply chains in a time where real-time information flow and electronic integration are becoming strategic business success factors.

KEY WORDS

Business performance measurement, communication, information, information flow efficiency,information systems, supply chain, and supply chain management

ACKNOWLEDGEMENTS

I would like to thank and acknowledge the following individuals and institutions for their support throughout and contributions to this research project:

- Professor JA Badenhorst-Weiss, for the professional and constructive manner in which she has guided and supported me during this research as well as her generosity with time, advice and enthusiasm.

- Professor T Brevis-Landsberg, for her support specifically in the area of information technology.

- The Centre for Business Management for the financial support with regard to the statistical consultation services and the professional language editing.

- Dr Marthi Pohl, for her professional and valuable statistical and technical advice.

- My colleagues at CBI Electric Aberdare ATC Telecom Cables (Pty) Ltd, specifically the Planning, Purchasing, Operations and Financial Departments, for their support.

- My wife, Luisa, and our two children, Isabella and Natasha, for their love, patience and understanding during this period of research.

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LIST OF COMMONLY USED ABBREVIATIONS AND ACRONYMS

3PL	-	Third party logistics
AI	-	Artificial intelligence
APS	-	Advance planning and scheduling
ATP	-	Available-to-promise
B2B	-	Business-to-business
BPM	-	Business process management
BSC	-	Balanced scorecard
CBIS	-	Computer-based information system
CCS	-	Corporate communications scorecard
CMC	-	Computer mediated communication
CPFR	-	Collaborative planning, forecasting and replenishment
CRM	-	Customer relationship management
CRP	-	Capacity requirement planning
CSC	-	Communication scorecard
DEA	-	Data envelopment analysis
DFD	-	Data flow diagram
DIKW	-	Data-information-knowledge-wisdom (hierarchy)
DRP	-	Distribution resource planning
DSS	-	Decision support system
EDI	-	Electronic data interchange
EDMT	-	Effective decision-making theory
ERP	-	Enterprise resource planning
ES	-	Expert systems
EVA	-	Economic value added
IS	-	Information system
IT	-	Information technology
KPA	-	Key performance area
KPI	-	Key performance indicator
LIS	-	Logistics information system
MES	-	Manufacturing execution system
MIS	-	Management information system

MPS	-	Master production scheduling
MRP	-	Material requirement planning
MRPII	-	Manufacturing resource planning
PMF	-	Performance measurement framework
POS	-	Point-of-sale data
RFID	-	Radio frequency identification
ROI	-	Return on investment
SC	-	Supply chain
SCE	-	Supply chain execution
SCM	-	Supply chain management
SCO	-	Supply chain orientation
SCOR	-	Supply chain operations reference model
SCP	-	Supply chain planning
SCPM	-	Supply chain performance measurement
SCS	-	Supply chain scorecard
SDI	-	Standard definition of information
SIS	-	Supply chain information system
SRM	-	Supplier relationship management
VMI	-	Vendor managed inventory
WIP	-	Work-in-progress

DEFINITIONS

Communication:	Communication is the flow or transfer of information from a sender to a receiver via a channel,subject to noise as well as the encoding and decoding of the message in terms of the frames of mind of the sender and receiver.
Information:	Information is a collection of facts organised in such a way that they have additional value beyond the value of the facts themselves
Information flow:	Information flow is the transfer of information between two or more persons or entities, or between persons and entities, from the point of higher information content to the point of lower information content.
Information flow efficiency:	Information flow efficiency is the timely, unencumbered, cost effective, and secure flow of correct, agreeable, understandable and correctly formatted information.
Supply chain:	Supply chain generally refers to a set of three or more companies directly linked by one or more of the upstream and downstream flows of products, services, finances and information from a source to a customer.
SCM:	Supply chain management generally refers to as the management activities relevant to a supply chain.
Key performance Indicator:	A financial or non-financial quantifiable measurement indicator(KPI)that reflects the critical success factor (key activity) of anorganisation or supply chain.

Indicator:	According to the International Institute for Sustainable Development (IISD), "[a]n indicator quantifies and simplifies phenomena and helps us understand complex realities. Indicators are aggregates of raw and processed data but they can be further aggregated to form complex indices" (http://hostings.diplomacy.edu/baldi/malta2001/statint/Statistics_Int_Affairs-27.htm). For the purpose of this study, an indicator is referred to as a financial or non-financial measurement that may consist of one or more metrics which, when evaluated together, provide a quantifiable measurement for one specific sub-section of the entire information flow perspective.
Metric:	A metric is the measurement of a particular characteristic of an activity's performance or efficiency.
Synergy:	Synergy is the effect of interactions between the elements of systems, which produce results, which are greater than the sum of the results of the individual actions of each element in isolation.

CHAPTER 1
INTRODUCTION

1.1 OVERVIEW

The business environmentin which organisations operate today is everchanging and, in addition,it is becoming more and more complex. Organisations, both private and public, are experiencing increasing pressures that areforcing them to respond quickly to changing conditions and to be innovative in the way in which they operate (Turban, Aronson, Liang& Sharda, 2007:3). Speed of reaction, order accuracy, visibility of product flow, low to just-in-time inventories, operational flexibility, sustained quality and a reputation for hassle-free business processes are becoming the price of entry for doing business today (Bauer,Poirier, Computer Sciences Corporation, Lapide, Bermudez& AMR Research, 2001:1–3). In addition, customers are placing a high value on these characteristics, which have become the basics for successful business today.

Iforganisationsare to become more flexible and reliable, it is essential that they recondition themselves and adopt new strategies (Turban et al., 2007:3). In essence, the task of a supply chain in servicing a slow-moving, industrial mass market has been transformed into the challenge of servicing a fast-paced, fragmented general market. This situation is depicted in figure 2.6in chapter 2 (Mentzer, 2001:13; Hugos, 2006:21).

According to Stadtler and Kilger (2008:21), supply chain management (SCM) attempts both to integrate organisational units along a supply chain and to coordinate material, information and financial flows in order to meet (ultimate) customer demands with the aim of improving the overall competitiveness of the supply chain.

The successful realigning of a supply chain depends largely on the use of efficient communication and information technology. In order to assist this process, software providers started supplying material requirements planning (MRP) and resource requirements planning (MRPII) programs. However, these programs were quickly developed into enterprise resource planning (ERP) and advanced planning and scheduling (APS) software, and also into supply chain planning (SCP) and supply chain execution (SCE) software. Hugos (2006:131) contends that the use of supporting technology is essential for effective supply chain operation. All information systems comprise technology that performsthe following three main functions, namely, data capture and communication, data storage and retrieval and data manipulation and reporting. Different supply chain systems have different combinations of capabilities in these functional areas andspecifically include enterprise resource planning (ERP), customer relationship management (CRM) and manufacturing execution systems (MES). Stadler and Kilger (2008:109,182,270–271,275–282) also mention the use of advanced planning and scheduling (APS), inventories available-to-promise (ATP), collaborative planning, forecasting and replenishment (CPFR) and vendor managed inventories (VMI).

Based on the attempt to integrate all players within a supply chain, including the suppliers' supplier and the customers' customer, a supply chain may, thus, be seen as a network of organisations, linked by one or more of the upstream and down-stream flows of products, services, finances and information (Mentzer, 2001:6; Monczka, Handfield, Guinipero, Patterson & Waters, 2010:6–9).

However, Mentzer (2001:6) and Lambert (2008:197) point out that supply chains exist as a phenomenon in business, whether they are managed or not. The management of the supply chain, however, entails overt management efforts on the part of the organisations within the supply chain. According to Hugos (2006:4–6), supply chain management requires continuous decisionmaking in five distinct areas − production, inventory, location, transportation and information − by each of the supply chain members, both individually and collectively. The sum of these decisions will define the capabilities and effectiveness of the entire supply chain. In order to make the necessary decisions in the five key areas, there is one key area that receives considerably more attention than the others, namely, information and information transfer or flow. Both information and the efficient flow of information provide the basis for all decisionmaking and, therefore, connect not only the other four key areas but all the key activities and operations in the supply chain (Hugos, 2006:15–16).

Information is required mainly to coordinate the daily activities relating to the functioning of the other four key areas − production, inventory, location, and transportation − and also as regards forecasting and planning in order to anticipate and meet future demand. In order to provide the relevant parties with information, the information collected at certain points in the supply chain has either to be transferred or to flow efficiently between the functions of an organisation and between the member organisations of the supply chain (Hugos, 2006:16).In addition, it is essential that the information be accurate, comprehensive and provided in a timely manner. However, efficient information flow as well asthe accuracy, reliability and comprehensiveness of the information are directly associated with the effective interoperability between the various applications and entities handling this information. Achieving interoperability means a faster information flow, and a more effective decision-making process (Tyrinopoulos, 2004:101).

Jain (2004:4–5) argues that information constitutes one of the most important assets of an organisation. Consequently, managing information strategically must be a high priority for any organisation that wants both to compete and to win in the marketplace. In addition, the importance of information increases significantly, if the correct kind of information is available to decision makers at the right time, for the purposes of decision making, problemsolving and investigation.Jain (2004:5) asserts that it is essential that an undistorted information flow exist throughout an organisation. It is, thus, important that organisations adapt the use of technology to record business transactions, create operations-oriented databases, facilitate centralised data collection, and provide decision-making support.

Information may be either useful or not useful. It may consist of raw data or interpreted versions of raw data, depending on a person’s frame of understanding. In addition, it must not be assumed that information flows unrestrictedly as personal interests, personality traits and incompatible or non-existent technology may interfere with the transfer of information from one point to another. The inability to transfer information correctly to where it is required and when it is required will definitely impact significantly on the decision making in the other four key areas, as listed above, and, therefore, on the performance of the entire supply chain.

Key performance indicators were developed in order to assess the performance of a business and, in particular, of a supply chain. Traditionally, key performance indicators were financially oriented and concentrated solely on the financial performance of an organisation. During the 1990s, Kaplan and Norton developed a balanced scorecard (BSC) suggesting a performance measurement framework that had evolved into a strategic management framework.

Kaplan and Norton investigated the cause-and-effect relationship between the different perspectives of a business and developed the BSC performance measurement framework. This framework includes four distinct perspectives, namely, finance, internal business processes, customer perspective, and learning and growth. The framework was also used to measure supply chain performance in the form of a supply chain scorecard. In particular, metrics such as order fulfilment, processing and forecasting accuracy, supply chain response time, total supply chain cost, inventory turns and others, were proposed (Swink, Melnyk, Cooper & Hartley, 2011:42).

It thus follows that, in the same way that information and information flow form an important element of managing an organisation, both information and information flow are important for the management of the supply chain − seedetailed discussion in section 2.2.2 in chapter 2. However, the information flow in and between organisations is more complicated than the information flow in a single organisation.

Accordingly, in this study, information flow efficiency will be explored as a main contributor to supply chain performance. In addition, indicators and metrics with which to evaluate information flow efficiency in a supply chain will be identified. Information flow efficiency indicators and metrics will, therefore, contribute to the understanding of supply chain performance, in conjunction with the existing supply chain performance indicators and metrics, which are, amongst others, based on an efficient information flow.

In an attempt to identify the current potential evaluation criteria to evaluate information flow efficiency, it was found that it was not possible to identify other literature or studies which deal specifically with the measurement of information flow efficiency in supply chain management.

1.2 SUPPLY CHAIN MANAGEMENT AND INFORMATION FLOW

1.2.1 Introduction

In this section the concepts of supply chain, supply chain management and information flow and its importance will be explored. Related concepts and theories will also be explored with the aim of learning from other disciplines and developing new insights into the particular information flow and the measurement of the efficiency of information flow in the supply chain. Accordingly, besides exploring supply chain, supply chain management and information flow, this section will also explore communication theories, information systems and performance measurement.

1.2.2 Supply chain and supply chain management

1.2.2.1 The development of supply chain management (SCM)

The term *supply chain management*evolved in the late 1980s,but came into widespread use in the 1990s (Hugos, 2006:2). The main reason for the development of supply chain management was the effect of the drastic changes which took place in the business environment in the last 30 years and, specifically, during the 1990s.

From a historical perspective, during the 1960s, companies began to develop specific marketing concepts in orderboth to capture customers and to harness customer loyalty. In the 1970s, in an attempt to make products more readily available to their customers,the focus of businesses shifted to logistics and physical distribution management (Habib, 2010:82; Hugo, Badenhorst-Weiss & Van Biljon, 2004:3–4). In the 1980s,the emphasis was on manufacturing with organisations being required to become more flexible and responsive in order both to modify existing products and processes and to reduce cycle times and costs so as to meet the ever-changing customer needs (Handfield & Nichols, 2002:3; Simchi-Levi, Kaminsky & Simchi-Levi, 2009:7). In addition, a growing information technology and software market provided new software such as materials requirements planning (MRP) and distribution requirements planning (DRP) to support operations in an endeavour to increase value for the customer. This development continued into the early 1990s, when MRP and DRP were merged with financial transactions and accounting principles into enterprise resource planning (ERP) systems, as all-encompassing business solutions.

The 1990s were also distinguished by the development of strategic logistics management as a critical business activity. The emphasis of logistics moved from internal efficiency to external relationships with the supply chain partners (Simchi-Levi et al., 2009:7–9). The reason for this paradigm shift may be found in the profound changes taking place in the business environment. These changes includedthe following (Hugo et al., 2004:4):

- Increasing national and international competition
- Growing number of strategic alliances between organisations
- Organisational structures starting to align with business processes
- Manufacturing system enhancements through MRP and ERP
- Growing appreciation on the part oforganisations for the total cost focus from source to consumptions
- Reduction in number of suppliers
- Outsourcing of non-core activities
- Sharing of information between vendors and customers
- Shift from mass production to customised products.

The consequence of these changes was the realisation that, a single organisation does not have the technology and resources available to satisfy customer demand, and that member companies of a supply chain have a decisive role to play in fully understanding and meeting customer requirements. As a result, the member organisations of a supply chain began to collaborate and integrate their management, processes and infrastructure across organisational borders (Hugo et al., 2004:4; Lambert 2008:1–3). Further progress in information technology enabled organisations to share information − one of the most critical factors in building integrated supply chains.

From the above discussion it is clear that the new management philosophy, which has been termed *supply chain management*, encompasses the traditional functions such as logistics but, in addition,extends further to include activities such as customer service, new product development, marketing and finance across the organisational borders while considering the supply chain as a single entity (Hugos, 2006:4).

1.2.2.2 The supply chain concept

Trkman and Groznik (2006:38) define a supply chain as the integration of key business processes from end user through to the original suppliers that provide the products, services and *information* that add value for the customer as well as other stakeholders. Material and information flow both up and down the supply chain. Thesekey business processes or supply chain activities include new product development, system management, operations and assembly, purchasing, production scheduling, order processing, inventory management, transportation, warehousing and customer service. Supply chains are, essentially, a series of linked suppliers and customers. Every customer is, in turn, a supplier to the next downstream organisation until a finished product reaches the ultimate customer.

This view is widely shared by other writers such as Lambert (2008:4), Burt, Dobler and Starling (2009:7) and Hautala (2010:9), who describethe supply chain network as the sum of all the organisations participating in such a chain and extending from the raw materials to the ultimate consumer. According to Dong (2001:1–2), a supply chain may also be defined as a system of suppliers, manufacturers, distributors, retailers and customers, in which materials flow downstream from suppliers to customers,while information flows in both directions. Angerhofer and Angelides (2000:343) define the supply chain as a system of which the constituent parts include material suppliers, production facilities, distribution services and customers which are all linked together via the feed-forward flow of materials and the feedback flow of information. Pedroso and Nakano (2007:1) and Mentzer (2001:5) define the supply chain as a set of three or more companies directly linked by one or more of the upstream and downstream flows of products, services, finances and information from a source to a customer. Similarly, Webster (2008:4) describes a supply chain as two or more parties linked by a flow of resources, typically material, information and money.

Coyle,Bardi and Langley (2003:18-19) refer to the supply chain concept as a "series of integrated flows that must share information and physical products to ensure a smooth, integrated flow …" and requiring the presence of information if the supply chain is to function successfully.

Govil and Proth (2002:7) define the supply chain in a similar manner, while clearly emphasising the need to "improve the flows of material and information between suppliers and customers at the lowest cost and highest speed …", thus also referring to efficiency in the information flow.

Hugo et al. (2004:6–8) cite several definitions of the supply chain, while clearly stipulating the requirement and necessary existence of information flows. One of these definitions, namely, "The supply chain encompasses all activities associated with the flow and transformation of goods, … as well as the associated information flows …" emphasises the information flow directly, whereas other definitions infer the existence of the information exchange by referring to "integration" and "up and down-stream linkages" which are, in turn, managed mainly by information systems management activities.

The above perspectives on the concept of the supply chain illustrate the interdependence or cooperation between vertically linked organisations in terms of which the information flows in both directions are vitally important. However, in view of fact that an organisation may be part of numerous supply chains and at different levels, it is not possible to regard the supply chain structure as a straightforward chain in all cases (Lambert, 2008:3).

Based on the definitions cited above, the supply chain may be graphically represented as is shown in figure 1.1 below.

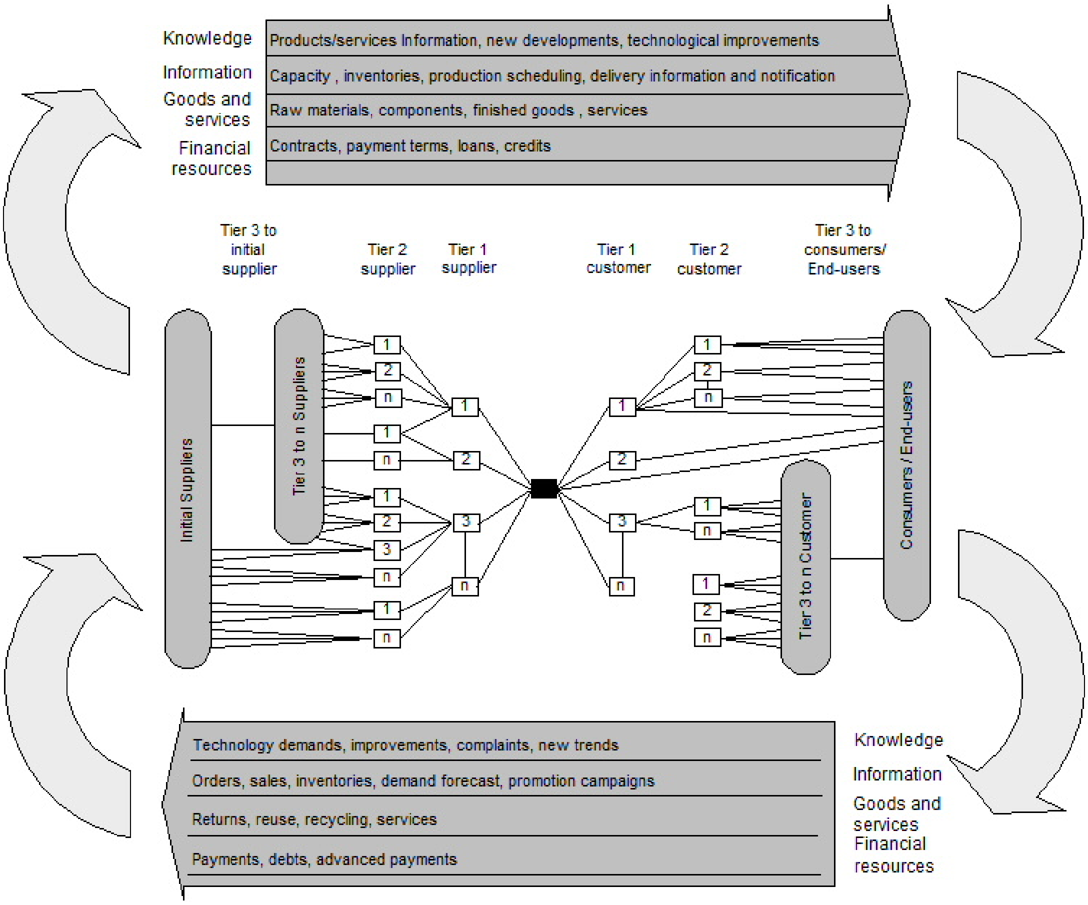

Figure 1.1: Visual representation of the supply chain network

Source: Adapted from Lambert (2008:4) and Pedroso and Nakano (2007:4)

In essence, the representation in figure 1.1 above depicts the integration of all the activities involved in the flow of materials and services and as well as illustrating that the supply chain consists of customers, manufacturing facilities, distributors, suppliers, processes, products and information (Lambert, 2008:4), and is also focused on customer value creation.

According to Mentzer (2001:5–7) and Hautala (2010:9),there are different types of supply chain. These range from the most basic type, represented by a company, an immediate supplier and an immediate customer, to the extended supply chain, which includes suppliers of an immediate supplier and customers of an immediate customer, all linked by one or more of the upstream and downstream flows of products, services, finances and information, to the ultimate supply chain. The ultimate supply chain includes all the companies involved in all the upstream and downstream flows of products, services, finances and information from the initial supplier to the ultimate customer. Mentzer (2001:6–7) and Lambert (2008:3–4) further conclude that a supply chain may grow to include complex networks. Mentzer (2001:6–7) also points out that that such supply chains do, in fact, exist, whether they are managed or not. Accordingly, it is possible to draw, a definite demarcation between supply chains as phenomena that exist in business, and the purposeful management of those supply chains, with the latter being characterised by overt management efforts on the part of the organisations within the supply chains. Supply chain management and its role in the supply chain will be discussed in the following sections.

1.2.2.3 The concept of supply chain management (SCM)

The second issue requiring elucidation is SCM. If the management principles, as discussed by Hugo, Badenhorst-Weiss, Van Biljon and Van Rooyen. (2006:3–5,59–60), are taken into account, it follows that supply chain management must deal with planning and organising the entire supply chain as well as providing the necessary resources and leadership. In addition, SCM also involves taking appropriate action in cases of deviation in such a way that the outcome of the whole is greater than the sum total of the outcomes of the individual areas covered by the supply chain. This approach is based on the fact that the individual areas of the supply chain represent a system of open subsystems that require integration. Angerhofer and Angelides (2000:343) define supply chain management as a process-oriented, integrated approach to procuring, producing and delivering products and services to customers. According to them, integrated supply chain management covers the management of material, information and fund flows.

However, according to Salo andKarjaluoto (2006:20), supply chain management is the integration of key business processes from the end user through the original suppliers, with this integration providing products, services and information that add value for both customers and stakeholders.

Webster (2008:5)perceives SCM as encompassing the planning and management of all activities involved in sourcing and procurement, and conversion,as well as all the logistics management activities including the coordination and collaboration with channel partners. These channel partners may be suppliers, intermediaries, third party service providers and customers. In addition, Webster (2008:5)details logistics management as that aspect of supply chain management that plans, implements and controls the efficient and effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption.

All the definitions cited above embrace the requirement pertaining to the integration of the processes from the original supplier to the end-users and as well as includingthe *management of information flow*. Pedroso andNakano (2007:1–2) also include the flow of funds.

The phenomenon of increased efficiency as a result of integration is commonly referred to as *synergy*, and may be included to enhance the definition of supply chain management.

In conclusion, the concepts of supply chain and supply chain management have been discussed above. The supply chain was found to consist of a network of organisations which are connected through flows of material, services, funds and information. Supply chain management reflects the overt management efforts of the member organisations of the supply chain to manage the flows so as to optimise customer value. During the discussions on SC and SCM it became apparent that both information and the efficient flow of information have a crucial role to play in the establishment of integrated supply chains. The importance of the information flow in the supply chain is embedded in the various definitions of supply chain and supply chain management as described by the many authors highlighted in sections1.2.2.2 and 1.2.2.3.

The importance of information flows between the entities of the supply chain has, further, been singled out as a cohesive force in the supply chain. Information sharing and the complex linkages, vital to the functioning of the supply chain, would be impossible without modern information flows. In fact, during the previous discussions it was emphasised that it is regarded as essential that information sharing occur on a real-time basis in order to decrease the uncertainty between the members of the supply chain and to lead to a smoother and more efficient functioning and integration of the supply chain.

1.2.2.4 Impact of information and information flow on supply chain performance

The importance of measuring the efficiency of the information flow in a supply chain will become obvious in the following discussion on the negative effects of poor information flow and the benefits of an efficient flow of information in a supply chain.

Busch (2011:2) and Simchi-Levi et al. (2009:154-165) emphasisethe necessity of collaboration between the entities of the supply chain. Theyargue that supply chain information which has been derived from the supply chain entity either immediately ahead or in front of an individual supply chain partner only, may lead to the bullwhipeffect. In addition, Busch (2011:2) attributes increasing errors in forecasts to diminishing data quality in those instances where each supply chain partner plans individually without a supply chain-wide data exchange.

Derrick (2003:1) and Trkman andGroznik (2006:38) describe the bullwhipeffect as the ever-larger ripples in demand forecast errors that travel back through the supply chain and which is caused by slight discrepancies between individual company demand forecast and real demand. Derrickbelieves that companies do share information, but of a limited nature and scope, thus leading to the bullwhip effect. Simchi-Leviet al.(2009:158) maintain that the reasons for the bullwhip effectmay be found in the lack of demand information at each stage of the supply chain. According to them, the longer an organisation takes to respond to changes in the primary customer demand, in terms of passing the correct information ontimeto either the next or the previous tier, the higher the variability in the forecast order quantities in that tier. The bullwhip effect is, thus, a direct consequence of a lack of real-time information sharing and efficient information flow through the entire supply chain.

Lee and Whang (2001:1–15) and Simchi-Levi et al. (2009:154–165) describe the benefits of sharing information in an integrated supply chain. These benefits include:

- Reduced bullwhip effect
- More effective forecasts
- Faster response and reduction in lead time
- Lower cost
- Better capacity utilisation
- Improved service
- Better asset utilisation
- Higher efficiency

Susarla, Barua, Konana andWhinston (2004:1–4) are of the opinion that information sharing impacts significantly on operational performance, on operational metrics and on the operations of upstream organisations (i.e. manufacturers and suppliers).

Besides the importance of an efficient information flow, it is also clear from the various contributions that it is essential that the information flow be managed in SCM with the measurement of efficient information flow forming an integral part of the management of information flow. Hence, it is the aim of this study both to explore and to make a contribution to the measurement of information flow efficiency in SCM. Accordingly, the two main focus points of this study will be *information flow* and the measurement of the efficiencyof information flow.

1.2.3 Information flow in the supply chain

1.2.3.1 Introduction

It will emerge from the literature review on information in chapter 3 that the "flow of information" is closely connected to and is, in fact, almost inseparable from the concepts of*knowledge* and *communication*. Logical reasoning will conclude that there will be no meaningful flow of information if knowledge is not transferred or if there is no communication. Information flow and the concepts closely related to it will be analysed in this section.

1.2.3.2 Perspectives on information

It is clear from theliterature that information may be defined in various ways, depending on the primary context. For example, Boisot and Canals (2004:1) contend that information is often associated with data, whereas other writers associate information with knowledge. Reeker and Jones (2002:1) argue that a new characterisation of *information* is necessary, one which delineates the salient properties of information, quantitative measures for those properties, methods for computing these measures and linkages between the measures and system performance. This section will, thus, explore the various views on the concept of*information*.

The National Institute of Standards and Technology (NIST) has offered a general definition by stipulating that information refers to "any communication or representation of knowledge such as facts or data, in any medium or form, including textual, numerical, graphical, cartographic, narrative or audiovisual forms" (National Institute of Standards and Technology (NIST), 2010:1-2).

Reeker and Jones (2002:5–6) contend that information requires a physical component which, in turn, characterises a possible transmission of information and a component of meaning which, ultimately, synthesises meaning into information.

Boisot and Canals (2004:7) define information as follows: “Information is an extraction from data that, by modifying the relevant probability distributions, has a capacity to perform useful work on an agent’s knowledge base.” This definition embraces the fact that information is extracted from data and, thus, is not equal to data, and that it must be useful in the sense that it increases knowledge.

Stair andReynolds (2011:5) define information as “a collection of facts organized in such a way that they have additional value beyond the value of facts themselves”. According to them, information may be extracted from data by applying either a transformational process or a set of logical, related tasks performed in order to achieve a defined outcome to the data, which involvesapplying knowledge by selecting, organising and manipulating data (Stair & Reynolds, 2011:5–7).In other words, information is data in a transformed, usable state.

This definition reflects the context within which this research is conducted. Accordingly, for the purposes of this study,*information* will be defined as follows:

Information is a collection of facts, organised in such a way that they have additional value beyond the value of the facts themselves.

It is possible to derive from this definition of information a definition of supply chain information in order to contextualise this study of information in supply chain management:

Supply chain information is represented by a collection of facts about the supply chain, and structured and interpreted in such a way that they have additional value beyond the pure facts and data themselves.

However, in order to obtain greater insights into the other dimensions of the concept of information, it may be necessary to explore the various ways in which information is categorised.

According to Reeker and Jones (2002:6–7), information is transmitted in two different components. Firstly, as outlined above, there is a physical component − the so-called *potential information* −which is capable of transmitting information, but without attaching any meaning to the information. The second component has been termed *mediate information*and it is through this component that the potential information becomes meaningful. These components are clearly depicted in figure 1.2 and in table 1.1.

Meriluoto (sa:4) categorises information on the basis of *probability interpretation* and *qualitative interpretation*withthe probability interpretation providing physical, syntactic and semantic information, whereas the qualitative interpretation provides pragmatic, epistemic, doxastic, modal, data-derived and meta-information. An exposition of this categorisation of information is depicted in table 1.1.

Physical information represents the orientation degree of systems and is the opposite of entropy. Syntactic information is attached to communication in any channel where notation systems are used. Semantic information refers to the philosophy of signs that deals with meanings.

Pragmatic information is expressive or knowledge-related information and is related to the significance of the information to the persons that receive the information while epistemic information relates to information such as general knowledge and scientific information. Doxastic information pertains to beliefs, thoughts, judgements, opinions, desires and wishes. We may knowthat something is as stated by information and we may also believe that something is so, but such belief may be true, false or both. Modal information refers to absolute values or norms, commands or questions while data-derived information requires the processing of raw data in accordance with certain procedures or algorithms, in order to arrive at this specific information. Meta-information, on the other hand, is a crucial component of organisational system strategy and it provides data either about the data itself or the media where the data is stored and retrieved.

Table 1.1: Categorisation of information

Main category	Sub-category	Authors
Meaningful information	Potential Mediate	Reeker & Jones
Probability interpretation Qualitative interpretation	Physical Syntactic Semantic Pragmatic Epistemic Doxastic Modal Data-derived Meta information	Meriluoto

Source: Compiled from Reeker andJones (2002:10) and Meriluoto (sa:4)

Different categories of information may be found in supply chain management. The transmitters and receivers of information are required to send information between the entities of the supply chain. In addition, words and sounds, which form part of mediate information, are necessary in order to relay meaning. It is clear that potential and mediate information form part of the categories found in the supply chain. The qualitative interpretation dimension of supply chain information is evident as a result of the importance of relationships and interdependence in supply chain management. Accordingly, the information within the supply chainmay also be categorised as *pragmatic*, *epistemic*, *data-derived* and *meta information* as thisinformation also includes general knowledge, scientific information and processed data.

Following the definition and typology of information, the central concept and actual object of this research, information flow, will be dealt with in the next section.

1.2.3.3 Information flow and related concepts

The flow or exchange of information is often used to model communication (Jonker, Treur & Wijngaards, 2000:1). Huhtinen and Ojala (2001:6) offer the following definition of communication which is specifically relevant to the business environment, namely, *communication* is "the transfer of information between two or more persons or larger entities, such as the departments of an organisation or within an organisation". Accordingly, communication may be considered as the activity of conveying information (WordReference.com; http://www.Wordreference.com/ definition/communication).

Reeker and Jones (2002:10) expand on the definition of communication by differentiating between *potential information* and *mediate information*. According to them, *potential information* encompasses the physical dimension of information. The physical transmission of symbols via a communication channel may be described in terms of Shannon's information theory (Shannon, 1948:379–423, 623–656). Shannon (1948:379–423) dealswith communication in a purely mathematical manner and provided a numerical measurement for the quantity of information processed or transmitted in terms of bits. He concurs that the messages transmitted during communication processes frequently have meanings although these meanings areirrelevant to the mathematical considerations of information.
According to Reeker and Jones (2002:5), the physical part of information constitutes a carrier only for what is actually meaningful, while meaningfulness lacks a satisfactory theoretical basis. The theoretical construct dealing with the meaningful dimension of information has been termed *mediate information* (Reeker &Jones, 2002:5).

In order to illustrate these concepts graphically, figure 1.2 depicts a model for conveying knowledge. This model is an extension of the historical communication model as described by Shannon (1948:379–423, 623–656).

Figure 1.2 depicts a simple *transfer process* of information from one person to the next person. The transfer process is illustrated usinga spoken utterance as an example of potential information. This spoken utterance is, transferred by sound waves while the mediate information comprises certainnotions of the relevant mediate information in order to render the potential information meaningful. The mediate information converting the potential information into meaningful information partiallycomprises a set of conventions commonly held by the speaker in the belief that the listener would interpret the information using the same conventions. Although most mediate information is stored in the minds of the communicators, some of it may arrive simultaneously with the spoken utterance, for example, non-linguistic information. By passing meaningful information through filters tuned by the cognitive and affective expectations of the communicators, their existing knowledge base will be broadened.

Boisot and Canals (2004:2) contend that information is necessary in the formation of *knowledge*. However, knowledge may be derived from information only if sufficient contextual background knowledge exists, with this contextual background knowledge allowing for further interpretation of the information received. Accordingly, only the existence of prior knowledge will allow for a change in the current state of knowledge, and for the appropriate adaptive action. It is, however, clear that, in order to broaden the knowledge base, a priori *transfer* or flow of information has to occur.

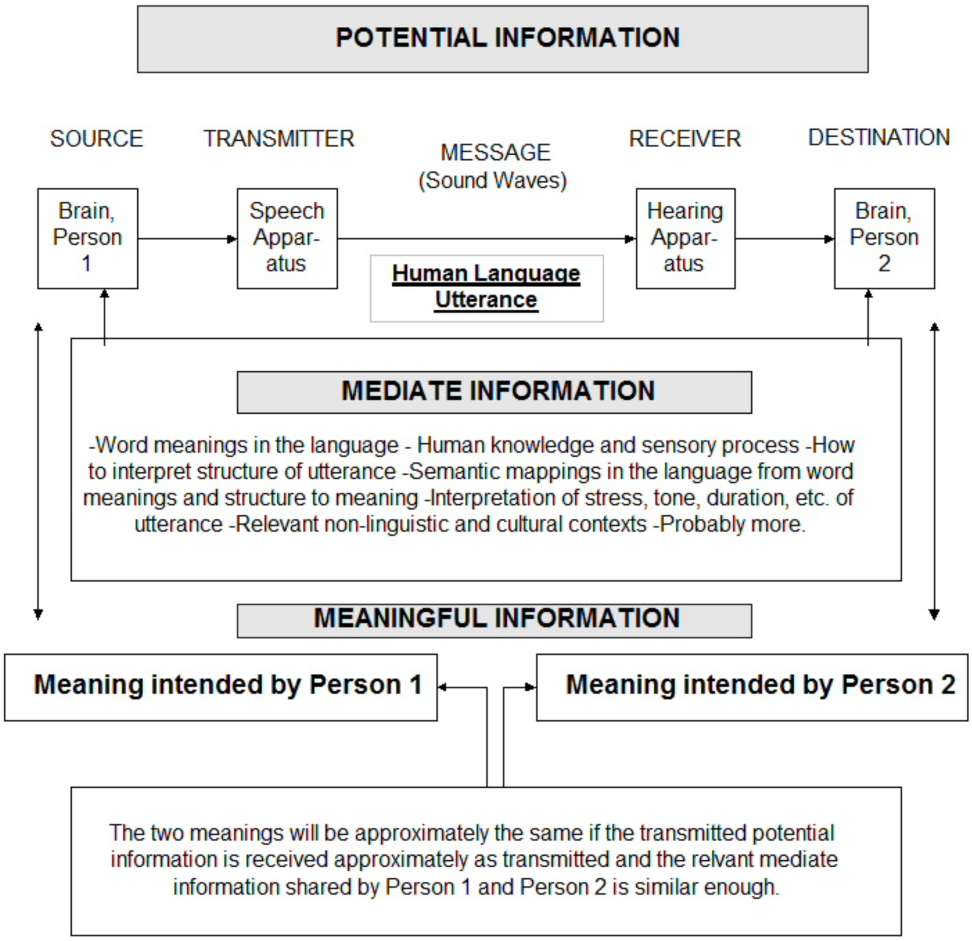

Figure 1.2: The conveyance of knowledge process

Source: Reeker and Jones (2002:10)

Learning in terms of an individual as well as an organisation is another important related concept related to information theory and information flow. Accelerated environmental changes are, increasingly, pushing organisations to evolve, to adapt and to be flexible. However, this process requires the management of existing knowledge as well as the exploration of new knowledge (Castiaux, 2004:1). The exploration or creation of knowledge is important as it creates new ideas and practices that need to be shared (Newell, 2005:276). According to Husman (2001:3), knowledge constitutes input into learning. In other words, knowledge transfer in many cases generates new learning. *Organisational learning* is important to organisations as it allows organisations to renew themselves, innovate and, possibly, enjoy first mover advantages (Husman, 2001:3). However, as depicted in figure 1.2, this research study will deal with the information flow and communication from person-to-person within and between organisations in supply chains, with or without the aid of electronic systems. This study is, therefore, not directly concerned with the creation of new knowledge, but with the efficient flow and sharing of information. In the literature the capture, codification and distribution of knowledge and information has been termed first generation knowledge management (KM) (McElroy, 2000:199).

Information technology is widely used in the capture, storage, retrieval and access of current information and knowledge and this, in turn, has led to the data warehousing, document management, imaging and data mining applications of today (McElroy, 2000:199). However, it is clear that the use of such applications requires a strong interaction and communication between humansbeings and computer technology.

Piltz (2001:1–12) and Grooms (2003:1–3) describe human/electronic communication as computer-mediated communication (CMC). They further define this computer-mediated communication as "synchronous and asynchronous communication using text messages sent via the computer" and "the interpersonal communication with the assistance of computers as a transfer medium, transferring spiritual or intellectual content via two spatially separated computers or terminals, connected to a central computer by means of cables".

According to Piltz (2001:3), the main difference between person-to-person communication and CMC is the fact that the communication between persons, in the case of CMC, is limited to a visual, textual channel which lacksboth the direct cognitive perception and observation of the communication partner and the situational, physical and social context.

The following basic applications form part of CMC (Piltz, 2001:3):

- Electronic messages
- Electronic mail (e-mail)
- Electronic discussion forums
- Computer conferences

In view of the fact that these forms of communication have readily become part of the communication within the supply chain, they are used to transfer information − the focus of this research study. Another important aspect of CMC isthe computer-created reports that originate from information systems. These systems will be described in the next section.

1.2.3.4 Influences determining information flow efficiency

Information flow and its related concepts have been defined in the sections above. In addition, the importance of an efficient information flow was emphasised in section 1.2.3.3. However, it is important to stress, that the flow of information in business organisations, and particularly in supply chains, affects productivity and innovation because it determines the speed with which individuals are able to act and to plan future activities (Wu,Huberman, Adamic& Tyler 2004:1).

Information flow and the control thereof involves numerous heterogeneous technologies, including, but not limited to, computers, printers, digital image archiving systems, electronic records, paper-based records and human speech (Moser, 2004:9).

Scala Business Solutions NV (2004:7) emphasises that it is vital for a supply chain that crosses multiple companies to generate value so that the individual participants are able to see, in near real time, the upstream demand and downstream supply. This implies that systems need to communicate and to be able to share information, both internally and externally. Traditional, paper-based transactions are becoming increasingly obsolete. Accordingly, most of the required information should be recorded electronically and the associated transactions should be performed with a minimum of human intervention. In a perfect world, all participants in the supply chain would support real-time, online communication, sharing data using non-proprietary standards with a very low cost of entry for new participants.

However, the flow of information or the sharing of information may be problematic, and it is not possible to assume that information will be readily available or that it will flow uninhibited between two parties (Trkman,Stemberger & Jaklic,2005:562).

Obstacles to the efficient flow or transfer of information may be encountered at different levels of the supply chain organisation as well as regardsthe different types of information flow.

Person-to-person information transfer depends largely on

- the expertise of the persons in the relevant area (Borgatti, 2005:1)
- the acquaintance of the persons involved in the information transfer (Borgatti, 2005:1)
- the social and cultural barriers between the persons involved in the information transfer (Borgatti, 2005:1)
- trust, psychological safety and dependence factors between the persons involved in the information transfer (Borgatti, 2005:2)
- varying goals of interest (Saariluoma, 2006:1)
- geographic differences (Saariluoma, 2006:1)
- shared interests of persons exchanging information (Wu et al., 2004:1)
- personal privacy policies of persons exchanging information (Wu et al., 2004:1)

In the case of human-to-computer interaction it is essential that additional variables be taken into account, including:

- errors in data collection processes (Newcorn, 2003:58)
- ERP does not facilitate inputs (Newcorn, 2003:58)
- training in using the system (Newcorn, 2003:58)
- user-friendliness (Newcorn, 2003:58)
- access to the computer system (Borgatti, 2005:2)
- information behaviour (Johnstone, Tate& Bonner 2004:6)
- lack of formal procedures (Moser, 2004:10)

- incompatibility between human paper-based and electronic information systems (Moser, 2004:3)

As regards machine-to-machine information transfer, the following factors must be taken into account:

- Systems that are not able to understand each other (Moser, 2004:3), i.e. software incompatibility, protocol incompatibility.
- Different interpretations of data at different network points/plants (Newcorn, 2003:58)
- Proprietary systems are not easily adaptable (Cisco, 2005:4)
- Proprietary systems offer limited scalability (Cisco, 2005:4)
- Disconnected and disjointed systems (Newcorn, 2003:58)

From an organisational supply chain perspective, information flow may be differentiated at the various organisational levels. On a strategic level, the information flow between companies may be inhibited by a lack of trust between the supply chain members. In such a case the partners would be unwilling to share information such as lead times, and production and sales data. This phenomenon occurs specifically the more independent the member companies (Trkmanet al., 2005:562). In another instance, Kauffman andMohtadi (2003:2) report that the incentive of a buyer either to share information with or to withhold information from a supplier may be driven by the leakage of information to potential rivals.

The determinants of the information flow at the operational level within the organisation approximate the decisive factors of the information flow between humans and humans, and humans and computers, as detailed above.

Despite the level of the information flow in the supply chain, or the mode of the information transfer, the speed with which information flows from one point to another in a network of organisations or smaller entities of a supply chain, is also determined by the length of the path between the points or nodes of the network (Borgatti, 2005:2). The longer the length of the shortest path between a pair of nodes, the longerit will take for information to flow between these nodes.

Accordingly, networks with high average path lengths take longer to transmit information to all the members of the networks.

It is, therefore, clear that the speed of the information flow has a direct influence on business and supply chain efficiency. In many cases, companies employ information systems which are specifically applicable to supply chains in order to improve the information transfer to the members. The nature of these information systems will be explored in the next section.

1.2.4 Information systems in supply chain management

1.2.4.1 Introduction

Information systems (IS) have become increasingly important and, indeed, critical to the operation of a supply chain (McLaren, Head &Yuan, 2004:1).

In recent years, collaboration has become the focus of supply chain management. The ability to link and work effectively with suppliers and customers as well as the integration of internal processes, has produced newsystems for application in the supply chain arena, for example, scan-based trading, enterprise resource planning (ERP), vendor-managed inventory (VMI), collaborative planning, forecasting and replenishment (CPFR), supplier relationship management (SRM) and customer relationship management (CRM) (Simchi–Levi et al., 2009:416–417). An IS may, thus, be regarded as an important tool in the SC in terms of analysing myriads of data. Information systems also play a major role in supporting strategic advantage, managerial decision making and business operations (Stock & Lambert, 2001:166).

The following section will provide a more specific discussion of information systems.

1.2.4.2 Definition

An IS may be seen as a set of interrelated components that collect input data, process the data, output both data and information and provide a feedback/control mechanism (Stair & Reynolds, 2011:4).

A more detailed definition is given by The Alliance for Telecommunication Industry Solutions (ATIS, 2001:1). According to ATIS an information system

- is a system, whether automated or manual, that comprises people, machines and/or methods to organise, collect, process, transmit and disseminate data that represents user information or, more generally,

- an information system may also be defined as the entire infrastructure, organisation, personnel and components for the collection, processing, storage, transmission, display, dissemination and disposition of information.

For the purposes of this study on SCM, both the above views of information systems are important withStair andReynolds (2011:4) emphasising the technological approach, whereas ATIS emphasises the interaction with human activities.

1.2.4.3 Components of an information system

It is, thus, clear that an IS comprises several components. According to Haag, Cummings andMcCubbrey (2004:17–19), information systems consist of

- hardware resources
- software resources
- network resources
- data resources
- people resources

- input, processing, storage, output and performance monitoring resources.

According to Haag et al. (2004:17–19), information systems capture raw data (input), which is converted into useful outputs (processing), and then presents these outputs, usually in the form of documents and reports (output). Feedbacks and controls provide for a mechanism to make changes to these basic processes of input, processing and output (see figure 1.3).

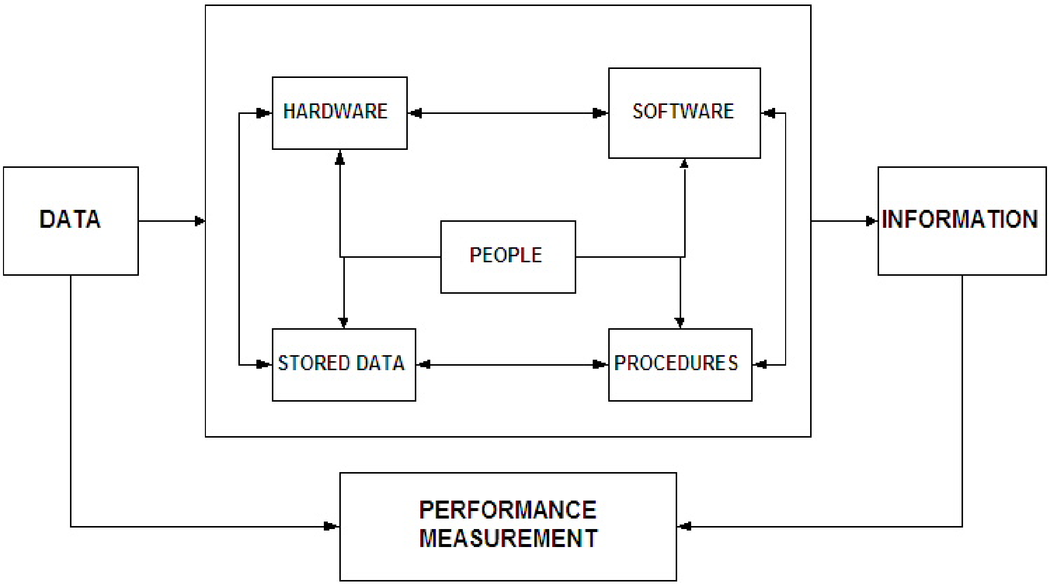

Figure 1.3: Graphic representation of an IS

Source: Adapted from Johnstone et al. (2004:19)

The processes of input processing and output creation play a particularly important role in supply chain management. As regards supply chain management the information systems typically process raw data, such as inventory levels, point-of-sale (POS) data, etc., which is communicated between the entities of the internal and external supply chain, and produce useful information that enables the supply chain partners to react and to arrive at more effective operational and managerial decisions.

1.2.4.4 Supply chain management information systems

1.2.4.4.1 Requirements

If information systems are to be of use to the endeavours of supply chain management, then it is essential that these information systems must have essential capabilities. McLaren et al. (2004:1–3) studied the capabilities of supply chain information systems and found that the following were the most frequently cited requirements:

- The IS must have the ability to reduce the organisation's operating costs by improving operational efficiency.
- The IS must be able to increase the organisation's supply chain responsiveness.
- The IS must coordinate the information flow between the internal and external partners of the supply chain, such as customers, suppliers, and logistics providers.
- The IS should enable more accurate and timely information and also information coordination.
- The use of the IS should result in reductions in inventory and lead-times, an increase in sales and an improvement in customer relations.
- The IS should exhibit planning and analysis capabilities, including collaborative planning, forecasting and replenishment (CPFR).

However, the priority accorded to the above requirements for an IS varies according to the degree of importance which an organisationattaches to the individual requirement and the capability of the IS to meet the organisation's goals (McLaren et al., 2004:7–9). However, compliance with these requirements does have a direct influence on the information flow and the eventual efficiency (and success) of a supply chain.

In realising the aims of this study as regards measuring the information flow performance or efficiency in supply chains, the study will place considerable reliance on the computer-mediated communication (CMC), as defined in section1.2.3.3 above. The following section will provide an overview of the information systems which have been developed for supply chain management.

1.2.4.4.2 The development of information systems for supply chain management

The primary goal if information technology in the supply chain is to link the point of production to the point of delivery or purchase, in order to achieve an information trail that follows the physical product (Simchi-Levi et al., 2009:415). This will allow for planning, tracking and estimating lead times based on real data. Information systems in supply chains are used as tools to collect, access and analyse information, to integrate systems, and to collaborate with supply chain partners (Simchi-Levi et al., 2009: 414).

McLaren et al. (2004:1–15) found that, by implementing one or other IS, organisations will integrate, both internally and externally. Systems allowing specifically internal integration are generally known as enterprise resource planning (ERP) systems while others, such as electronic data-interchange (EDI) and e-market places, concentrate more on external integration.

Historically, material requirements planning (MRP), distribution requirement planning (DRP) and capacity requirements planning (CRP) systems were installed and run as stand-alone systems. However, over the years, manufacturing resource planning (MRPII) systems evolved into enterprise resource planning (ERP) systems and then into advanced planning and scheduling (APS) systems and, now,into supply chain management systems (Swink et al., 2011:448–464).

Jacobs, Chase andAquilano (2009:459) contend that the core of ERP systems, which were developed in the 1990s, includes the following applications:

- Materials management
- Production planning and control and human resource, benefits and payroll
- Projects/works orders
- Sales and distribution and asset management

- Financial control
- Financial accounting
- Costing
- Quality management
- Plant maintenance

The complete process of planning and managing an organisation's resources has, thus, been integrated.

However, according to O'Neill (2005:1–2), not all ERP systems currently offer all of the above-mentioned modules and organisations would,typically, have had some legacy system before implementing the ERP software. In many cases this will have resulted in a combination of both, the old and the new systems, thus requiring additional interfaces and non-continuous interaction.

Although systems such as ERP and MRP are internal to an organisation, multiple sites may be connected to them. It is, however, not common to find organisations connected to their customers or suppliers via these systems although, according to SAP AG (2004:1–24), the internet technology does allow for such possibilities.

A further integration of supply chain participants may be derived from electronic data interchange (EDI). According to Murphy andWood (2004:64), EDI represents a computer-to-computer transmission of business data in a structured format. In addition, since EDI provides a seamless transmission of data across organisations, it may also facilitate the integration of organisations across the supply chain. There are a number of benefits to EDI (Murphy & Wood, 2004:64),including the following:

- Faster exchange of data without errors, thus reducing the communication cost, document preparation, processing time and shipping errors
- Streamlining logistics processes, resulting in reduction of lead times, ontime delivery and inventory reductions
- Improving cash flow and billing accuracy

In addition,as GXS, a B2B commerce solutions provider, (http://www.gxs.com/wp-content/themes/GXS/pdfs/whitePapers/wp_Benefits_of_EDI.pdf) points out, it is possible to reduce purchase order handling while associated costsmay be dramatically cut with EDI. On the other hand, Vermeer (2000:1–9) maintains that a growing number of organisationsare reporting negative impacts as a result of using EDI. These negative impactsare caused by insufficient data quality, leading to more errors and the need to implement preventative measures, thus reducing the expected benefits as outlined above. Further impediments to EDI include high set-up costs, lack of standard formats and incompatibility of computer hardware and software (Murphy & Wood, 2004:64).

A further development of EDI comprises the collaboration between the organisations in a supply chain in terms of collaborative planning, forecasting and replenishment (CPFR). In this scenario, suppliers, manufacturers, wholesalers and customers collaborate voluntarily, particularly in the areas of planning, forecasting and replenishment. As shown by De Min (2003:1–16), the success of CPFR depends critically on the infrastructure of the wide area network, which connects all the relevant entities joined by the CPFR process. According to him, it is essential that the network be designed to provide security, simultaneous operation, global access based on real-time information.

As shown above, information flow and the efficiency thereof have a profound effect on the efficient operation of the supply chain network.

Any delays in response to information transferred or delays in transferring information between supply chain members will, ultimately, affect the efficiency of the supply chain. It is, therefore, important that the efficiency of the information flow/transfer be measured as a part of the performance evaluation of SCM. Accordingly, the aim of this research is to investigate the measurement of the efficiency of the information flow in supply chain systems.

1.2.5 Indicators and metrics in supply chain management

1.2.5.1 Introduction

The performance measurement of either a business or a supply chain is a complex activity (Coyle et al., 2003:482–483). There are several key performance indicators (KPIs) for key performance areas (KPAs) which are aimed at judging the performance of logistical and supply chain activities. However, as a result of the complexity of the supply chain, a comprehensive set of performance metrics is required. The following sections will contain a description of performance measurement and an outline of the metrics for SCM. The discussion will also clearly reveal a lack of metrics for information flow efficiency.

1.2.5.2 Key performance indicators (KPIs) and metrics in SCM

Thesectionabove introduced the concepts of KPIs and metrics. In this section these concepts will be explained in greater detail.

1.2.5.2.1 The concepts

A key performance indicator (KPI) may be defined as "financial or non-financialquantifiable measurements that reflect the critical success factors (key activity) of an organisation"(Von Haaren& Malyshko, 2007:9).

According to Giannoccaro, Ludovico and Triantis (2007:91), a performance metricmay be defined as quantifying *the effectiveness and/or efficiency of actions. Measurements are typically expressed in terms of time, quantity, quality or cost* (Hugo etal., 2004:100–108).

In short, it should be noted that key performance indicators provide a performance measure for a specific key performance area of an organisation, i.e. customer satisfaction, whereas metrics offer performance criteria for activities within a key performance area, such as on-time delivery.

The following section will outline specific KPIs as well as the metrics used in SCM.

1.2.5.2.2 KPIs and metrics in use in supply chain management

According to Coyle et al. (2003:482–485), it is knowing what to measure that influences the overall benefit derived from the measurement process. There are a multitude of metrics in use to gauge the performance of supply chains, including, inter alia,outbound freight cost, order fill rate, finished goods inventory turns, returns and allowances, customer complaints, back orders, order cycle times, forecast accuracy, invoice accuracy to orders processed per time unit, cash-to-cash cycle time and inquiry response. Other metrics used include confirmed fill rate, response delay (in terms of confirming a delivery date), work-in-progress stock (WIP), sales/inventory ratios and sales (Kleijnen & Smits, 2003:1–2).

If it is taken into account that a supply chain consists of various organisations, then clearly the measurement of a supply chain is even more complex than that of a single organisation (Hugo et al., 2004:101). In addition, Hugo et al. (2004:101) reported that traditional metrics relied heavily on financial metrics such as the return on investment (ROI). However, as a result of the fact that, besides cost, the supply chain is also driven by other factors such as quality, delivery and speed, it is obvious that a single metric may not be sufficient to express the performance of a supply chain.

Although it would appear that there has been insufficient research into supply chain performance measurement(Hugo et al., 2004:101), it is, nevertheless, possible to find traces of diversified development to fully encompassing models, with the supply chain scorecard as depicted in Santos, Gouveia andGomes (2006:2–4) providing an example of such developments. In addition, Santos et al. (2006:2–4) propose a supply chain performance measurement framework based on the following four perspectives of the BSC:

- Customer perspective
- Business process perspective

- Financial perspective
- Innovation and learning perspective

Each of these BSC perspectives encompasses a number of KPI's, which may be selected depending on the relative level of importance in each business and supply chain. The supply chain BSC is depicted in figure 1.4. (Santos et al., 2006:1–2),

Another example of the variety of KPI's that may be used within the context of SCM performance measurement is provided byVon Haaren andMalyshko (2007:11). Their proposed performance measurement framework comprises five balanced scorecard perspectives, including the four perspectives mentioned above with the additional perspective of "cooperation".

Both Santos et al. (2006:2–4) and Von Haaren andMalyshko (2007:11) define specific KPIs and the metrics that maybe used to evaluate supply chain performance, given certain key assumptions such as strategy and the network selected.

However, it is clear from figure 1.4 that "efficient information flow" as a key objective for supply chain performance has not yet been taken into account, despite the fact that its influence on supply chain performance is undeniable. The following section will present reasons why the information flow perspective as well as the relevant indicators and metrics should be included into the BSC for the supply chain.

1.2.5.3 The supply chain scorecard

According toSantos et al. (2006:2–4), a supply chain scorecard representing proposed KPIs and metrics is depicted inFigure 1.4. These metrics correspond with the metrics proposed by the Supply Chain Council's supply chain operations reference (SCOR) model (http://www.supply-chain.org; Simchi-Levi et al., 2009:381; Swink et al., 2011:42). However, according to Santos et al. (2006:2–4), it is essential that metrics be linked to business strategy, operational plans, goals of individual departments as well as global goals. It follows, thus, that metrics may vary from industry to industry and company to company and that the requisite metrics must be developed for each perspective (Swink et al., 2011:41).

In general, writers agree that the four key perspectives, namely, *financial, customer, internal business process related and learning and growth perspectives* should be adopted for the measurement of supply chain performance (Kaplan &Norton, 1996: 7–10;Santos et al., 2006:2–4). Writers such as Von Haaren andMalyshko (2007:11) do offer reasons for the inclusion of additional perspectives.

The SCOR model addresses the following five basic dimensions of performance (Swink et al., 2011:42):

- Delivery reliability
- Responsiveness
- Flexibility
- Costs
- Asset management efficiency

According to Swink et al. (2011:42), shareholder concerns may also be addressed by adding performance indicators such as “profitability” and “effectiveness of returns”.

It emerges from a closer inspection of the SCORmetrics,as proposed by Swink et al. (2011:42) and Simchi-Levi et al. (2009:381), that these SCOR metrics may be related to theBSCmetrics within the BSC framework of key performance indicators. Both the performance measurement frameworks, BSC and SCOR, include measurements relating to the financial, business process, customer and innovation and learning perspectives.

Perspective	**Primary and support activities/proposed KPIs**	**Metrics**
Customer perspective	Sales/customer support	Quality − % non-conformity
		Forecast accuracy
		Market share
	Logistics	On time delivery
		Number of products /distribution channel
		Damaged shipments
Financial perspective	Sourcing	Material acquisition cost
	Manufacturing	Non-quality cost
		Warehousing cost
		Manufacturing unit cost
	Warehousing	Cost of carrying inventory
	Logistics	Logistics cost
		Transportation cost
	Accounting processes	Cash flow
		EBDITA (earnings before depreciation, interest and tax)
		Income
		EVA (economic added value)
		Operating ratio
		ROI (return on investment)
		Revenue per employee
		Return on asset
Internal business process perspective	Sourcing	Supplier on-time delivery
		Material inventories
		Material quality
		Supplier cycle time
	Planning	% of orders delivered according to plan

		Schedule changes
		BOM (bill of material) accuracy
	Manufacturing	Adherence to schedule
		% defective products
		Number of finished products /SKUs (stock keeping units)
		Manufacturing cycle time
		Setups/Changeovers
		Plant utilisation
	Delivery/storing	Finished goods inventory turn
		Stock keeping units
Innovation and learning perspective	Innovation	% new product development
	Social responsibility	Social programs invested
	HR	Absenteeism
		% employee training
		Employee productivity
		Motivation
		Employee turnover

Figure 1.4: The supply chain balanced scorecard
Source: Santos et al. (2006:2–4)

As depicted in figure 1.4, it is essential that thoseorganisations that adopt the supply chain scorecard find key performance indicators and metrics which suit their type of business (Webster, 2008:356). In other words, the metrics and KPI's may vary between organisations and industries. In order to support business in their efforts to measure the performance of their supply chains, software vendors offer computerised solutions, which are either stand-alone systems or systems that integrate with the ERP systems in use within the specific organisation, to support the measurement process (IBM, 2009:1–4).

1.2.5.4 Communication scorecards

It was indicated previously that *information flow* and *communication* are closely related concepts. Accordingly, in a quest to measure information flow efficiency it makes sense to make use of developments in this area of communications.

In view of the fact that that this research focuses on the development of indicators and metrics for the measurement of information flow efficiency, this section will discuss relevant communications extensions of the BSC as well as the specific performance measurement frameworks of other relevant communications with a view to business performance assessment.

1.2.5.4.1 The corporate communications scorecard (CCS)

Besides the well-known BSC model and the proposed metrics, Zerfass (2004:1–7) suggests an expansion of the BSC to include communications for corporate strategic controlling purposes. This extended scorecard has found applications in industry. The corporate communications scorecard (CCS) aims specifically at incorporating a *communication* perspective into the BSC, which deals with the public relations communication of an organisation with its stakeholders on a strategic level. In particular, in terms of the expansion suggested by Zerfass (2004:1–7), the *social-political perspective* was introduced into the standard BSC. Zerfass (2004:1–7) described explicit value drivers and metrics with which to assess this new perspective, namely, the social political communication which was derived from the expectations that, for example, citizens and politicians, may show goodwill towards the specific organisation.

These value drivers may include:

- Improving the corporate citizenship
- Public knowledge about the organisation
- Accepting responsibility for the environment

Applicable metrics may include:

- Number of job opportunities created
- Successful registration according to standards emanating from environmental audits
- Percentage purchases from disadvantaged suppliers

These metrics impact directly on the supply chain and, thus, they require the sharing of information from a strategic perspective across both the organisation and the supply chain.

1.2.5.4.2 The Communications scorecard (CSC)

According to Huber andPfeiffer (2007:8), communications may be regarded as a value-creating factor that contributes to both the efficiency and the effectiveness of an enterprise's strategy. The CSC combines tangible and intangible assetswhich cannot be separated in the enterprise strategy. Huber and Pfeiffer (2007:8) maintain contendthat seamless implementation is achieved by a simultaneous planning of all communication instruments and methods based on their functional, timeous and hierarchical relationships. The CSC expands each of the existing perspectives of the BSC with a view to communications.

As is the case of the BSC, the CSC begins with an analysis of the strategic goals of an enterprise and defines both the key performance indicators and the operative value drivers. It is then possible to deduce, the key communications indicators and value drivers from these strategic goals. Thereafter, business economic and communications goals must be synchronised. Quantifying the success parameters makesit is possible both to measure and to evaluate the communications contribution. It is in this way that the contribution of communications to increasing the value of the enterprise may be verified (Huber & Pfeiffer, 2007:8–9).

1.2.5.4.3 The communications control cockpit

According to Zerfass (2005:5), the communications control cockpit, as published by Rolke (2004:47-54), is based on the reputation quotient (RQ). However, the reputation quotient does not allow for a direct measurement of the contribution of communicationto theenhancement of the reputation of an enterprise and, therefore,to an increase in its business success. The RQ concept asserts only that,based on statistical deliberations, a general relation between enterprise value and reputation value does exist. However, Zerfass (2005:5) argues that an advantage of the communications cockpit approach it that it proposes to calculate the communications values, ImEx (Image or Reputation Value), and to compare these values with the economic value added (EVA) of the enterprise.

In particular, the ImEx consists of the reputation values of the stakeholder groups of customers, public, employees and shareholders, and the total of all the communication budgets, as depicted in figure 5.7.

Three key performance indicators have been provided by the communications control cockpit, namely, communications efficiency (KommEf), value-value-relation (2VR) and return on communications (RoCom). The deduction of each of these KPI's is depicted in figure 5.7.

The communications control cockpit will be discussed in greater detail in chapter 5.

1.2.6 Information flow efficiency measurement

1.2.6.1 Approach to measuring information flow efficiency

The measurement process, in this case, the measurement of information flow efficiency, is not merely concerned with the collection of data associated with a predefined standard with performance measurement rather being perceived as an overall management system involving the prevention and detection of non-satisfactory performance in a particular key performance area.It is the aim ofthe measurement process to improve the relevant underlying business process in order to bring about better customer service. In addition, the measurement process is also concerned with the optimisation of the relevant process based onthe increased efficiency and effectiveness of the particular process under investigation (Kellen, 2003:3–6). The performance measurement paradigm may be applied in order to develop indicators and associated metrics of information flow efficiency in organisations and/or supply chains.

Real-time contextual data enables users to make better, faster decisions by providing information across both the plant and the supply chain in a single format. However, there is the possibility of abundant data-handling and information-sharing inefficiencies (MMS MAG, 2006:12). Control systems use proprietary data formats and lack information sharing capability while legacy systems often lack the capacity or intelligence to provide useful data. It is, thus, clear, that the efficiency of information sharing or of the information flow has a direct bearing on the speed with which decisions may be made about the future state of a supply chain. From a performance measurement point of view, the process concerning the information flow efficiency which must be investigated and measured, thus,also involves the methods of information transfer within an organisation and between the member organisations of a supply chain.

Performance measurement systems typically comprise one or more metrics. Metrics are quantitative values that may be used for the purpose of comparison. The comparison may involve a comparison of a metric with itself over long time horizons, pre-set targets, or together with other metrics (Kellen, 2003:3). However, metrics have already been developed for several processes and key performance areas. For example, the supply chain scorecard, as depicted in figure 1.4, presents the metrics which were proposed for the evaluation of supply chain performance.

As it is evident from the literature on supply chain (Hugo et al., 2004:8; Mentzer, 2001:5–6), the flow of information plays a critical role in the functioning and integration of the supply chain. However, amongst all the metrics which may be applied to assess the performance of the supply chain, there are none to evaluate the efficiency of the information flow throughout the entire supply chain. Accordingly, this research study aims to provide such metrics for the evaluation of information flow efficiency in supply chain management (SCM) in order to identify possible areas of improvement in the SCM process.

In an attempt to develop new indicators and associated metrics for information flow efficiency, the measurement framework, which is similar to the BSC and the supply chain scorecard as illustrated in table 1.2 below, will be presented.

Furthermore, existing characteristics of the measurementsapplied in the various fields of business administration, business performance measurement, information technology and financial information qualitywere evaluated in terms of their usability in an information flow efficiency measurement framework.

Table 1.2: Information flow efficiency measurement framework

Performance measurement terminology	**Example**
OBJECTIVE	Information flow efficiency
INDICATOR	Information integration %
METRIC	1. Average information transmission time (seconds) 2. Information cycle time (hours)

The characteristics which are applicable to information systems, as detailed by Stair & Reynolds (2011:7), include

- timeliness
- content, in terms of accuracy and usefulness
- complexity.

These characteristics could be considered applicable to the measurement of the efficiency of the information flow in supply chain management and, depending on their measurability, such characteristics may be used as indicators and metrics of information flow efficiency. Other characteristics, such as those described in paragraphs 1.2.6.2 to 1.2.6.4, also lent themselves to be used as metrics for the measurement of transactions on an operational basis, providing individual values for the numerical performance in terms of each indicator. For example, timeliness could be considered as a measure with which to judge the timely distribution of information, whereas characteristics such as information transfer-time, frequency of information transfer and information validity time periods, could be considered as metrics within the timeliness indicator

In order to identify suitable characteristics, which may be used as indicators and metrics for the measurement of information flow efficiency, this study conducted a literature review, followed by a survey. The aim of the survey was to ascertain the opinions of business executives about the suitability of certaincharacteristics that may influence the efficiency of the information flow inthe supply chain.

1.2.6.2 *Characteristics of business process measurement*

In order to develop indicators and metrics for information flow efficiency − the aim of this study − it is important to evaluate those characteristics, which are available in the field of business performance measurement and also in other fields, for example, information technology, for their suitability in terms of measuring information flow efficiency. Kellen (2003:22–23), for example, lists the following key design characteristics of metrics which he deems desirable in any business performance measurement system. These characteristics include the following:

- Controllability
- Validity
- Relevance
- Specificity
- Comprehensibility
- Repeatability
- Reliability
- Timeliness
- Responsiveness
- Accuracy
- Automation
- Cost-effectiveness
- Completeness

- Information dissemination
- Strategic alignment
- Organisational coverage

According to Kellen (2003:23), the term *business performance measurement system* refers to both the information technology and the human process that interacts with the technology. The two are joined in a symbiotic relationship with each other and, hence,it is essential that the design characteristics take both aspects into account.

This research study will concentrate on identifying suitable characteristics of information flow efficiency which may serve as indicators and metrics of information flow efficiency. The generally accepted norms of business performance measurement and information technology measurements represent one source for both the indicators and the associated metrics of information flow efficiency.

1.2.6.3 Characteristics of business process measurement as drivers of efficient information flow

Kellen (2003:4) affirms that the characteristics listed above represent the design characteristics of either a metric or a metric set of a business performance framework. In addition, it is essential that the information provided in the measurement framework is in accordance with these characteristics.

The efficiency of information flowis embedded in the characteristics above, for example, “timeliness”, “accuracy” and “reliability”, because any shortcomings in the fulfilment of these characteristics will lead to additional time being required either to obtain the correct information or to correct any false information. This, in turn, would require more resources than would have been the case had the information been correct. If information is not on time, additional resources will be required to find the information and delays may occur in any decisions that need to be made based on the information which is not available. It may, thus, be logically concluded that the above characteristics constitute the drivers of an effective and efficient information flow because,not only must the information provided be correct, but it must also pass and flow from the source to the users effectively and efficiently.

The provision of metrics arising from data, transactions or events, through the transformation of such data into useable information, such as metrics,together with the associated flow of information to the end user is depicted in figure 1.5 below.

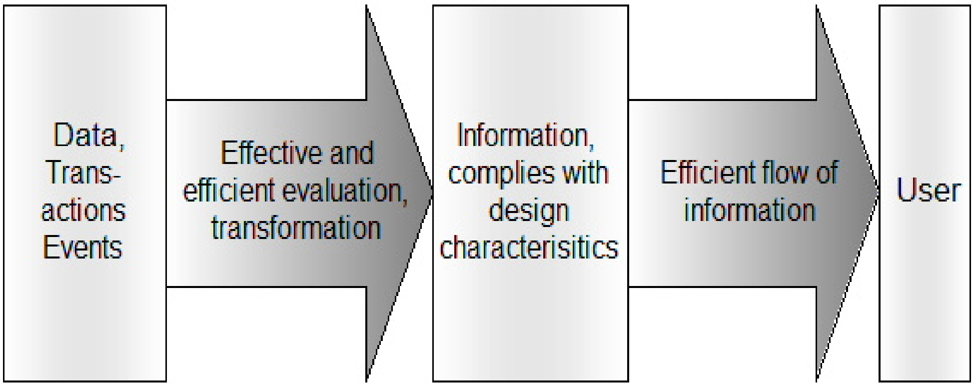

Figure 1.5: The effective and efficient provision and flow of information to the user

Source: Compiled by researcher and adapted from Stair andReynolds (2011:7)

The prerequisitefor the provision of effective and efficient information is that both the information and the flow of information must comply with the design characteristics, as detailed in section 1.2.6.2, if the information and the flow of information are to have the capability of producing metrics that comply with the same design characteristics. It may, therefore, be concluded that design characteristics comprise the key factors of or drive efficient information flow. Accordingly, an assessment of the compliance/performance of the aforementioned key factors or design characteristics will provide a measurement of the efficiency of both the information and the information flow.

1.2.6.4 Characteristics of financial/accounting information quality

Another important source of possible indicators and metrics for information flow efficiency may be found in the characteristics of financial information quality. Carmichael, Whittington andGraham (2007:67), Epstein, Nach andBragg (2009:33), and Porter andNorton (2010:60) all contend that the primary objective of financial reporting is the provision of useful information for the making of both investment and credit decisions. According to them, those qualities that render information both useful and understandable have been designated its *qualitative characteristics*. According to Nikolai, Bazley andJones (2010:46), the United States Financial Accounting Standards Board has specified the characteristics of information as depicted in figure 1.6. These characteristics will ensure that information is at its most useful. In addition, Carmichael et al. (2007:68) argue that, without usefulness, there would be no benefits from information to offset against its costs.

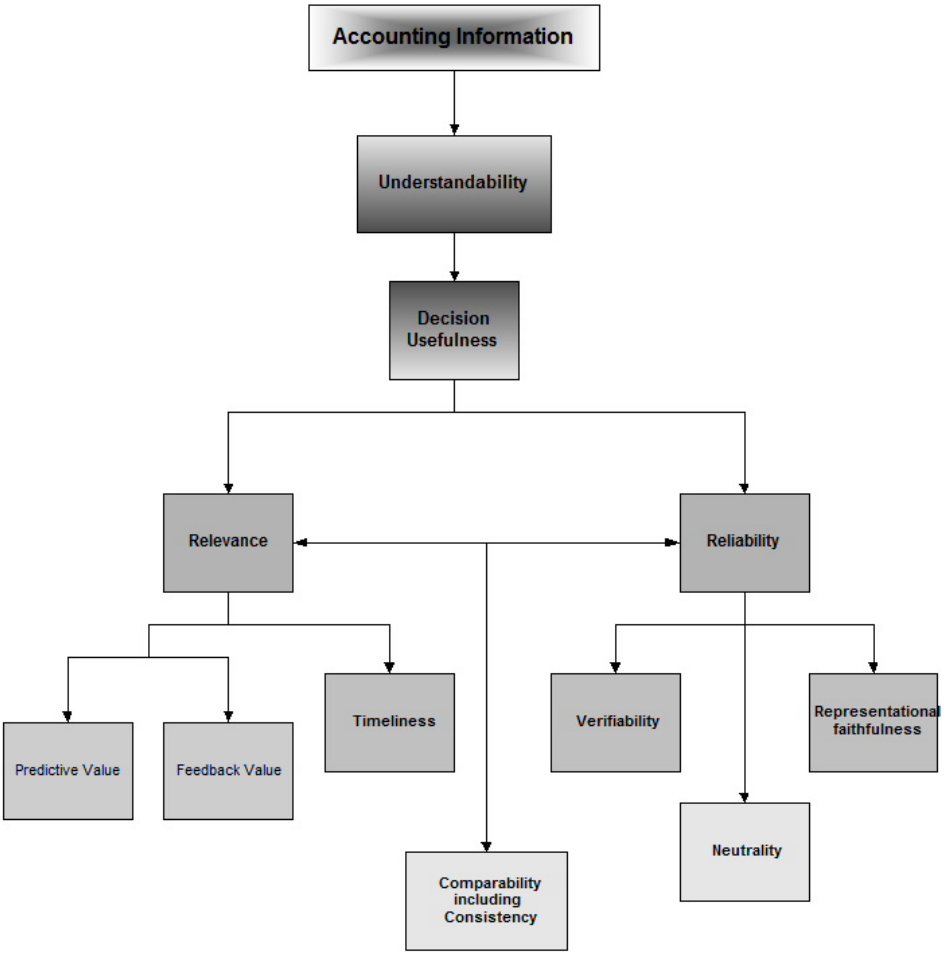

Figure 1.6: Characteristics of accounting information

Source: Adapted from Nikolai et al. (2010:47)

However, despite the hierarchical structure of the characteristics of financial and accounting information, which distinguishes between user-specific and decision-specific qualities (Carmichael et al., 2007:69), Nikolai et al. (2010:46) argue that this hierarchy is not designed to assign priorities to the qualitative characteristics, and that both financial and accounting information must possess each of the qualitative characteristics to a minimal degree. It is these characteristics that distinguish that information which is more useful to the user, and which may result in better decision making, from information which is less useful. It is, therefore, clear that these characteristics drive the provision of useful and understandable information for superiordecision making. In addition, these characteristics may also be understood to provide information effectively and efficiently as, if any of the above criteria are not met, this would result in less efficient decisions because of the additional time required either to obtain the correct information or to correct any false information.

1.2.6.5 *Extension of the supply chain scorecard to include information flow efficiencyindicators and associated metrics*

The importance of information flow and, therefore, information flow efficiency, in the supply chain has been explained in section 1.2.2.4. As already stated writers generally agree that the sharing of information and, hence, the flow of information is extremely important for the successful completion of supply chain activities.
In view of the fact that it is the aim of this research to develop indicators and metrics for information flow efficiency which will enable supply chain managers to evaluate the efficiency of the information flow it is, thus, conceivable that these indicators and associated metrics of information flow efficiency should form part of the overall supply chain performance measurement. As such, information flow efficiency would form an essential part of the supply chain BSC in terms of either a new perspective or a key objective within a current perspective.

In order to develop indicators and associated metrics for information flow efficiency, it is necessary to review existing literature in terms of its applicability to supply chain management. For example, Schuppener (sa:1–20) prepared a communications scorecard (CSC) which measured the additional economic gains, within the four perspectives of the balanced scorecard, by using communication instruments. Zerfass (2004:1–7) proposed the corporate communications score card (CCS) for the strategic control and measurement of an enterprise, as regardsthe enterprise’s communications strategy with its stakeholders, using the social-political performance of an organisation as a KPI in order to measure communication success. The latter clearly emphasises the public relations activities of an organisation;however, the communication and information flow between stakeholders in the SC in order to improve the operational process in the SC is the focus of this study.

Although both of the above extensions of the BSC focus on different areas of communication compared to those contemplated in this research, the importance of communication efficiency as regardsan organisation and its stakeholders − includes the supply chain and the measurement thereof −are undeniable. In particular, the participants (suppliers and customers) in the supply chain may be considered as stakeholders of the supply chain. Therefore, it is not only justifiable, but also important, to include the measurements of information flow efficiency into the supply chain scorecard for the purpose of controlling supply chain activities in order to improve the efficiency of the SC as a whole. This is, indeed, the focus area of this study.

1.2.7 Conclusion

The above sections provided an overview of the supply chain and supply chain management and presented insights into the importance of the efficient flow of information in the supply chain. In particular, it was shown that several writersare in agreement that a supply chain is hardly able to function without anefficient flow of information both along the supply chain and between supply chains.The literature also showed that organisations have been trying to improve the flow of information by installing electronic information systems and EDI, as well as collaborative metrics such as CPFR and VMI.

Nevertheless, despite the fact that the importance of an efficient information flow has been recognised, there is little evidence that any attempt has been made to devise measurement instruments with which to determine the information flow efficiency within a supply chain. In addition, no model exists that is able to provide a holistic overview of information flow efficiency in supply chain management.

In this research study an effort will be made to identify indicators and metrics for information flow efficiency in supply chains. Such indicators and metrics will make it possible to view the efficient information flow from a (supply chain) management point of view, thus implying that information flow should be planned, measured and reviewed, as is commonly required of all managerial activities.

In the following sections the research process adopted in this study will be described.

1.3 PROBLEM FORMULATION

1.3.1 Problem statement

Many writers (as cited in the previous sections) have agreed that the flow of information, either in form of raw data, processed data or interpreted data, plays an important role in the smooth functioning of the entire supply chain. However, despite the importance of the flow of information, little attempt has been made to measure the efficiency of the information flow in supply chains. However, it is possible that such measurement may make a profound contribution in illustrating any shortcomings in the flow of information and, thus, in the functioning of the supply chain. In the light of the above the following question forms the basis of the research problem in this research study:

What indicators and associated metrics may be used to evaluate information flow efficiency in the entire supply chain?

The scope of the research problem is clearly reflected in the primary and secondary objectives of this study, as detailed in the following sections.

1.3.2 Primary objectives

The primary objective of this research study is

- **to develop and to conduct an exploratory test of an instrument for the measurement of information flow efficiencyin the supply chain**

However, in order to realise this goal, it is necessary to divide the primary objective into secondary objectives, as detailed below.

1.3.3 Secondary objectives

The following secondary objectives have been identified:

- To identify possible indicatorsof information flow efficiency

- To identify or develop possible associated metrics for the measurement of each indicator

- To determine the most important indicators and associated metrics for information flow efficiency in a sample case study of a specific telecommunications cable manufacturing supply chain in South Africa

- To develop scales for each metric against which the performance of each metric maybe assessed

- To use these indicators, metrics and scales developed to conduct an exploratory test of the information flow efficiency measurement instrument in the sample case of a telecommunications cable manufacturing supply chain

1.4 RESEARCH METHODOLOGY

1.4.1 Research process

In order to realise the objectives of the research, namely, to develop indicators and associated metrics for information flow efficiency, it was necessary to review existing literature on this and related matters, and to gather data and information from both primary and secondary sources in an appropriate manner. Furthermore, the data and information were subject to an appropriate method of analysis, as detailed below and as presented in figure 1.7.

1.4.1.1 Step 1: Exploratory research/literature study

As depictedin step 1 of figure 1.7, qualitative research and, in particular, exploratory research was carried out in this study in order to explore the research problem stated above (Creswell, 2002:58–61). This, in turn, led to both, a definition and an understanding of the concept of information flow and related concepts, as well as the identification of possible indicators and associated metrics for information flow efficiency.

In order to solve the research problem a literature study was conducted in order to ascertain existing knowledge on the topic, prior to solving the research problem. Secondary sources of information, namely, textbooks and journal articles, were also consulted. In addition, the Internet was used for searches relating to contemporary information relating to the research problem with sources includingtopics such as supply chain management, information management, operations research, communication, management information systems and business performance measurement principles relating to both objective and subjective data. The exploratory literature study served to identify possible factors which may have been applicable to the measurement of the efficiency of information flow.

The research process reviewed the literature on available measurement frameworks,characteristics of information, quality of information and business performance measurement for their incorporation into the survey which was to be conducted.

This aspect of the research process was important as, in a real supply chain, not all the communication activities between the members of the supply chain and between the functions in individual organisationsmay be assumed to have been computerised, nor will every company employ computerised information systems in the same manner, thus leading to differences in the speed of transfer of information.

The efficiency with which information flows in a supply chain determines the speed with which information may be evaluated and converted into decisions and actions. Accordingly, information flow efficiency has a determining influence on the performance of a supply chain.

1.4.1.2 Step 2: Empirical survey

In step 2 of the research process a more descriptive research method is followed in order to describe the "who, what, when, where and how" of a situation or phenomenon. In this research study specifically, particular insight is required in terms of how and which indicators and metrics to apply to the measurement of information flow efficiency (QuickMBA:Marketing: 1999–2010:3).

In order to identify the most important information flow indicators and the metrics associated with each measure, an empirical survey was conducted to collect information on the opinions of leaders in a specific telecommunications cable manufacturing supply chain as regards the proposed indicators and associated metrics. The participating organisations were chosen as a result of their affiliation with the aforementioned telecommunications cable manufacturing supply chain and in an attempt to gather as much information as possible from this supply chains and to try to achieve representative sampling for the particular population mentioned above.

To aid the study this survey also investigated the current state of information systems use and information integration in the telecommunications cable manufacturing supply chain, thus, providing evidence of information flow efficiency within the supply chain.

1.4.1.3 Step 3: Evaluation of research results and development of scales

The survey questions concernedboth the ranking and the rating of the characteristics of information and information transfer that would be used as indicators and associated metrics. The process of ranking and rating produces ordinal data. This, in turn, implies that it is not possible to use standard statistical procedures involving the mean and standard deviations to evaluate the survey data and, instead, nonparametric statistics were applied.

In order to evaluate the characteristics or indicators of information and information flow efficiency, box plot diagrams were first used to evaluate the spread of the data and any potential outliers. However, when computing a measure of location for this particular question, the medians will be used rather than the means.

The selection of the indicators of information flow efficiency will be explored firstly by utilising statistical hierarchical clustering procedures. Cluster analysis involves a mathematical method of grouping data based on the inherent similarity or dissimilarity of data − see section 8.2.8.2.3. The results of the cluster analysis, in conjunction with the importance rankings, will determine the selection of a master set of indicators.

Once the set of indicators and associated metrics to measure information flow efficiency have been selected using statistical analysis and explorative data analysis, the scales for the actual measurement process need to be developed − see step 3 of the research process.

This research adopted the use of continuous scales ranging from 0% to 100%. Scores were allocated in such a way that a 100% score would be recorded if it was possible to meet the requirement of the metric to be assessed in the best possible manner, was fully present and/or had been carried out to the complete satisfaction of the expert assessing the fulfilment of the individual requirements. A 0% score would be allocated if the requirements of a metric were not met The use of experts ensured that values between 0% and 100% were assigned according to the degree to which the requirement of a metric was metIn order to assess the compliance of metrics to requirements, a time scale was used,as discussed in section 8.3.4of the study, for time related metrics, as well as a subjective scale based on set anchor points − seesection 8.3.5.

1.4.1.4 Step 4: Case study in telecommunication cable manufacturing supply chain

After the indicators and associated metrics for the objective "*information flow efficiency*" had been developed, a case study research wasconducted in step 4 of the research process in order to obtain actual measurements of information flow efficiency so as to prove the viability of the indicators and metrics formulated. Accordingly, the information flow efficiency in different organisations in the telecommunication cable manufacturing supply chain was measured. The relevant organisationswereselectedby means of convenience sampling which wasbased on

- the willingness of the organisationsto participate in the study
- their willingness to provide resources in terms of personnel and time
- their willingness to provide their expert opinion in terms of the metrics assessed, without, however, compromising the confidentiality requirements.

According to Castillo (2009:1–2), convenience sampling is a non-probability sampling technique in terms of which subjects are selected based on their convenient accessibility and proximity to the researcher. The most obvious criticism as regards convenience sampling is sampling bias and also the fact that the sample is not representative of the entire population, in this case, manufacturing concerns in other industries.

However, every possible supply chain partner of the company selected was included in the case study.

Crosthwaite, MacLeod and Malcolm (1997:1–16) have identified the following criteria as regards the appropriateness of the case study method:

- Specifically answers "how" and "why" questions
- Is explanatory in nature
- Represents an empirical enquiry into a contemporary phenomenon within a real life context
- The researcher has no control over the events

- The internal validity of the case research findings is assured by a credible causal relationship, well specified procedures as well as statistical techniques

In view of the fact that the overall problem has, as yet, not been solved, it represents a contemporary phenomenon within a real life context and the researcher has no influence over both the outcomes and the interaction between the metrics as observational methods only will be used in order to obtain the necessary data.

The domain is clearly restricted to the SCM field. In practice, indicators and metrics of information flow efficiency, as identified during the first part of the research, were tested in actual company/supply chain environments.

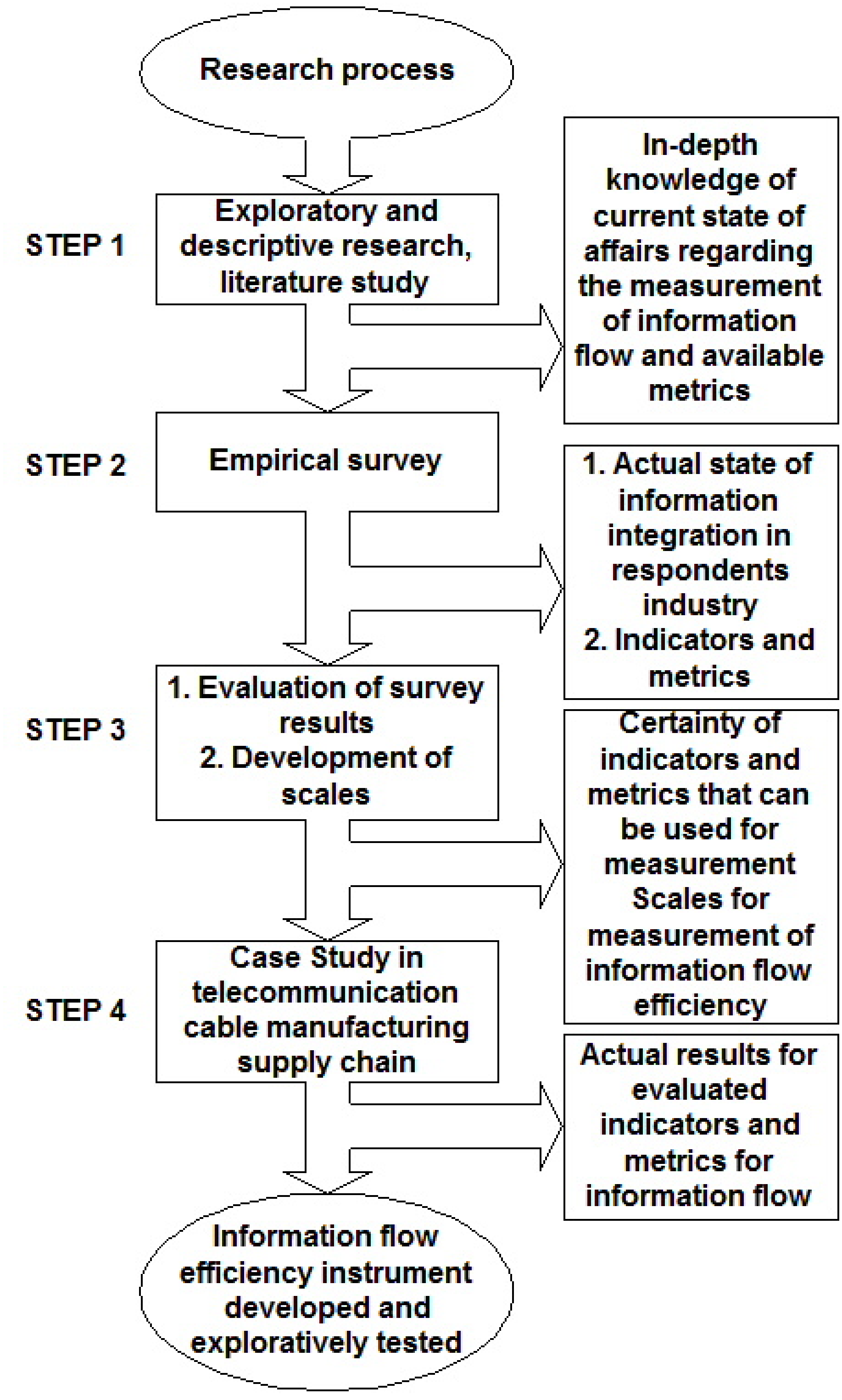

Figure 1.7: Research process

1.4.1.5 Conclusion

In conclusion, the proposed research study was conducted in four stages. The first stage was of an exploratory nature and was aimed at identifying possible indicators and associated metrics applicable to the measurement of information flow efficiency. The second stage dealt with the development of a survey instrument and the collection of data by means of a survey. During the third stage the data obtained from the survey was statistically analysed and scales for the assessment of information flow efficiency indicators and metrics developed. During the last stage, the information flow indicators and metrics which had been developed were tested exploratively. The resultswere linked to the primary objective of the research study, thus ensuring internal validity. External validity refers to the ability to generalise the results of a research study to a largerpopulation. As regards this research the external validity involved validating the information flow instrument which had been developed for application in any given supply chain − a topic for further research.

1.4.2 Limitations of the research

This research study focused on the development of indicators and associated metrics that may be employed to measure information flow efficiency.

However, this research study recognises the existence of a number of limitations in terms of both the applicability of the indicators and associated metrics identified and the ability to generalise the findings of this research.

These limitations arise specifically from the sampling method chosen, the use of expert opinions, the scale development process and the limitations of those indicators and associated metrics which were derived from the literature review.

Convenience sampling was the sampling method chosen. The researcher was forced to decide on this sampling method as a result of the non-response which the researcher would have faced if he had chosen to sample a wider population, i.e. an entire industry. In addition, this latter method of sampling would have entailed time constraints. Accordingly, the researcher selected, a single supply chain, namely, a South African telecommunications cable manufacturing company and focused the research on this supply chain.

Several of the metrics used to assess the information flow efficiency in the organisations selected for this purpose requiredthe subjective judgmentsof respondents who were regarded as experts in their field, as a result of the scales developed for these metrics.However, there are disadvantages that may emanate from expert opinions.

In addition, this research does not claim that the list of indicators and metrics developed is exhaustive, although these indicators and metrics do provide a framework for the measurement of information flow efficiency using indicators and associated metrics that were judged to be the most important by the experts of the organisationsin this study.

The study does not attempt to address the following items as this would be beyond the scope of the study:

- The indicators and metrics that have been developed will be measured individually and no attempt will be made to provide weightings for the combination of all the metrics into one numeric value for a performance index of "information flow efficiency".In addition, weighting will also not be applied for the group of metrics associated with a particular indicator,

- This research will not prescribe which of the indicators and associated metrics should be used for the individual assessment of a company and/or a company's supply chain, although a choice of indicators and associated metrics from which the most appropriate may be selected will be provided.

1.5 CONCLUSION

The purpose of this study is to make a contribution to the existing body of knowledge of supply chain management. In particular, the measurement of information flow efficiency in organisations and supply chains was investigated. In realising this aim, this research has defined indicators and associated metrics which are suitable for evaluatingthe information flow efficiency in organisations and supply chains.

The preceding sections provided an overview of the concepts of supply chain and supply chain management. In addition, the importance of information flows in the supply chain and supply chain management was highlighted.

In essence, the supply chain was recognised as a complicated network of linked customers and suppliers with associated flows of materials, services, finances and information. Each customer represents a supplier to the next company downstream in the supply chain. In order to enable each supply chain member to operate efficiently and effectively as regards the common goal of optimising customer value throughout the supply chain, information and data are required to flow up and down the supply chain in as near real-time as possible. The speed of the information transfer, or information flow efficiency, determines the ability to arrive at decisions about future supply chain activities which will result in improved supply chain performance.

However, the information does not consist solely of data with the information requiring that the data be interpreted within a certain context in order to increase the knowledge about the status of the supply chain and its performance.

The flow of information was defined in terms of a communication process, which involves the transmitter, receiver, medium and message. Communication in the supply chain may take place either between persons, between persons and computers, or between computers.

The importance of information flow efficiency means that it is important that both information and information flow be managed. The management of activities involves the setting of standards and the measurement and revision of achieved activity levels. However, there are no communication or information flow standards available that are applicable to supply chain management.

In order to realise the objectives of this study, it was necessary to conduct a literature study so as to establish the current status of knowledge about information flow efficiency in supply chain management.

In addition, in order to identify indicators and associated metrics that are suitable for evaluatingthe information flow efficiency in supply chains, it was a further requirement that thecharacteristics of efficient information flow be identified and that known indicators and metrics from different fields, such as business management and information technology, be validated.

The empirical aspect of this research study used the indicators and metrics which had been identified in practice, in terms of both organisations and supply chains, in order to evaluate information flow efficiency.

Accordingly, the research focused on the identification of indicators and metrics, applicable to the measurement of an efficient information flow, as an additional measurement, in conjunction with existing supply chain indicators and metrics, to identify weaknesses in the supply chain process. Finally, it wasargued that the new indicators and associated metrics should be incorporated into the balanced scorecard measurement framework and, particularly, into the supply chain scorecard, in order to provide a more complete understanding of the performance level of supply chain processes.

CHAPTER 2
THE SUPPLY CHAIN AND SUPPLY CHAIN MANAGEMENT

2.1 INTRODUCTION

As detailed in chapter 1, this research study endeavours to identify indicators and metrics of information flow efficiency in supply chains. In order to recognise such indicators and metrics in supply chains, it is important to take cognisance of the basic concepts underlying the supply chain and its management. Accordingly, this chapter presents an in-depth review both of these concepts and the way in which they evolved.

The business environmentin which organisations operate today is ever changing. In addition, it is becoming more and more complex. Organisations, both private and public, are being subjected to increasing pressures that are forcing them to respond quickly to the changing conditions and also to be innovative in the way in which they operate (Turban et al., 2007:3). Speed of reaction, order accuracy, visibility of product flow, low to just-in-time inventories, operational flexibility, sustained quality and a reputation for no-hassle business processes are becoming the price of entry for doing business today (Bauer et al., 2001:1–3) with increasing numbers of customers attaching a high value to these characteristics which have, thus, become essential for conducting successful business today.

If organisationsare to become more flexible and reliable, it is vital that they recondition themselves and adopt new strategies (Turbanet al., 2007:3). In essence, the task of a supply chain to service a slow-moving, industrial mass market has changed and a supply chain now faces the challenge of servicing a fast-paced, fragmented general market. This situation is depicted in figure 2.6 (Mentzer, 2001:13; Hugos, 2006:21).

With the growing awareness of the importance of SCM came a realisation of the importance of information technology and information systems to manage the supply chains. In the effort to improve their competitiveness, organisations began to realise the potential of information technology as regards transforming their business (Awad & Nassar, 2010:17). To assist this process, software providers started supplying material requirements planning (MRP) and resource requirements planning (MRPII) programs. However, these were soon developed into enterprise resource planning (ERP) and advanced planning and scheduling (APS) software, and into supply chain planning (SCP) and supply chain execution (SCE) software. Hugos (2006:131) contends that the use of supporting technology is essential for effective supply chain operation. All information systems comprise technology that performs three main functions, namely, (1) data capture and communication, (2) data storage and (3) retrieval and data manipulation and reporting. However, different supply chain systems have different combinations of capabilities in these functional areas. Specifically, these include enterprise resource planning (ERP), customer relationship management (CRM) and manufacturing execution systems (MES). Some concentrate specifically on advanced planning and scheduling (APS) and inventories available-to-promise (ATP), collaborative planning, forecasting and replenishment (CPFR) and vendor managed inventories (VMI) (Stadtler and Kilger, 2008:109,182,270–271,275–282).

2.2 THE SUPPLY CHAIN

2.2.1 The supply chain concept

The supply chain was defined in the introductory chapter 1.2.2.2 as a set of three or more organisationswhich are directly linked by one or more of the upstream and downstream flows of products, services, finances and information from a source to a customer. Figure 2.1 provides a visual representation of a simplified supply chain and includes the local organisation, its customers, suppliers and intermediaries. Hugos (2006:23–27) distinguishes various supply chains based on the number of parties in the supply chain. According to him, the supply chain structure may be described in terms of a *basic supply chain*, an *extended supply chain* and an *ultimate supply chain*. The basic supply chain consists of a company, an immediate supplier and an immediate customer, directly linked by one or more of the upstream and downstream flows of products, services, finances and information. The extended supply chain includes the basic supply chain as well as the suppliers of the immediate supplier and the customers of the immediate customer. On the other hand, an ultimate supply chain includes all of the organisations involved in the upstream and downstream flows of products, services, finances and information, from the initial supplier to the ultimate customer. However, it should be noted that two organisations − a seller and a buyer collaborating with each other − are not considered as a supply chain, but rather as a partnership. The three forms of supply chains are depicted in Figure 2.1.

The two-way arrows in Figure 2.1 indicate not only product flows, but also denote flows of services, finances and information through these linkages between the organisations.

The final partof figure 2.1, depicts a more complex supply chain structure which includes third party logistics providers (3PLs) carrying out logistics activities between the member organisations and finance providers, offering financial advice and financing activities, as well as market research organisations providing information about the ultimate customer to the local organisation. Moving from the partnership to the ultimate supply chain, the number of two-way arrows increases. This, in turn, implies that the flows of product, services, finance and, specifically, information become more multifaceted and also more difficult to manage.

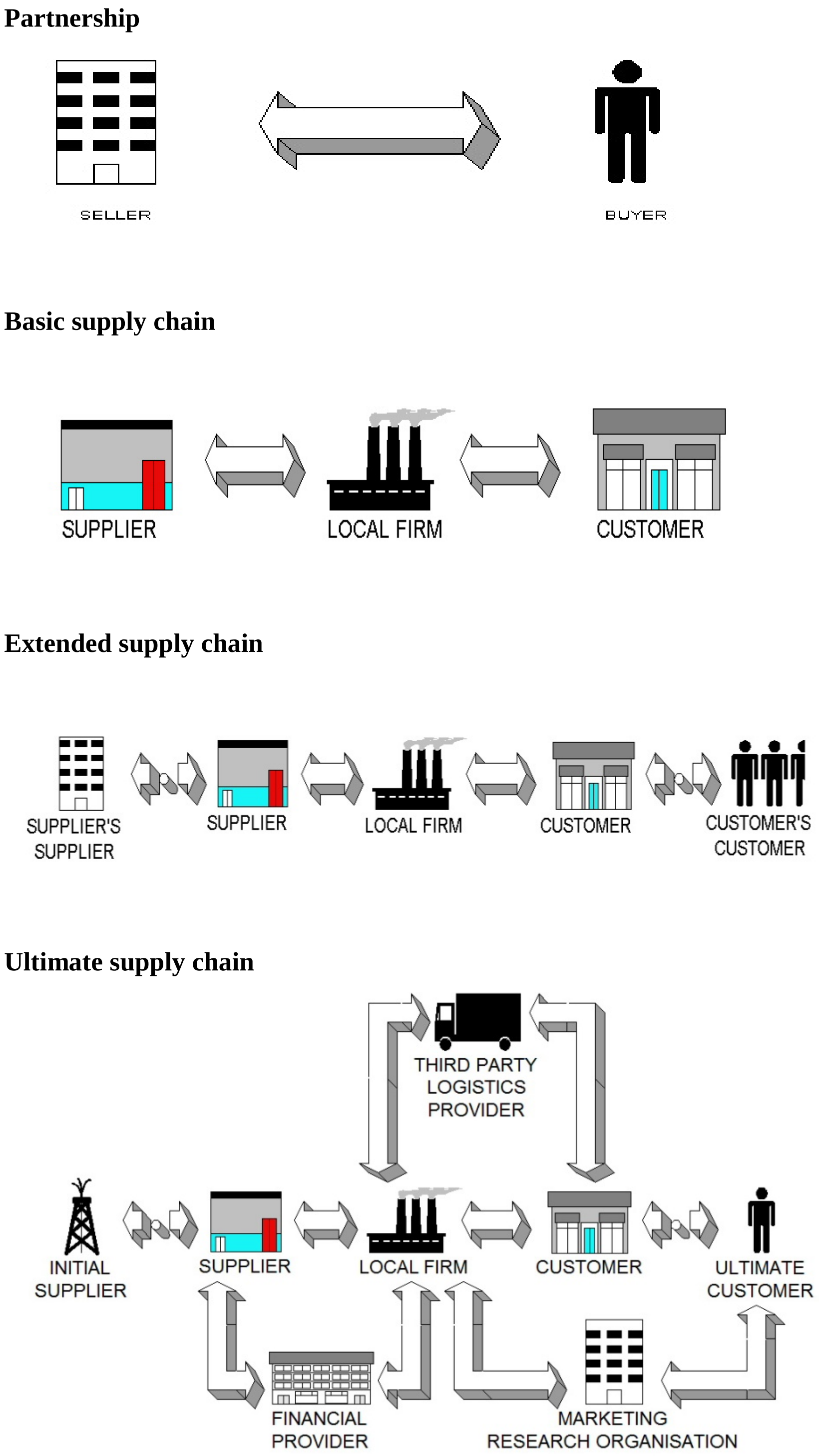

Figure 2.1: Types of supply chains

Source: Adapted from Mentzer (2001:7)

Mentzer (2001:7) points out that a single organisationmay be part of numerous supply chains that give rise to the network nature which is a characteristic of many supply chains. Hugos (2006:26) suggests that the mix of supply chain participants changes over time, thus necessitating changes in supply chain strategies. Mentzer

(2001:6–7) contends that the supply chain exists simply as a result of the fact that a distribution channel for specific products or services exists.

Hugos (2006:5) suggests there is a basic pattern to the practice of supply chain management. Each supply chain has its unique set of market demand and operational challenges, and yet the decisions to be made by the supply chain, as a collective entity, involve production, inventory, location, transportation and information. However, Burt et al. (2009:37) expand these decision areas to include six key business functions, which have to be managed and integrated. These functions are:

1. *Creation* −the idea or design function,
2. *Finance* − the capital acquisition, financial planning and control function
3. *Personnel*− the human resources and labour relations function
4. *Supply* − the acquisition of requisite materials, services and equipment
5. *Conversion* − the transformation of materials into economic goods and services
6. *Distribution* − the marketing and selling of the goods and services produced.

These six key business functions are consistent with the four decision areas of Hugos (2006:5) as the production area of decision making may be compared with the conversion function, the location area includes the personnel function, the transportation area comprises the distribution function and the inventory area encompasses the supply function. Although Burt et al. (2009:37) separate the financial function it may still be seen as an area of decision making within each of the four areas as proposed by Hugos. However, according to both Hugos (2006:17) and Burt et al. (2009:37),these six functions are basic to a business and the sum of the decisions taken concerning each of these functionsconditions will define the capabilities and effectiveness of a company's supply chain. In effect, it is essential that these decisions fulfil a set of value-adding activities, which connects the company’s suppliers to its customers (Harrison,Lee & Neale, 2003:4). The supply chainmay as a basic unit, thus, be illustrated as shown in figure 2.2.

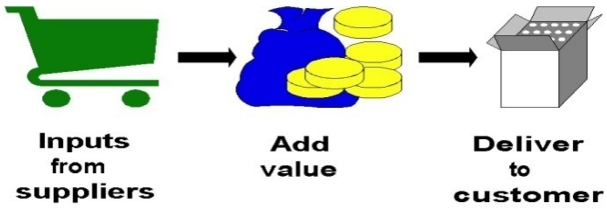

Figure 2.2: The supply chain as a basic unit
Source: Adapted from Harrison et al. (2003:4)

2.2.2 Supply chain drivers and information flow

The importance of information flow has been discussed briefly in section 1.2.2.4. The starting point for appreciating the importance of the information flow in the supply chain was a collection of definitions of the supply chain as provided by the literature. Most of these definitions encompass the flow of information associated with, firstly, the activities involved in transporting goods and services up and down the supply chain and, secondly, with integrating the linkages between the supply chain partners. However, a better understanding of the importance of the information flow in the supply chain may be derived when considering the areas within which each company makes the decisions that define the organisation’s supply chain capabilities. According to Hugos (2006:5–6), Hasan andAlim (2010:36–37) and Willis (2011:1–4) these areas include *production, inventory, location, transportation and information.* He goes on to definethese areas as performance drivers that may be managed in order to provide the required supply chain capabilities. A visual representation of the five supply chain drivers is depicted in figure 2.3.

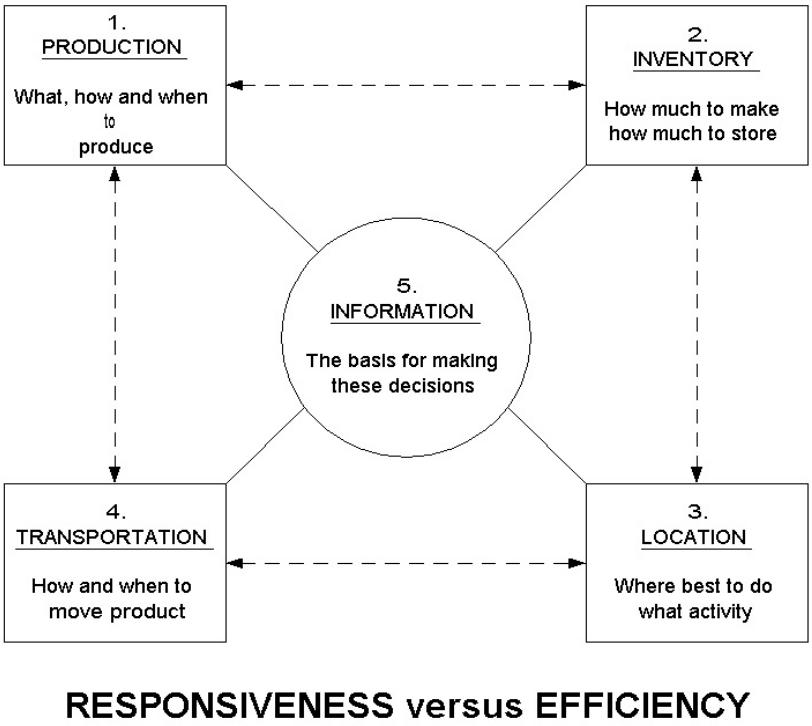

Figure 2.3: The five major supply chain drivers
Source: Hugos (2006:17)

As regards these drivers on an individual basis, production refers to the capacity of a supply chain both to make and to store goods. The fundamental decisions that managers must make when faced with production problems involve how to offset effectiveness and responsiveness. Effective production lines almost fully utilise production equipment, whereas responsive production facilities typically exhibit excess capacity. Responsive manufacturers are able to deal with fluctuations in demand, whereas effective producers manufacture at lower costs as compared with responsive manufacturers. It is, therefore, necessary to achieve a mix of responsiveness and effectiveness in order to keep the overall supply chain costs low and to provide optimum capacity to deal with demand fluctuations in order to satisfy customer requirements.

The second driver, inventory, includes raw materials, work-in-progress and finished goods. Again, a trade-off decision must be made in terms of responsiveness and effectiveness. Responsiveness will be achieved by holding large quantities of inventory throughout the supply chain but this is not cost-effective. Large inventories attract high carrying costs, butthe ordering cost will increase when ordering small lots of inventory. Accordingly, an optimum position must be found that allows the reduction of carrying costs, but also ensures sufficient inventory to manage demand variations.

The third driver, location, requires decisions in terms of centralising or distributing manufacturing activities as well as settling on the product range best suited to each facility. Centralised facilities generally tend to score on economies of scale and efficiency, whereas decentralised facilities in more locations may provide greater responsiveness as they are situated closer to both customers and suppliers. Further parameters that must be taken into account when deciding on location include infrastructure, the cost of labour and facilities, the availability of skills, tariffs and taxes, and proximity to suppliers and customers.

The fourth driver, transportation, refers to the movement of goods through the supply chain from the supplier to the final customer. In this case, the important trade-off decision between responsiveness and effectiveness is centred on the mode of transportation. Fast modes such as airplanes provide high levels of responsiveness, but are extremely costly, whereas slow modes such as trains and sea vessels carry large volumes and, hence, are more efficient and less costly. Given these transport modes, and depending on the facility location and number of facilities, as well as the volumes to be transported, it is essential that networks and routes be designed that supply the goods to the supply chain members in a cost-effective and suitable manner.

Lastly, information, considered as the fifth driver, forms the basis for all decision making with regard to the other four drivers in the supply chain. Without information and the flow of this information between supply chain members, it is not possible to make any real time decisions about production volumes, inventory positioning, or when to transport goods. However, despite the fact that accurate and copious information may lead to responsive operational decision making, the installation of systems to provide such information may be prohibitively expensive. Again, a trade-off decision must be made between expensive andcopious information, leading to efficient decision making, and less abundant information which may, however, be absorbed faster and lead to decisions that are more responsive. For the supply chain as a whole, the member organisations must decide how much information may be shared and which information must be kept private. The more information about suppliers, customers, products, and demand and production schedules that may be shared, the more responsive the reaction of the supply chain to customer requirements.

Hugo et al. (2004:38) and Madhani (2008:239) concur that information is a key enabler and driver of the supply chain process, which ensures supply chain visibility and a seamless pipeline effect. However, without modern information flows, the capturing of data across functional areas and organisations and the uninhibited and immediate interchange of data and information, it would not be possible for supply chainsto function.

Stadtler and Kilger (2008:15) argue that information is shared freely amongst members in order to facilitate inter-organisational collaboration. In addition, they consider this as essential for an effective supply chain.

Li (2008:313) contends that,as a result of the assistance of the Internet, information sharing between the members of a supply chain has increased dramatically. In addition, materials management decisions may be improved if accurate demand information is available, with the same holding true for demand management, as regardsthe availability of improved information about demand. Rapidly changing customer requirements not only tolerate little inventory in the supply chain but also require drastic modifications in the supply chain topologies. This, in turn, requires sufficient flexibility on the part of ERP and other systems, as supply chain needs keep changing (Jung, Chen &Jeong; 2007:133).

Further insight into the complex information flowsthat exist in business may be gained by considering some of the main business processes as identified by Li (2008:5), namely,*sourcing*, *production* and *distribution* as well as the information flow between supply chain members. Sourcing includes the purchase of materials, the selection of suppliers, negotiating of contracts, formulating the purchase process and processing orders. Production is responsible for transforming materials, parts or components into a finished product. Distribution is responsible for managing the flow of material and finished goods from the manufacturer to the customer, inclusive of handling the associated orders. These processes will be discussed in greater detail in the following sections (sections2.2.3to 2.2.7)

2.2.3 Information flow in sourcing or order management cycle

The required information and information flows associated with the stages of the order cycle have been detailed by Murphy andWood (2004:84–96) and are discussed in the following section.

Order planning encompasses the customers of an organisation making a choice as regards what material in which quantity is required by when. In order to select the correct product, quantity and requirements date, wholesalers, for example, need to scan their inventory positions and survey the requirements of their end customers. In a fully integrated supply chain, such information is shared freely amongst the members, for example, through point-of-sale (POS), data transmission or EDI. However, in less integrated supply chains, this process requires telephonic enquiries, manual stock counts and other means of information transmission, including e-mails and faxes.

Once the decisions regarding product, quantity and time have been finalised, the *order* must be *transmitted* to the organisation which either stocks or manufactures the particular order items. Depending on the depth of the information integration of the organisation and its customers, order transmittal may instantaneous by simply entering the order into the organisation’s order planning table, or it may be delayed as a result of using slower processes such as mail, fax and e-mail. Certain intermediate methods, such as ordering via barcode and utilising telephone lines, or other EDI methods, may reduce the delay time in the order transmission process.

Upon receipt of the order, the organisation needs to *process the order*. The processing of an order entails the following activities:

- checking order information for completeness and accuracy

- carrying out a credit check
- entering the order into a computer system
- crediting the sales person with a sale
- recording the transactions in the accounts department
- locating the inventory and updating the inventory records, or planning the order for production or assembly, thus purchasing any raw materials required, manufacturing or assembling the order and moving it into the finished goods inventory
- transporting the items ordered to the customer
- crediting the customer's account and checking for payments according to the payment terms

A more detailed account of information flows and activities is illustrated in the flow chart of the order processing system depicted in figure 2.4.

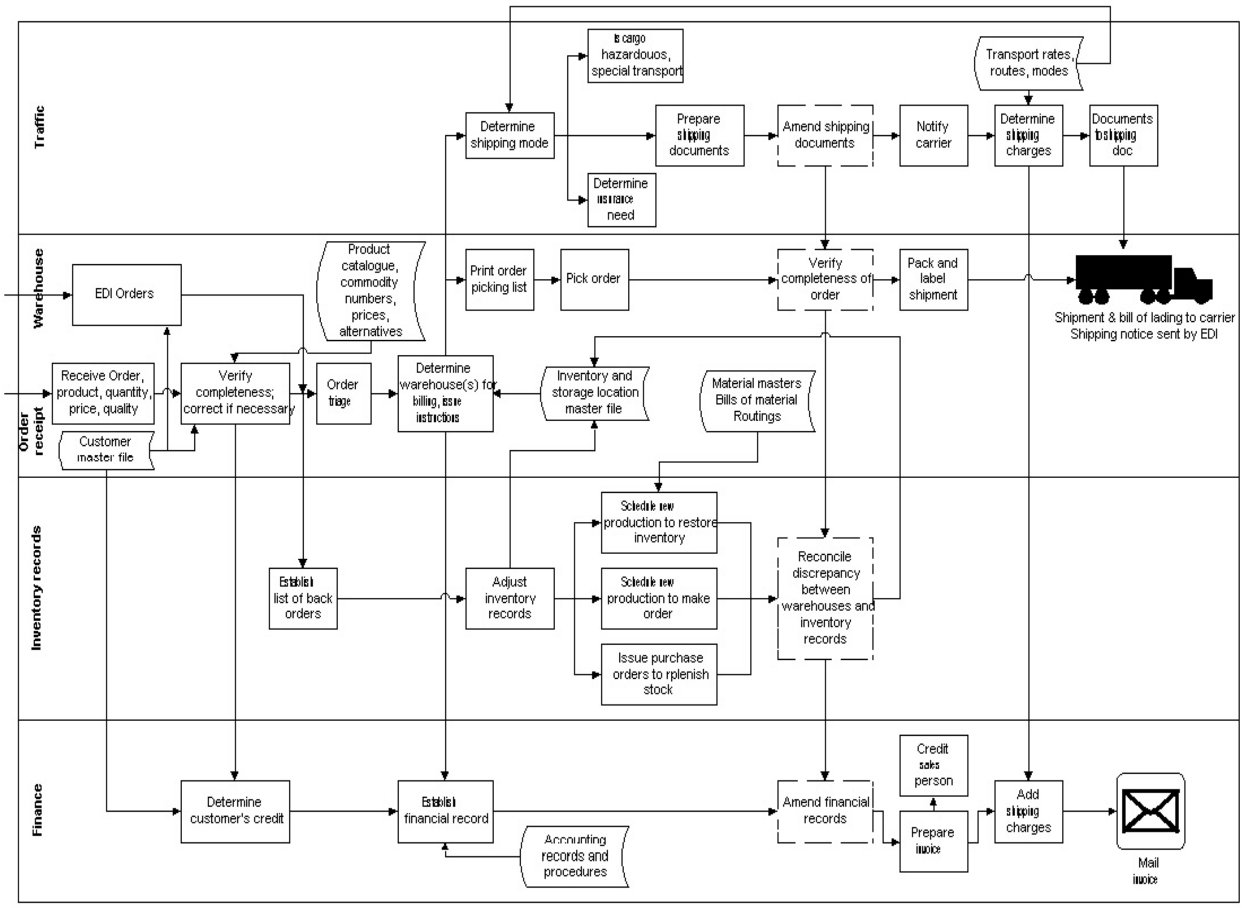

Figure 2.4: Flow chart of the order processing system

Source: Adapted from Murphy andWood (2004:91)

Following the receipt and verification of the order, as depicted in figure 2.4 above, the *order* must either be *picked* from the warehouse, or manufactured if in a make-to-order environment. If the order is picked, the necessary information regarding material and quantity must be sent to the warehouse. After picking, the inventory records need to be updated. The quantities and materials picked will also be forwarded to the finance department which creates the records for the specific customers.

In the case of manufacture, raw materials need to be purchased based on the bill of materials for the specific order. The manufacturing processes required must be planned on a manufacturing schedule to ensure that the processes are carried out. These schedules are based on the routing information for the specific material. On completion of the manufacture of the product, the finished goods inventory will receive the material. Inventory records will be updated and the necessary accounting details concerning the cost accumulation of the manufacturing process will be posted.

The final phase of the order cycle is the *order delivery*. Cargo loads must be planned in time to ensure that the product arrives timeously at the customer. The traffic function of the organisation informs the customer of the impending delivery. The finance department will send the invoice. The customer will sign the delivery note, which will be returned to the organisation to complete the order cycle.

The above description of the order cycle clearly indicates that the efficient flow of information impacts significantly on the efficient completion of the order process.

2.2.4 Information flow in procurement

According to Hugo et al. (2006:14–23) and Benton (2007:125), the procurement or purchasing cycle consists of a series of consecutive tasks that must be performed in order to complete the cycle. These tasks include the following:

- Origin of need
- Specification
- Source identification
- Selection of suppliers
- Bidding and negotiation
- Placing the order/concluding the contract
- Following up and expediting/contract administration
- Receipt, inspection and distribution
- Inspection of incoming goods
- Handling faulty consignments and rejections
- Analysing the invoice
- Closing the order
- Maintaining files and records
- Measuring supplier performance

Each of these tasks requires that certain information be available if the task is to be accomplished. Considering the individual steps in the purchasing cycle as outlined above, the following information may be necessary (Hugo et al., 2006:14–23; Chitale &Gupta, 2006:2005–217; Monczka et al., 2010:33–43):

- The user of the item purchased, the required date of receipt, and quantity and quality initiated by the user and sent to purchasing
- A clear description of the above purchase requirements to the supplier. Technical departments or technical buyers are mainly responsible for delivering this information
- The availability of the required material in the market, the price and the lead-time, and possible alternatives. Purchasing departments research the market using product catalogues and online, web-based applications
- The suppliers' capability as regards providing/manufacturing the material according to specification, their capacity and the technology, provided by the supplier.
- Legal information on orders and contracts, company procedures and policies, provided by legal specialists and company management and given to purchasing
- Informing the supplier of order placement, order confirmation and final delivery date
- Information about delays in delivery on the part of the supplier
- Date of receipt of material, actual quality of a material received and quantity received. This information is supplied to purchasing, the user and quality department by stores.
- Quantity of material received, not conforming to specification, and tobe returned, date of return, cost of return, and date of re-delivery. Firstly, information about the receipt of non-conforming material will flow from quality to stores and purchasing, whereupon the supplier will be notified. The supplier or the organisation must make arrangements on the return of the goods, and the re-delivery of the outstanding order quantity.

- Invoice verification, compare price and quantity charged against price agreed upon and quantity delivered, passing on invoice to finance department. The supplier sends the invoice to the organisation where the invoice is checked. If purchasing approves the invoice, it is passed on to the finance department who will pay the supplier in accordance with the agreed payment terms. Irregularities must be resolved between purchasing and the supplier timeously.
- Supplier performance. The organisation's purchasing department will verify the quantities received, quality of product, price and on-time delivery in order to rate the supplier in accordance with procedures.

The above particulars summarise the information necessary in order to implementthe basic purchasing process, and indicates the flow of information between the different parties concerned. In the case of global purchases, the information required is more complex as it will include information that passes between countries as well as involving transport across borders. The latter generally requires some form of customs clearance, which may be carried out by third party service providers.

2.2.5 Information flow in manufacturing and planning

Once a final demand forecast has been realised or orders are on hand, it is essential that the most cost effective way of satisfying this demand be found (Taylor, 2004:215). Meeting the demand encompasses three core processes, namely, procuring the necessary materials, producing the goods and distributing the goods to customers.

Taylor (2004:215–216) argues that the actual techniques used to produce the goods differ substantially, depending on the systems and software used to plan and schedule production. Generally, the items contained in the demand forecast and in the orders on hand are composed of different raw materials and may have to undergo several sequences of processes, rather than a single operation.
The production planning and scheduling processes share information with customers and suppliers for their own planning processes (Swink et al., 2011:448).

According to Stadtler and Kilger (2008:199), the main purpose of production planning, involves generating detailed production schedules for the shop floor over a relatively short time horizon. A production schedule indicates, for each order to be executed, the start and completion dates and times at which the resources will be required for processing. Accordingly, a production schedule also specifies the sequence of orders to be processed as regards a give resource. The sequencing of orders may be further complicated by the existence of bottleneck resources.

In order to generate a feasible production schedule, Stadtler andKilger (2008:202–203) propose the building of a model, which captures the specific properties of the production processes and corresponding flows of materials in detail. This,, in turn, will allow for generating feasible plans at a minimum cost. With the aid of this model, the master plan may be disaggregated into individual item requirements per resource by balancing the available capacities. Taylor (2004:218–219) explains that two software modules, the distribution requirements planning (DRP) module and the master production schedule (MPS) module, are involved in this first step. These modules normally plan backward from the given completion date, but without considering the feasibility of the dates produced. In the second step, material requirements planning (MRP) re-calculates the start and end dates for each process, by taking into account purchasing and material constraints. Accurate information is essential for effective MRP performance. Swink et al. (2011:449–450) argue that the outputs of MRP, which include information about assembled and finished product, such as forecasts, inventory data, lead-time estimates and product information, may be wrong if the inputs into the MRP planning process are incorrect.

During the MRP planning process, although production constraints are recognised, no re-planning takes place. However, if the production schedule proves not to be feasible as a result of machine constraints, then human planners will examine the problem and look for alternatives. Should planners not be able to resolve the constraints by exploring possible alternatives, then some order delivery dates may have be pushed out in order to achieve a workable plan.

After generation of a feasible production schedule, the manufacturing of the items may commence. Upon completion of each process, the schedules must be updated and the relevant consumption of materials in that process be posted to the inventory ledger. Upon completion of the product, the quality status of the product may be appraised and recorded. Once the product has been found to comply with specification, it is released into finished goods for delivery.

2.2.6 Information flow in demand management

According to Stadtler andKilger (2008:135–158), effective demand management or demand planning may lead to significant benefits by reducing inventories and, thus,decreasing cost. The main issues surrounding demand management include demand forecasting, demand simulation (what-if analysis) and safety inventory determination. Stadtler andKilger (2008:134–135) argue that the main characteristic of forecasts is that the forecasts are wrong although the accuracy of forecasting directly influences the quality of the processes using the forecast. In order to achieve high forecast accuracy, it is necessary to implement appropriate control mechanisms. The difference between planned and actual sales as per forecast influences the service level of the entire supply chain. Whilst safety stock acts as a buffer against uncertainties, the main activities in demand management should focus on the reduction of uncertainties. Demand planning implies predicting the future as accurately as possible and, therefore, demand planning requires that all the relevant information from the supply chain be taken into consideration. Ballou (2004:287) contends that demand varies in *time* as a result of growth and decline, seasonality and general fluctuations in sales rates, whereas *spatial* variations involve the location from where the requirements emanate. According to him, most short-term forecasting activities involve temporal variations, known *as time series*.

The information required in order to forecast future demand begins with the customer requirements as forwarded by the sales personnel while marketing intelligence and economic indicators may constitute further inputs into demand forecasting. Ballou (2004:288) rationalises that products are forecast in terms of product groups, which exhibit various demand patterns over time. Demand mayusually be decomposed into trend, seasonal and random components. There are different methods available with which to forecast these components of demand,including (Stadtler & Kilger, 2008:134–148; Ballou, 2004:291–310):

- Statistical methods
- Qualitative methods
- Historical projections
- Causal methods

Once the demand for a specific product group has been forecast and decomposed into individual items, using one of the above methods, the demand data constitutes input into the master production planning process, as detailed in the previous section.

However, demand simulation incorporates additional information, which was not previously considered. This additional information may include information originating from promotions, marketing campaigns, changes in the number of stores and other information that may be perceived to have an influence on demand. These additional outcomes may be used in the master planning process.

However, it is not possible for one organisation in isolation to plan overall supply chain demand. Accordingly, collaborative forecasting in the supply chain involves collecting and reconciling the information from diverse sources, both inside and outside the company, with the aim of developing a single, unified statement of demand for both the company and the entire supply chain (Li, 2008:117).

2.2.7 Information flow between supply chain members

Having discussed the fundamental business processes and the associated information flows, it becomes apparent that it is incumbent on each member of the supply chain to accomplish these processes. In fact, a supplier's sales form another company's purchases until the final customer has been reached (Hugo et al., 2004:254–256) − see figure 2.5 below. If a company is able to integrate the back-end systems of its supplier with its own backend systems, thus, expediting the flow of information, it is possible to realise significant benefits, including the reduction of stocks and the need for warehousing. In addition, by integrating the supply chain electronically and automating tasks, overall supply chain costs may be reduced (Hugo et al., 2004:256).

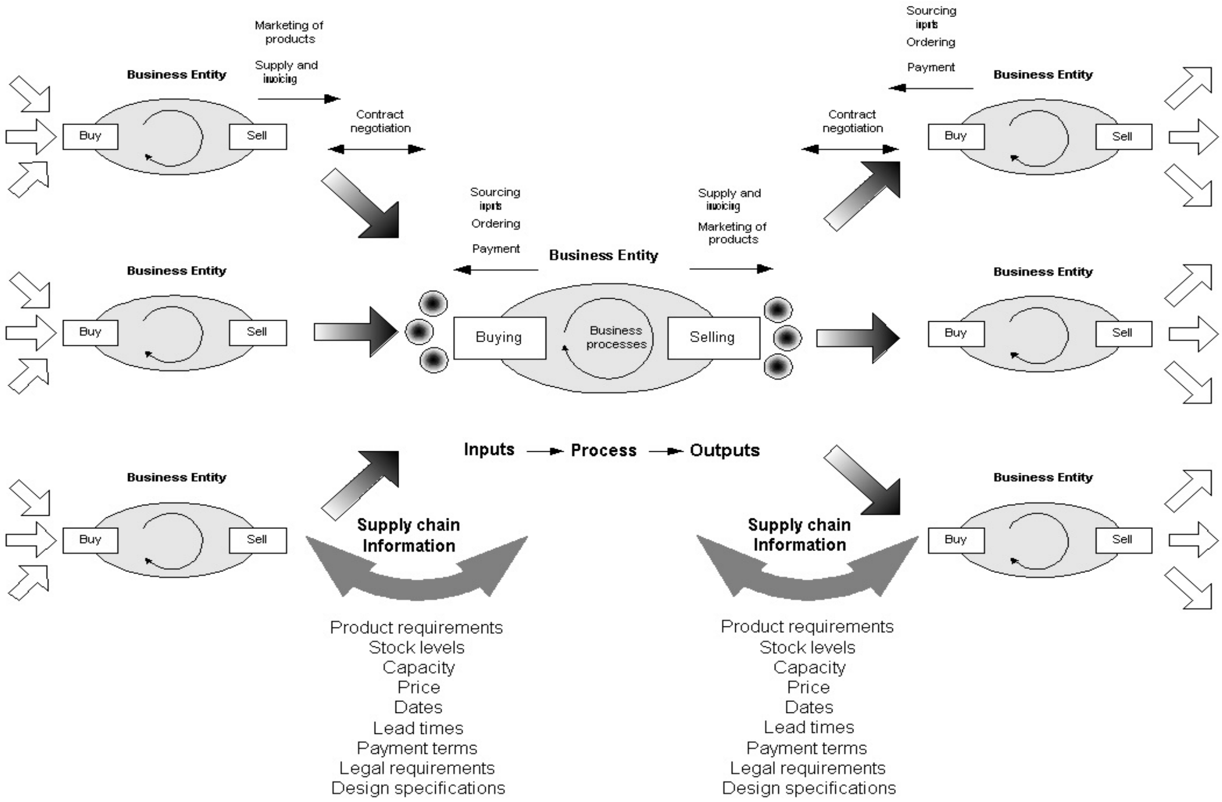

Figure 2.5: Information flow between supply chain members
Source: Adapted from Hugo et al. (2004:255)

Scala Business Solutions NV (2004:7) emphasises that it is vital for a supply chain that crosses multiple organisations to generate value so that the individual participants are able to see, in near real time, the upstream demand and downstream supply. This means that systems need to communicate and be able to share information, both internally and externally. Traditional paper-based transactions are becoming increasingly obsolete. Most of the required information should be recorded electronically and associated transactions should be performed with a minimum of human intervention. Ideally, all the participants in the supply chain would support real-time, online communication, and sharing data using non-proprietary standards with extremely low cost of entry for new participants.

2.3 SUPPLY CHAIN MANAGEMENT (SCM)

2.3.1 Concepts

Mentzer (2001:7) contends that a supply chain exists in business, while supply chain management represents overt management efforts on the part of organisations in the supply chain. In view of the complex structure of the supply chain, the question arises as to what supply chain management should encompass and, thus, how it may best be defined. The literature provides several definitions for SCM with the following examples illustrating various approaches to defining SCM.

Long (2003:44) defines SCM as "the way the links are integrated to promote efficiency", thus emphasising supply chain integration.

Stadtler andKilger (2008:21) define SCM as "integrating organizational units along a supply chain and coordinating material, information and financial flows in order to fulfil (ultimate) customer demands with the aim of improving competitiveness of a supply chain as a whole". Similarly, Bauer et al. (2001:4) suggest that "SCM becomes the methods, systems and leadership that continuously improve an organization's integrated processes for product and service design, purchasing, inventory management, planning and scheduling, logistics, distribution and customer satisfaction". On the other hand, Ballou (2004:7) focuses on "managing the product and service flows in the most efficient and effective manner". All these definitions clearly accentuate the process nature of supply chain management.

Other writers stress the systems approach to SCM, viewing the supply chain as a single entity. For example, Hugos (2006:4) advocates that "SCM views the supply chain as a single entity. It brings a systems approach to understanding and managing the different activities needed to coordinate the flow of products and services to best serve the ultimate customer". Murphy (2004:37–38) adopts a comparable view that "supply chain management requires organisations to apply the systems approach across all organizations in the supply chain".

Mentzer (2001:22) offers the following broader and more general definition of SCM. This definition will be adopted for the purposes of this research, as it synthesises most of the disparate aspects of the supply chain management definitions:

> **SCM is defined as the systemic, strategic coordination of the traditional business functions within a particular company and across businesses within the supply chain, for the purpose of improving the long-term performance of the individual organisations and the supply chain as a whole.**

In addition, Mentzer (2001:9) points out that the definitions offered by variouswriters (also as mentioned above) may be organised into three categories, namely, a management philosophy, implementation of a management philosophy and a set of management processes. These are discussed briefly in sections2.3.1.2 to 2.3.1.4. The next section discusses the evolution of supply chain management strategy.

2.3.1.1 The evolution of supply chain management strategy

This section will conceptualise the evolution of supply chain management strategy in greater detail.

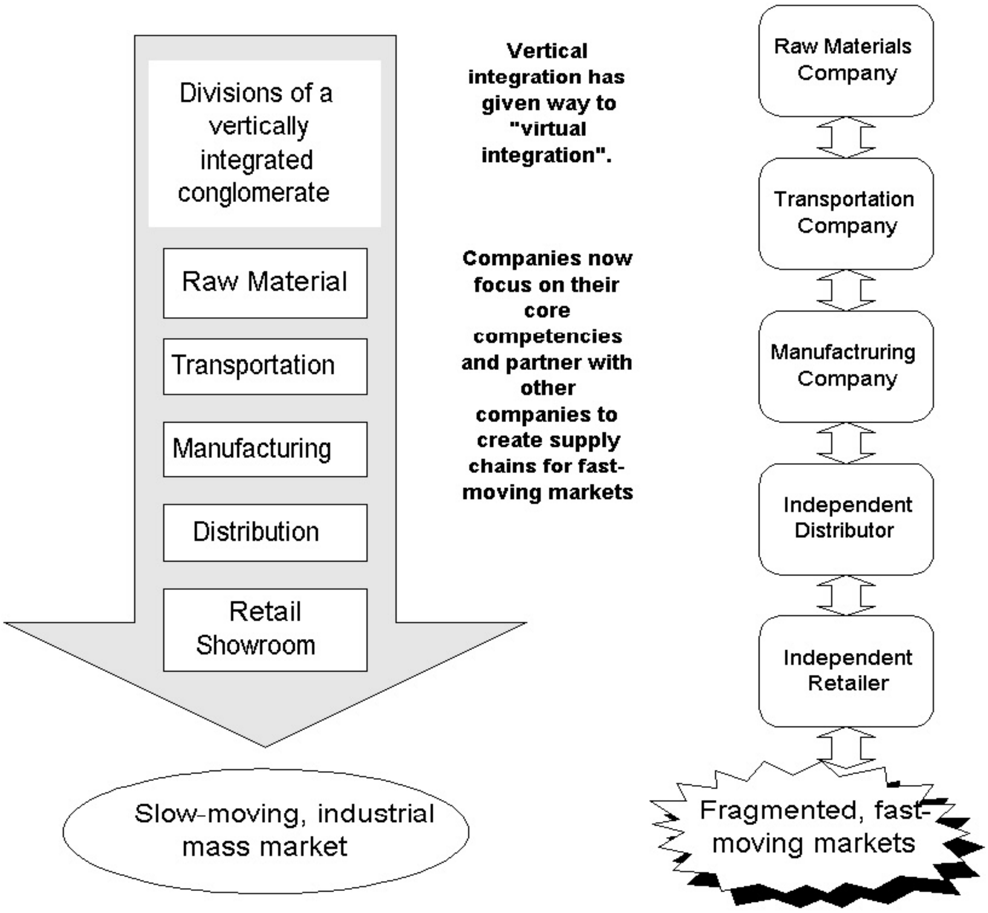

Figure 2.6: The evolution of supply chain management strategy

Source: Hugos (2006:21)

According to Hugos (2006:20), the participants in the supply chain are continuously making strategic decisions regarding the way in which they manage the five supply chain drivers, namely, production, inventory, location, transportation and information. Each organisation tries to maximise its performance in dealing with these drivers through combinations of outsourcing, partnering and in-house expertise. However, in the past, especially in the industrial age, it was a common strategy for organisations to integrate vertically and, thus, gain control over the supply chain. Such vertically integrated supply chains, however, served slow moving mass-markets only as it was the aim of these supply chains to gain maximum efficiency through economies of scales.

However, as a result of globalisation, intense competition and the rapid pace of technological change, slow moving mass-markets have given way to fast-paced, fragmented, smaller markets which requiremore flexible supply chains.

Iforganisationsare to become more flexible and reliable, it is essential that organisations recondition themselves and adopt new strategies (Turban et al., 2007:3). In addition, inorder to attain high levels of operating efficiency and to keep pace with the constantly changing technology, organisations now focus on their core competencies and find other organisations to carry out the other activities required in the supply chain. In other words, vertical integration has been replaced with virtual integration− see figure 2.6. The way in which a company defines its core competencies and how it positions itself in the supply chain it serves are the most important strategic decisions a company may make (Hugos, 2006:23).

2.3.1.2 Supply chain management as a management philosophy

According to Mentzer (2001:9), SCM requires a systems approach to viewing the entire supply chain as a single entity, rather than as a collection of individual organisations, with each organisationfocusing on its own interest. This view is confirmed by Hugo et al. (2004:10), who contend that the supply chain should be managed from an overall perspective, a holistic approach or systems paradigm, in terms of which one entity is ultimately responsible for ensuring that all the goals of the SCM are attained. However, Hugo et al. (2004:9) also explain that this is no easy task, considering the individual interests of the organisations involved in the particular supply chain. It is, thus, necessary to integrate the goals of the individual organisationsinto those of the entire supply chain as only then will it be possible to balance the customers’ requirements with the profit and growth motives of the organisations concerned.

This view is shared by Stadtler andKilger (2002:8–9) who are of the opinion that no single company is solely responsible for the competitiveness of its product or services. Accordingly, competition has shifted from single organisations to supply chains. Nevertheless, despite the fact that competitive supply chains deliver superior customer service in the eyes of the ultimate customer, it is essential that the goals of the individual organisations,as regards being able to make a profit and to grow,not be ignored. In order to convince an organisation to become part of a specific supply chain, a win-win situation must be established for each participant in the long term, although this may not always be the case in the short term. Stadtler andKilger (2002:9) also point out that there are two ways of improving competitiveness: firstly, closer integration of the organisations involved in the operation of the supply chain and, secondly, the enhanced coordination of material, information and financial flows.

Mentzer (2001:9) elevates the integration efforts of organisations to the convergence of intra- and inter-organisation strategic capabilities into a unified, compelling market force. He also proposes that SCM, as a management philosophy, should exhibit the following characteristics:

- A systems approach to viewing the distribution channel as a whole, and to managing the total flow of goods inventory from the supplier to the ultimate customer
- A strategic orientation toward cooperative efforts to synchronise and converge intra-organisation and inter-organisation operational and strategic capabilities into a unified whole, and
- A customer focus designed to create unique and individualised sources of customer value, thus leading to customer satisfaction.

2.3.1.3 Supply chain management as a set of management processes

Mentzer (2001:13) defines a process as a specific ordering of work activities across time and place, with a beginning, an end, clearly specified inputs and outputs, and a structure for action. If this concept of a process is applied, then several of the SCM definitions provided in the literature may be classified in the category of management processes For example, Van Eck (2003:4) adopts the following definition of SCM, namely, “a process for designing, developing, optimizing and managing the internal and external components of the supply system …”, thus emphasising the process character of SCM. Angerhofer andAngelides (2000:343), and Simatupang, Wright andSridharan (2002:290) propose a “process–oriented approach to procuring, producing and delivering products and services”. Lambert (2008:5) also highlights the implementation of business processes and refers to both strategic and operational sub-processes and the management of these sub-processes in order to integrate the supply chain. In his definition of SCM, Gesatzki (2001:1) refers directly to the management tasks of planning, managing and controlling the internal and external flows of products, information and finances. In conclusion, all the definitions cited above share the common feature that the supply chain is managed by a set of processes, which are recognised as key processes. According to both Mentzer (2001:13) and Lambert (2008:5), these key processes typically include

- customer relationship management
- supplier relationship management
- customer service management
- demand management
- order fulfilment
- manufacturing flow management
- procurement
- product development and commercialisation
- returns management.

2.3.1.4 Supply chain management as an implementation of a management philosophy

Once organisations have adopted a supply chain management philosophy, they need to identify the activities necessary to implement this philosophy and which enable them to operate in a manner consistent with the goals of that philosophy. Mentzer (2001:10) argues that it is essential that organisations demonstrate *integrated behaviour*, specifically with a view to integrating the supply chain, both internally and externally. According to him, certain activities will have to be identified if the philosophy is to be implemented. Accordingly, this set of activities, which represents a coordinated effort, may be viewed as supply chain management.

However, it is not easy to develop integrated behaviour and/or an integrated supply chain in which all the participants share the same goal and focus of serving the customer. Hugo et al. (2004:13–14) argue that the evolutionary process of integrated supply chains, that includes forging linkages, partnerships and strategic alliances, is a slow process which requires the building of trust and synergy amongst all the supply chain partners. Bauer et al. (2001: 18–20) corroborate this view by emphasising that organisations do not start with a perfectly aligned supply chain organisation, but follow a development pattern as depicted in figure 2.7.

According to Bauer et al. (2001:18–19),a company pursuesthe internal optimisation of its logistical and supply chain operations by applying best practices in the industry sector. This is depicted in figure 2.7,first section “Supply chain optimisation”. The second section of figure 2.7 depictsorganisations trying to implement advanced supply chain management processes such as improved partnering and supply chain collaboration. The third sector of figure 2.7 implies that organisations start implementing e-commerce and, specifically, internet procurement procedures. The fourth sector represents the implementation,in order, of more customer focused, web-based applications as well as creating alliances with partners who are able to provide top class services. This last sector specifically sets itself apart from the previous stages by building advantages for the business concerned and providing a global visibility of its supply chain activities and virtual manufacturing and distribution systems, in order to bring about speed and flexibility.

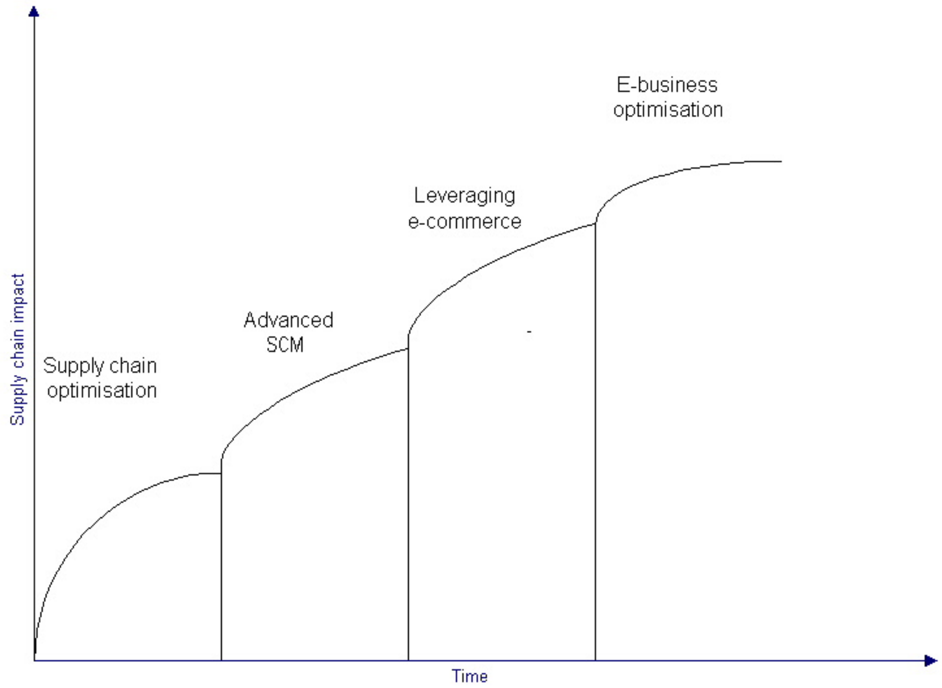

Figure 2.7: Supply chain evolution model

Source: Bauer etal. (2001:18)

Mentzer (2001:12) and Hugo et al. (2004:13–14) agree with a four-stage development model. However, the first stage in their model represents a baseline case in which the supply chain represents a fragmented operation of individual organisations. In their second stage, organisations start focusing on internal integration. Mentzer (2001:12) believes that, during this stage,organisationscontinue to concentrate on cost reduction instead of performance improvement, whereas Hugo etal. (2004:13) contend that, at this stage, the company has reached internal integration and is formulating long-term plans to integrate the entire supply chain. According to Mentzer (2001:12), it is only in the third stage that organisations integrate fully. However, Hugo etal. (2004:14) claim that organisations begin reaching out to construct the supply chain network and start formulating partnerships and strategic alliances in this stage. Nevertheless, both Mentzer (2001:12) and Hugo etal. (2004:14) agree that full external and internal integration is reached in the fourth and final stage.

However, despite the fact that there is some divergence of opinion between these writers as regards the development level at each stage, they do agree that the evolutionary supply chain integration process requires time and follows certain developmental stages before the supply chains become fully integrated.

In addition, in order to attain internal and external supply chain integration, Mentzer (2001:11) proposes that supply chain participants carry out the SCM activities as depicted in table 2.1.

Table 2.1: Supply chain management activities

Number	Activity
1	Integrated behaviour
2	Mutual sharing of information
3	Mutual sharing of channel risks and rewards
4	Cooperation
5	The same goal and the same focus of serving customers
6	Integration of processes
7	Partners to build and maintain long-term relationships

Source: Mentzer (2001:11)

2.3.1.5 Integrated view of supply chain management

Subramanya andSharma (2008:1) define supply chain management (SCM) as the *integration* of key business processes from end user through original supplier and that provides products, services and *information*which add value for both customers and stakeholders. By integrating the supply chain, organisationsare able to manage the supply chain through the use of information technology and systems (Salo & Karjaluoto, 2006:22).

According to Awad andNassar (2010:51),the information systems used in SCM facilitate inter-enterprise cooperation and collaboration with suppliers, customers and business partners. They assert that business process integration and redesign are important components of the management of the integration of supply chains. However, they also argue that integration not only involves the implementation of information systems, such as enterprise resource planning (ERP) and ensuring that these systems communicate or interface with the legacy systems, but that integration also involves integrating ERP with customer relationship management, e-procurement and e-marketplaces, as well as making them available over the WorldWideWeb in order to foster cooperation and collaboration across the entire supply chain.

Subramanya andSharma (2008:1) argue that information should be readily available to all organisations in the supply chain and that the business processes should be structured in such a way as to make full use of this information.

The complexity of information flows in each member company and between the member organisations of a supply chain has been detailed in the previous sections. Quad Inc. (2003:2–3) argue that it is obligatory for a company to transform data into actionable information in order to reduce cost, improve the quality of decision making and reporting and reduce the time required to market. Enterprise-wide information flow is the foundation for automating processes and streamlining operations. In addition, it will enable speedy access to all the necessary information required to make decisions, from every information system in the enterprise, seamless data exchange, the quick and cost-effective addition of new applications and fast adaptation to changes within the business environment and as regards demands.

Despite emphasising the benefits of supply chain integration and, specifically, information integration in the supply chain, Drake (2006:8) reports that few, if any, supply chains are fully integrated throughout the entire channel. Consequently, organisationsare not experiencing all of the benefits of supply chain management. Ballou (2004:6) concurs with this opinion. According to him, a study found that organisations do not practise SCM in its broadest sense, but limit their SCM activities to one tier upstream and one tier downstream. The literature presents examples of the difficulties associated with supply chain integration. Hugo et al.

(2004:72–74) reiterate that barriers to successful integration do exist. These barriers include the following:

- *The multiple variable problem.* When redesigning the supply *c*hain, a multitude of factors and variables in difficult-to-control circumstances present themselves, and are exacerbated by nonlinear and non-sequential flow and process problems

- *Complexity of the logistic network.* As a result of the complexity of supply chain networks, mistakes are made before the perfect configuration is found.

- *Conflicting objectives.* Each supply chain partner plays a different role to that of the other partners. In the case of low vertical integration levels, trade-offs are increasingly difficult to resolve.

- *Dynamic, ever-changing nature of the supply chain.* Changes in the form, configuration, relationships, capacities and capabilities are ongoing. Optimisation routines may have to be revised often and adapted to the new conditions.

- *Efficiency trap*. Supply chain managers often focus inwardly on optimising the operations of a particular organisation, rather than generating overall supply chain value.

- *Lack of trust and process ownership*. Mistrust and fear between supply chain partners are major obstacles to the integration effort and may lead to the partners not sharing information, although the information may be available. Resistance to change and a lack of communication also impact negatively on the integration process.

- *Inventory management is not less difficult*. Inventory problems may occur during the integration process with these problems originating in ever-present delays, slowdowns resulting from delays in material shipments and delayed communication on inventory statuses in the supply chain.

Murphy (2004:1–7) adds the cost and availability of technology as an additional barrier to supply chain integration. He argues that direct system integration is costly and that operating large networks is extremely resource intensive. In many cases, it is the larger organisationsonly that are willing to invest in such technology.

Fawcett,Magnan and McCarter (2005:3) add unwillingnessas regards information sharing, inadequate technology, misinterpretation of feedback among supply chain partners, organisational culture and structure, and a lack of managerial commitment to the list of barriers to supply chain integration.

However, as regards the barriers to supply chain integration, it must be emphasised that it is not only the lack of electronic integration but also human and organisational behaviour that lead to restraints in the information flow, as outlined above. Logical reasoning will, therefore, infer that removing the barriers will facilitate an improvement in the information flow. In fact, Hugo et al. (2004:74) list the following key success factors that must be realised if supply chain integration is to succeed.

- Organisational commitment and buy-in on the part of the top and middle management in all the supply chain partner organisations
- An unambiguous and realistic definition of the benefits for the supply chain and all its members
- Flexibility, agility and transparency in operational systems, processes and organisational structures
- Effective and efficient utilisation of information and communication technologies throughout the chain
- Supply chain leadership and a creation of a common vision for integration

- Effective utilisation of cross-functional and cross-organisational teams

According to Hugo et al. (2004:74), the above key success factors must be incorporated into and managed by the integration process if the supply chain is to be integrated successfully.

Fawcett andMagnan (2001:14–15) recognise that managers rely either on compartmentalised integration programs (ERP, CPFR, etc) or on ad hoc approaches to achieving the conceptual ideas of a seamless, value-added process. However, according to them, such approaches fail to provide the vision and understanding necessary to building an integrated supply chain.

However, it may be stated conclusively that the integration of a supply chain leads to improved information flows throughout the supply chain, as organisations consider systems to improve their data availability and data accuracy during the integration process so as to increase their response capability (Harrisonet al., 2003:96–97). In other words, information flow throughout the supply chain is indispensable for the proper functioning of the entire supply chain as a complete entity.

Although the supply chain management definitions offered by several writers may be categorised into three different groups, it is essential that these categories not be considered in isolation, but as an attempt to formulate an integrated supply chain management definition. In fact, Min and Mentzer (2004:2) propose that organisations in the supply chain need first to recognise the *systemic, strategic implications of the activities and processes involved in managing the supply chain* − known as *supply chain orientation* (SCO). Accordingly, they termed the actual implementation of the supply chain orientation across the supply chain and its members *supply chain management* (SCM). Mentzer (2001:14) emphasises, that it is not possible for a company which does not possess a supply chain orientation to implement SCM as such a company lacks the required underlying philosophy. Furthermore, he indicates that, althoughan organisation would be able to implement SCM techniques on a non-integrated basis if it had the required SCO, this would not lead to supply chain management, as it is essential that the SCO be present across the entire spectrum of organisations in the supply chain. Only if all the member organisationsexhibit a supply chain orientation, realising the activities as presented in table 2.1, will these organisationsbe able to implement SCM.

In other words, a supply chain orientation represents a management philosophy, whereas supply chain management corresponds to the *sum total of all the overt management actions undertaken to realise this philosophy*.

2.3.2 The management of supply chains

2.3.2.1 Introduction

The previous sections detailed the multifaceted nature of supply chain management (SCM). The question then arises as to the way in which such a complex structure as a supply chain network may be managed. If SCM is considered in the context of the business framework, then the goal of SCM is to achieve a sustainable competitive advantage (Li, 2008:5). Harrison et al. (2003:4) contend that SCM may be divided into a strategic component − supply chain design − and a tactical/operational component − supply chain execution. Hugo et al. (2004:16–18) also support this view when they refer to the general tasks of SCM as including supply chain design and to SCM as a management process inclusive of supply chain planning, organising and execution, as well as the implementation and controlling of the supply chain.

The management of the SC through (1) supply chain strategies, (2) supply chain design, (3) supply chain planning and execution and (4) supply chain measurement will be discussed in more detail in the following sections.

2.3.2.2 Business and supply chain strategies

Strategies are an essential aspect of running a business (Webster, 2008:348). According to Hines (2004:33), strategy has its origin in the Greek word *strategos* which means “general”,although the word has been interpreted differently in the modern literature. He contends that the wider interpretations of the word refer to "getting to a chosen position"' and "the means (how) to achieve the ends (objectives)". The latter of the two interpretations is the focus of several narrower interpretations. Hugo et al. (2004:23) and Swink et al. (2011:27) offer the following more detailed description, namely, "the direction and scope of an organization over the long term; which ideally matches its resources to its changing environment and, in particular, its markets, customers or clients so as to meet stakeholders' expectations". Strategy may also be described in terms of the state of being forward looking, integrating complex issues and countering the effects of turbulence and uncertainty.

Hugo et al. (2004:23) emphasise that it is essential that organisationsbe strategy and learning focused if they wish to survive in the competitive marketplace of today. This also applies to supply chains. In order to be successful, strategies must be implemented into the organisation and operationalised, thus aligning the organisation and the different levels of the business, namely, corporate level, business unit, functional unit and supply chain (Swink et al., 2011:26–27). This, in turn, implies that an SCM strategy should be an inherent part of the business strategy (Stadler & Kilger, 2008:21).

Hines (2004:56) asserts that organisations realise competitive advantage if they adopted one of the following three generic strategies, namely, *lowest cost*, *differentiation* or *focus* strategies. Typically, low-cost strategies rely on high volumes and low unit profitability which, when combined, achieve higher than normal returns on investment. The returns achieved by a differentiation strategy are higher than normal returns as a result of higher unit prices at lower volumes. A focus strategy may also employ cost or differentiation strategies. As depicted in figure 2.8, organisations, which attempt to pursue a mixed strategy of low cost and differentiation become "stuck" in the middle.

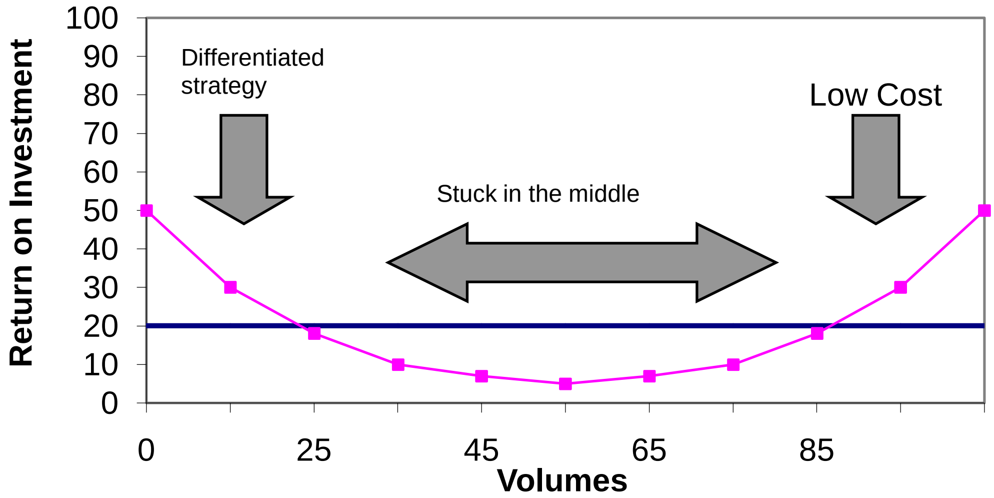

Figure 2.8: Return on investment versus chosen strategy

Source: Hines (2004:57)

The choice of strategy depends largely on environmental, market, political, social and global factors. Supply chain strategies are conducted under the umbrella of the corporate strategy of the organisation (Hines, 2004:57). However, if they are to be effective, it is essential that SCM strategies fit strategically into the corporate strategy. According to Hugo et al. (2004:23–24), the following ways have been identified in which an SCM strategy may add value to a corporate strategy:

- Creating a cost advantage
- Focusing on value adding
- Delivering superior customer service
- Designing for flexibility
- Innovating
- Creating a productivity and efficiency advantage

Although Hines (2004:56) agrees with the above findings, he maps the above SCM strategies against the three generic strategies mentioned above. According to Drake (2006:3–7), strategic advantages that may be achieved by SCM include cost, quality, flexibility and response time.

Once an appropriate strategy has been chosen, the supply chain must be designed in such a way that it provides a seamless and integrated flow of materials and information. The activities involved in supply chain design will be discussed in the following section.

2.3.2.3 Supply chain design

According to Stadler andKilger (2008:87–88), supply chain design refers to the process of determining the supply chain infrastructure − the plants, distribution centres, transportation modes and lanes, production processes, etc. that will be used in order to satisfy customer demand. These activities are strategic in scope and use a time horizon of several months or even years.

Harrison et al. (2004:6–7) contend that supply chain design addresses a wide range of strategic infrastructure issues in an organisation. The following include examples of the typical key issues to be considered:

- Manufacturing
  - i. How many plants are needed?
  - ii. Where should each plant be situated?
  - iii. Which products should each plant produce?
  - iv. Which process technology should each plant employ?
  - v. What markets should each plant serve?

- Supply base design
  - i. Simultaneously select suppliers for all parts within commodity groups
  - ii. Allocate suppliers to plants
  - iii. Determine selection criteria

- Distribution
  - i. Should stock be shipped directly from each plant?
  - ii. How many distribution centres are needed?
  - iii. Which distribution centre will serve which customers?

iv. What transportation modes will be used?

- Outsourcing
  i. Cost trade-off versus service considerations
  ii. What portion of the supply chain will remain in-house versus outsourced?

- New product and design process
  i. What infrastructure should be used when adding new items to an existing line?
  ii. At what demand points are new sources of supply needed and where should they be located?

In order to provide answers to these questions, supply chain modelling may be used as a tool to predict the expected organisational and supply chain performances (Stadler & Kilger, 2008:81; Li, 2008:51).

Hugo et al. (2004:76–80) emphasise design constructs on a more functional level. These specifically include push–pull demand strategies, vertical coordination, design for efficiency and parallel processing. According to Stadler andKilger (2008:19–21),it is vital that business functions be aligned with business strategies and, thus, basic business processes must be analysed, evaluated and improved. In addition, the fundamental network structure of both suppliers and customers must be improved. These activities may be accumulated under the umbrella of *business process mapping*. The industry standard Supply Chain Operations Reference (SCOR) model may be used to assist this process. SCOR has been developed and is distributed by the Supply Chain Council (www.supply-chain.org). SCOR attempts to capture the current or “as-is” state of the supply chain processes and derive the desired state of a process through benchmarking and best practices analysis (See figure 2.9 below)(Coyle et al., 2003:495–498).

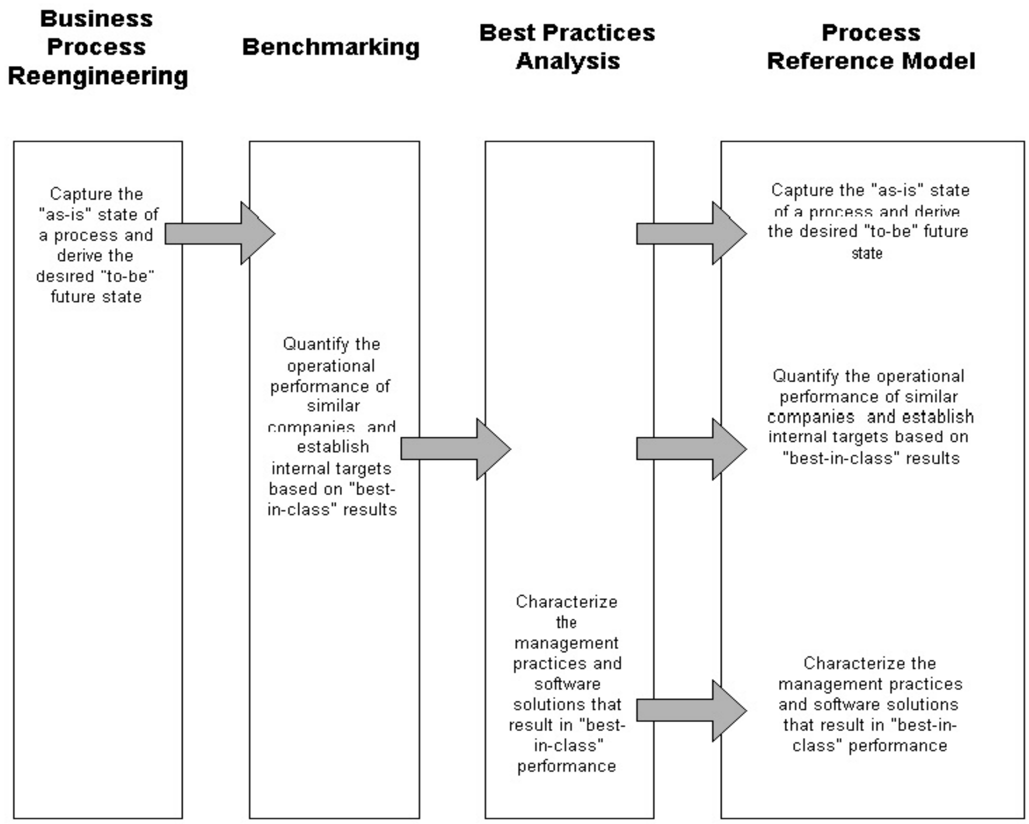

Figure 2.9: Supply chain operations reference model for business process re-engineering

Source: Supply Chain Council (www.supply-chain.org, 2005)

SCOR provides a framework for mapping the main supply chain processes, measuring the performance of the processes by means of a pre-defined set of measures, as well as considering cross-industry best practices that, when employed, may enhance performance (Kent, 2006:3). Once the current business processes have been mapped and the operational performance established against the competition, then future state options may be considered. The future state supply chain designs must seek to incorporate the best practices contained within the score model as well as the best practices already established in the company (Kent, 2006:3). As pointed out earlier in the section, operations research techniques, such as optimisation and modelling, may be used to prove the validity of the new future state supply chain design.

Once the supply chain has been designed and the design been validated, the supply chain operation then requires planning and execution.

2.3.2.4 *Supply chain planning and execution*

Supply chain planning and execution refers to the process of determining tactical and operational issues such as inventory policies and deployment, manufacturing and service schedules and transportation plans. In all these instances, production and transportation data usually vary within a known probability distribution, while the infrastructure is assumed to be fixed. The time period for the analysis typically spans days, weeks or months and focuses on implementing detailed, short-term plans (Harrisonet al. 2003:4).

According to Scala Business Solutions (2004:8–9), supply chain planning and execution include the following activities:

- Supply chain planning
    - i. Demand forecasting
    - ii. Supply planning
    - iii. Configuration planning

- Supply chain execution
    - i. Material management
    - ii. Manufacturing and shop floor control
    - iii. Purchase management

These activities are all covered by the scope of the SCOR model. As a reference model SCOR has identified five management processes, namely, plan, source, make, deliver and return (Swink et al., 2011:42; Webster, 2008:353).

The "plan" dimension encompasses the demand and supply planning and management. This task typically involves the balancing of resources with requirements, the establishment and communication of plans for the entire supply chain and the execution of processes. Demand forecasting involves the estimation and management of the customers' requirements. Specifically, it requires the gathering of information about the unmet needs of the customers and the sharing of demand information with all the relevant supply chain members. Webster (2008:353) refers to the "plan" element as the development and enabling of supply chain plans, source plans, make plans, deliver plans and return plans.

As regards the "source" activity deliveries are scheduled, receipts verified payments authorised, suppliers identified, assessed and selected and inventory managed.

The "make" activity refers to the scheduling of production, issuing and testing of products,as well as the management of performance, data, work-in-process, equipment and facilities, the production network and compliance with regulatory requirements.

The "deliver" dimension deals with the management of orders, customer enquiries, shipment routing, warehouses, receipt and verification of product at customer site, finished product inventories, information and transportation. The "return" activity involves all those processes involved in the return of goods from the customer as a result of incorrect delivery or paperwork or defective product.

The above supply chain planning processes interact with each other and are extremely complex. In addition, in order to achieve the desired performance from the supply chain, it is necessary to monitor and control operations on a daily basis. This, in turn, requires some form of comparison of performance accomplished against a laid down standard, or a form of measurement allowing for such a comparison. This will be discussed in the next section.

2.3.2.5 Supply chain measurement

The complexity of the supply chain operation, integration and coordination makes it difficult to measure the performance of the entire chain (Coyle et al, 2003:482–483). In addition, it is essential that the measures selected represent both the supply chain operation and its variables in reality (Hugo et al., 2004:100). The measures also need to provide management with an overview of the performance of the organisationand/or the supply chain (Santos et al., 2006:1). In order to accomplish a comparison both between the organisations and between divisions within the organisation, measures need to be designed which are suitable for both internal and external performance measurement.

Hugo et al. (2004: 101–102) contend that traditional measures relied heavily on financial and cost measures such as return on investment (ROI) and profitability. However, the supply chain is not driven merely by cost, but by any decision taken in terms of any of the supply chain drivers, but mainly production, inventory, location and transportation − see figure 2.3. Specifically, these decisions will influence variables such as quality, speed, transparency, responsiveness, collaboration and throughput, as well as the financial variables.

Although it would appear that supply chain performance measurement has been insufficiently researched (Hugo et al., 2004:101), nevertheless, it is possible to find traces of diversified development through to fully encompassing models. The supply chain scorecard of Santos et al. (2006:2–4) is an example of such developments. They proposed a supply chain performance measurement framework based on the four perspectives of the generic balanced scorecard,which had been developed by Norton and Kaplan. These four perspectives include:

- Customer perspective
- Business process perspective
- Financial perspective
- Innovation and learning perspective

Each of these BSC perspectives encompasses a number of KPIs, which may be selected depending on their relative level of importance in each business and supply chain. The supply chain BSC of Santos et al. (2006:1–2) is depicted in figure 1.4.

Another example of the variety of KPI’s that may be used in the SCM performance measurement context emerges from a study involving a performance measurement framework and which was conducted by Von Haaren andMalyshko (2007:11). This proposed performance measurement framework comprises five balanced scorecard perspectives, including the four perspectives mentioned above, but with the additional perspective of "cooperation".

Santos et al. (2006:2–4) and Von Haaren andMalyshko (2007:11) define specific KPIs and metrics that may be used to evaluate supply chain performance, given certain key assumptions such as strategy and the network selected.

A more in-depth discussion of scorecards and other measurement frameworks will be provided in section 2.4.

2.3.3 Information systems and supply chain management

2.3.3.1 Introduction

According to Simchi-Levi et al. (2009:407), information technology is an important enabler of effective supply chain management and, typically, spans the entire enterprise and beyond, encompassing suppliers at one end and customers at the other. However, in order to utilise information in supply chain management, information needs to be collected, analysed and shared for the purpose of collaboration (Simchi-Levi et al., 2009:414). In an effort to achieve this, Swink et al. (2011:299) argue that organisations can integrate their information systems with key suppliers. According to them, buyers can have supplier portals on their websites so that suppliers are able to access the buyer's scheduling information. Current scheduling information helps suppliers to establish priorities and carry out more effective operations planning. As a result, changes in schedules may be discussed between buyer and suppliers.

Customer relationship management software, which may form part of supply chain management information systems, has been developed to analyse and manage data from numerous sources both within and outside of organisations (sales calls, actual quantities purchased, call centres) so as to gain greater insight into the buying behaviours of customers (Swink et al., 2011:273–274).

Furthermore, in an attempt to reduce the total cost of the supply chain operation, organisations have been using optimisation models in the areas of sourcing, manufacturing, transportation, warehousing and customer service management (Van Eck, 2003:35; Shapiro, 2002:1; Li, 2008:5). Such models, which may form part of other stand-alone solutions, endeavour to provide optimisation by integrating certain of the above areas. The fact-based decision making and optimisation accomplished by these models has helped many organisations to produce plans that have enabled these organisations to reduce their supply chain costs significantly.

Lee (2003:1–2) is of the opinion that sound and scientifically based inventory replenishment models, which incorporate statistical and operations research techniques, are needed. These techniques are necessary in order to analyse the richness of the data and to deduce the required patterns, trends, variability and dynamics of customer demand. In addition, these scientific techniques enable organisations to balance various costs − inventory, transportation, handling warehousing and other direct and indirect labour − while simultaneously rendering optimal services to their customers. However, such a balancing act requires timely and accurate data, coupled with appropriate analytical techniques (Lee, 2003:1–2).

In the wake of faster and growing computer technology, more sophisticated modelling and optimisation methods have become both possible and available (Van Eck, 2003:35–36). However, according to Ganeshan and Harrison (1995:1–3), such models are huge and require a considerable amount of data. Nevertheless, as a result of the enormity of data requirements and the broad scope of decisions, these models often provide approximate solutions to the problems they describe.

With the development of optimisation from operational research methods, through MRPI/II programs and ERP packages to advanced planning and scheduling (APS) software, the aim of the next section is to provide a historical overview of the software development.

2.3.3.2 *Historical perspective*

Up to approximately 50 years ago, supply chains, mostly internal ones, were designed and managed using pencil and paper with a little help from calculators (Taylor, 2004:111). Computers then made their appearance and individual mathematical models were developed to manage schedules, capacity and inventories. During the 1980sand 1990s, manufacturing resource planning MRP(II) evolved from the material requirements planning (MRP) system. Manufacturing resource planning concentrated on a method for the effective planning of all the resources of a manufacturing company (Li, 2008:10). Following the MRP era, the existing software was developed into management information systems (MIS) such as the enterprise resource planning (ERP) system. These systems offer a partial or complete integration of several functions in the company, including accounting, purchasing, material management, transportation, human resources and manufacturing (Li, 2008:11). Following this evolution advanced planning and scheduling software was introduced to assist the supply chain planning process. In addition, several ERP vendors introduced additional modules such as business-to-business (B2B), customer relationship and online customer and supplier linkages as well as electronic commerce − "dot.coms" − to augment the integration of supply chain members (Handfield & Nichols, 2002:85–86; Li, 2008:11). The following section takes a closer look at the current supply chain software.

2.3.3.3 *Current supply chain software*

Internal integration and business information systems represent a critical step in SCM. Unless an organisation is able to communicate information effectively between its internal business functions, then the information flows with external supply chain partners are unlikely to succeed (Handfield & Nichols, 2002:85–86). It is essential that the huge amount of data emanating from the supply chain be filtered, analysed and converted into usable information to enable effective decision making. This is realised by information systems known as data warehouses, data mining and decision support systems (Stadler & Kilger, 2008:316–317; Handfield & Nichols, 2002:89–90). Knolmeyer,Mertens and Zeier(2002:4–6) assign different levels to the systems that support SCM. At the lowest level they list functions which they consider to be part of the intra company supply chain. In order to carry out these tasks at the lowest level operative or execution systems are commonly used. At the middle level we find advanced planning and optimising systems which, typically, support CPFR, demand planning, production planning and scheduling as well as the available-to-promise (ATP) function. The top level features systems that support both supply chain network design and the strategic planning of partnerships in the supply chain. These systems may all be found in a single ERP software suite or as an accumulation of standalone systems integrated to achieve a near real-time transparency of the supply chain.

Taylor (2004:114–116) and Stadler andKilger (2008:500) maintain that the advanced planning and scheduling (APS) system constitutes the most important application which is aimed directly at managing the supply chain with APS specifically supporting the top to middle levels, whereas ERP supports the middle to lower level functions of the enterprise. Despite the fact that APS systems offer a wealth of scheduling and planning possibilities, they normally do not provide the necessary modules with which to put these plans into action and integration into the existing ERP system is necessary. However, the importance of the relatively new APS applications may be appreciated when considering the definition of an APS system as supplied by Van Eck (2003:11): "An APS system is a system that sits like an umbrella over the entire chain, thus enabling it to extract real-time information from the chain, with which to calculate feasible schedules, resulting in fast, reliable response to the customer."

However, as Taylor (2004:117–120) points out, ERP and APS systems are not the only systems that support supply chain management. There are several other applications that serve the needs of a supply chain, including warehouse and transportation management systems which focus entirely on operational needs, inventory flow and storage of inventory as well as transportation network design, shipment tracking and route scheduling. He also indicates that the newest software also includes applications that handle customer relationship management (CRM) and which are aimed at integrating all customer contact activities, as well as supplier relationship management (SRM) − even newer than CRM.

Supply chain visibility is yet another development (Taylor, 2004:119–120). These applications track the movement of inventory as it flows through the chain, providing a graphical display showing actual and expected levels at certain locations. The supply chain event management software, in particular, allows for the definition of business process eventsthat trigger when the specified event occurs. This supply chain event management software also allows supply chain managers to act on exceptions rather than having to follow each movement and compare it to plan.

The above section is intended to provide an overview of the development of the information systems in supply chain management. Specific systems will be discussed in more detail in chapter 4.

2.3.3.4 Conclusion

According to Stadler andKilger (2008:313), the ubiquity of new telecommunications and the Internet has made real-time, online communications throughout the supply chain a reality. These systems have improved the accuracy, frequency and speed of communication between suppliers and customers, as well as internal customers. As a result of these improvements, information may be transmitted more rapidly through the supply chain, thus causing material to bepulled through the supply chain faster and this, in turn, results in improved deliveries, less waste, improved cost and increased customer value.

2.4 SUPPLY CHAIN PERFORMANCE MEASUREMENTS

2.4.1 Introduction

The measurement of supply chain performance, especially in relation to information flow efficiency,forms the basis of this research. In particular, this research study attempts to provide indicators and metrics of information flow efficiency from a supply chain performance point of view. As has been emphasised in figure 2.3 above, information is one of the critical drivers of supply chain activity and it remains the basis for decisions taken in the other four supply chain drivers, namely, production, inventory, location and transportation. In order to provide a further foundation for this study, this sectionwill, firstly, provide anoverview of general business performance measurement models involving general business performance metrics and the flow of information or communication and, secondly, current supply chain performance measurement practices and the manner in which information flow is being addressed.

2.4.2 General business performance measurement models

2.4.2.1 The Balanced Scorecard (BSC)

The balanced scorecard (BSC) is an integrative approach for developing strategic, organisational-level metrics (Swink et al., 2011:41). Robert Kaplan and David Norton of the Harvard Business School first introduced the BSC in the 1990s (Kaplan & Norton, 1992).

The BSC may be understood as a means of providing management with richer and more relevant information about the performance of certain key performance areas of their businesses (Stadler & Kilger, 2008:50–51). According to Hendricks,Menor and Wiedman(2004:1), the BSC requires that senior management translate the organisation's vision and strategy into the following four performance perspectives, namely, (1) financial, (2) customer, (3) internal business and (4) learning and growth − see figure 2.10. As the figure shows, objectives are devised for each perspective, measurements and targets are developed for each objective and the necessary initiatives put into place for the purpose of achieving the set objectives. The BSC aims to determine the cause and effect relationships between the objectives in the four perspectives as well as combining traditional financial measurements with non-financial measurements in a single report.

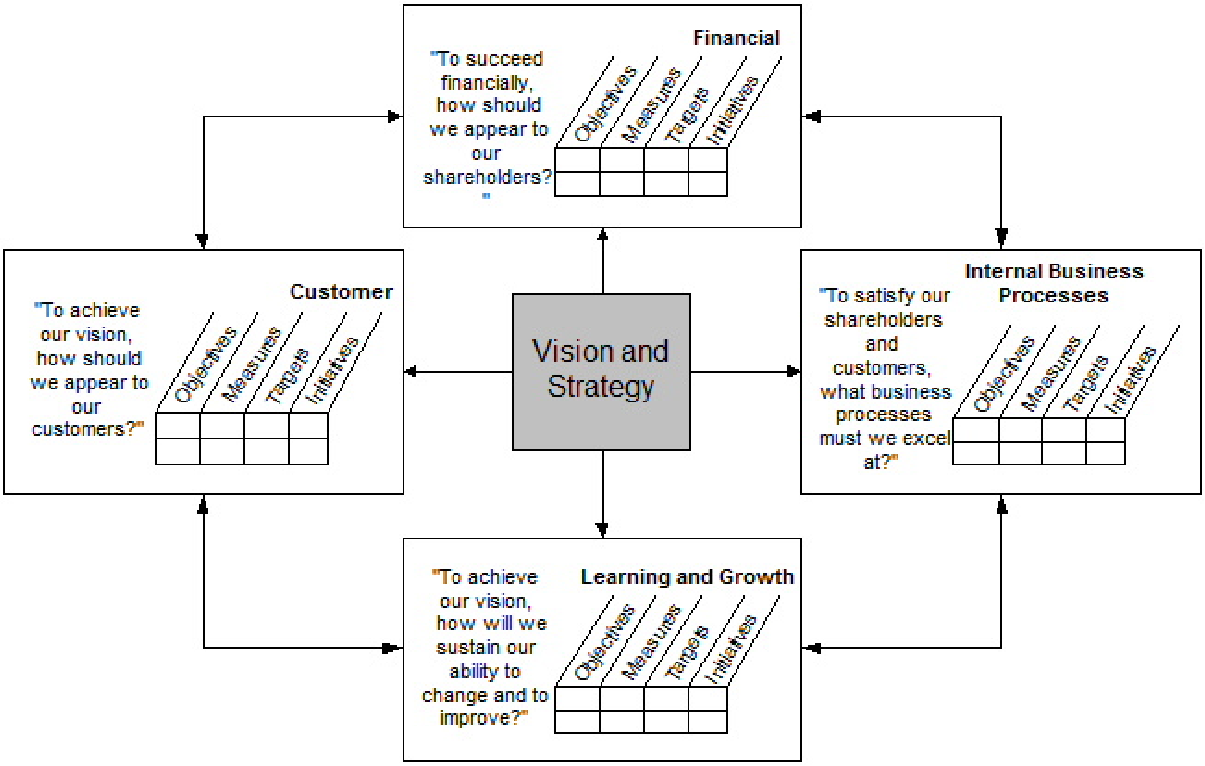

Figure 2.10: The balanced scorecard

Source: Swink et al. (2011:41)

2.4.2.2 *The communication scorecard (CSC)*

Pfannenberg andZerfass (2004:5) emphasise that the communication function in a business, together with other functions such as human resources, business development, marketing, finance, etc., create the necessary basis for the earning of returns through the delivery of an organisation's products and services and the marketing of these products and services. However, communication alone does not generate income, although it must be considered as an important driver for business success.

Zerfass (2004:4) elaborates further on this topic, and argues that the already existing models, which used the BSC to optimise the communication processes within the public relation function, are not sufficient in their application. In fact, he argues that their actual contribution to the realisation of the company strategy, originating from public relations exercises, such as market and employee campaigns, may be questionable. The communications efforts must be clearly linked to both business strategy and tactical communication tools and it is through the operationalisation of this concept that strategic communication goals and quantifiable measure may be identified and, in turn, linked to economic goals. Zerfass (2004: 4) also points out that, in addition to the above concept, a link between the communication programs identified and the actual actions within the available media mix is still required. Zerfass's work led to the development of the communication scorecard (CSC) − see figure 2.11. This figure depicts a BSC, but expandedto include the "*socio-political perspective*".

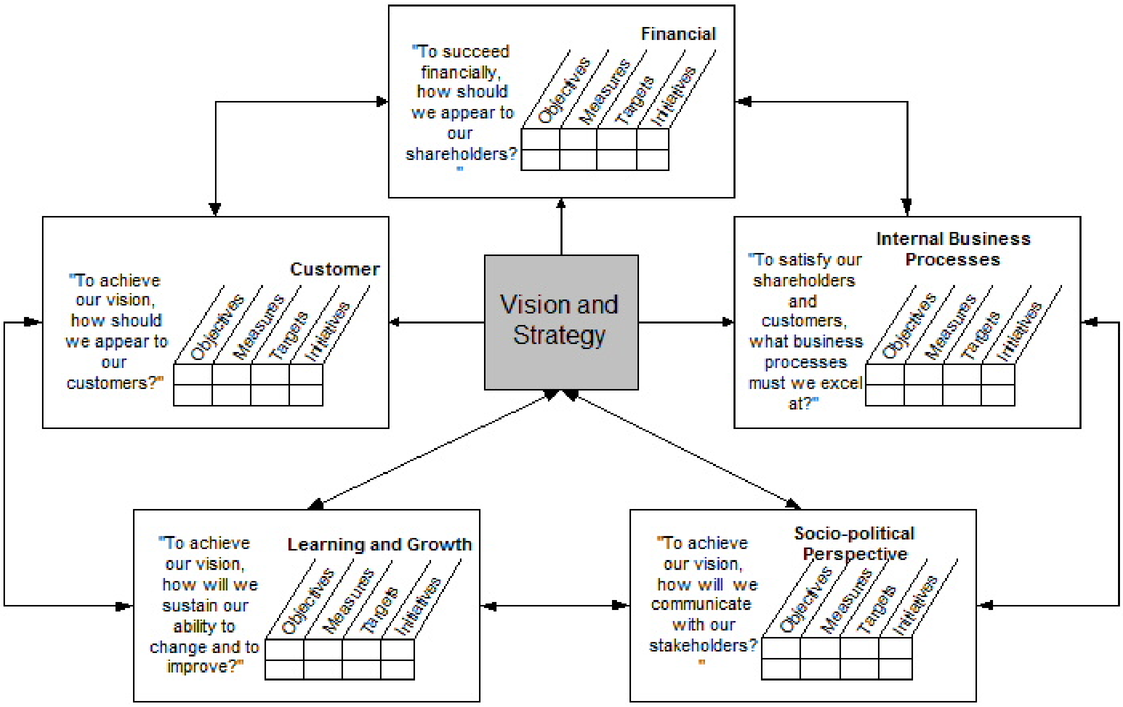

Figure 2.11: The communication scorecard

Source: Zerfass (2004:5)

Zerfass (2004:6) expands on his proposed CSC by introducing detailed socio-political goals. These goals may be deduced from the expectations of the stakeholders. He also introduces associated measurements to these goals, as required by a balanced scorecard approach.

However, the important point as regards this scorecard is the recognition of communication, which is only possible with the transfer of information, as a value driver for business success.

2.4.2.3 *The Skandia Navigator*

In order to evaluate the market value of an organisation, Skandia proposed to split the market value into financial capital and intellectual capital. Intellectual capital may be compared to an organisation's intangible assets (Marr,Schiuma& Neely, 2003:555). The Skandia Navigator divides intellectual capital into three basic concepts, namely, *human capital, structural capital* and *customer capital*. According to Malhotra (2003:7), the human capital includes the collective competence, capabilities, skills and experiences of employees and managers as well as their creativity and innovativeness. Structural capital, on the other hand,refersto the supporting infrastructure for human capital and comprises organisational processes, procedures, technologies, information sources and intellectual property rights. Customer capital consists of the value embedded in an organisation's relationship with its customers, suppliers, industry associations and market channels.

The implementation of this model concentrates on five areas of improvement − financial, customer, process, renewal and development and human capital with human capital including both human and structural capital. In its application, the Skandia Navigator imitates the balanced scorecard as depicted in figure 2.11

2.4.2.4 *The intangible assets monitor*

The intangible assets monitor was developed by Sveiby (1997) and defines three types of intangible assets that account for the book value − to market value discrepancy in the valuation of an organisation. The 'residual' that is not accounted for by the book value may be attributed to the individual competence of the employees, and to both the internal structure and the external structure (Malhotra, 2003:7). According to Marr et al. (2004:560–561), the measurements of these three intangibles may be divided into three measurement groups, which indicate the following:

- Growth and renewal
- Efficiency
- Stability

Marr et al. (2003:561) maintain that organisations are advised to develop one or two indicators for each intangible under each of the measurement groups. Table 2.2presents an example of an intangible asset monitor. The intangible assets monitor emphasises the internal perspective and is meant to act as a management and communication tool although not primarily as a valuation tool, although it is used as such. The monitor provides management with valuable information about intellectual property. However,on the downside, the monitor lacks the ability to be integrated easily into any broader performance measurement systems, which may be designed to establish a link between intangible performance drivers and performance outcomes.

Table 2.2: Matrix of intellectual capital measures for intangible asset monitor

	Human competence	Internal structure	External structure
Indicators of growth/renewal	Years in profession; Education level; Training cost; Turnover	Investments in internal structure; Customers contributing to systems/process building	Profitability per customer; Organic growth
Indicators of efficiency	Proportion of professionals in company; Leverage effect; Value added per professional	Proportion of support staff; Sales per support person; Corporate culture poll	Satisfied customer index; Win/loss index; Sales per customer
Indicators of stability	Average age of staff; Seniority; Relative pay Position; Professional turnover rate	Age of organisation; Support staff Turnover rate; Rookie ratio	Proportion of big customers; Age structure of markets; Devoted customer ratio; Frequency of repeat orders

Source: Marr et al. (2003:561)

2.4.2.5 The value chain scorecard

The BSC was introduced above as a measurement instrument to provide a measure for business performance in four perspectives, namely, the financial, the internal, the customer, and the learning and growth perspectives. As such, the BSC translates vision into objectives and associated metrics for facilitating performance measurement and strategic management. However, Bauknecht,Pröll and Werthner (2005:161–165) argue that a business model should be considered as the foundation for value creation, which is lacking in the BSC approach. They further contend that the BSC should be enhanced and adapted to incorporate a business model approach which includes distinct value dimensions as illustrated in figure 2.12. Bauknecht et al. (2005:161–165) emphasise the following five value dimensions, namely, market, supply chain, enterprise, product and service, and customer.

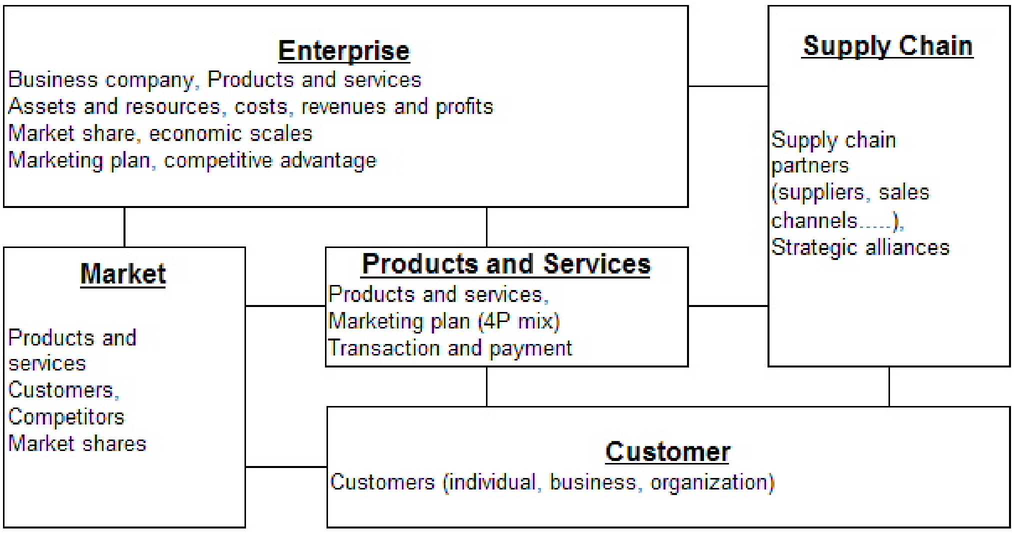

Figure 2.12: Business model with value dimension
Source: Bauknecht et al. (2005:162)

Based on this business model, a value related BSC with the same dimensions, as depicted in figure 2.13, is proposed. Notably, the enterprise and product and service dimension have been combined into a single enterprise-centric structure and process dimension.

Market Perspective	Supply Chain Perspective
Mission: To create market value and deliver value to shareholder. **Objectives:** To clarify success factors of market selection and segmentation To identify market opportunities and risks To specify goals on market shares, profit gains, and other market values. **Performance Indicators:** Level of market competitiveness Market revenues and profits Market share Return opn investment (ROI) Market capitalization Earning per share Increasing rate of thes indicators	**Mission:** To create and share supply chain related information and values. **Objectives:** To direct the partner selection and supply chain establishment, management and operation process To develop information and value sharing policies **Performance Indicators:** Cost and time reduction in information and production processing, market response and production/distribution cycle integration Revenue/profit increases for entire chain, Customer satisfaction level in time and location convenience
Business Structure & Process Perspective	**Customer Perspective**
Mission: To create business values including product, service, and process values, etc. **Objectives:** To leverage organizational capabilities To achieve decision effectiveness To improve internal processes To create business image and brand names To develop value-added products & services To provide transaction system and process To create business values and make profit **Performance Indicators:** Return on assets, asset utilization measures Cash flow ratios, profitability ratios Operating efficiency measures HR skill levels and productivity measures IT/IS ROI, IT/IS useability measures Innovation effectiveness measures	**Mission:** To create customer values and to gain customer shares **Objectives:** To specify customer clustering and classification rules. To enforce personalization and customization products and services. To generate customer shares and values from business process improvement and customer relationship management **Performance Indicators:** Number of registered customers Customer profitability levels (current gains and future potential) Customer shares, Customer satisfaction levels Increasing rate of these measures

Figure 2.13:A value-based BSC

Source: Bauknecht et al. (2005:165)

The BSC illustrated above provides some examples of mission, objectives and performance indicators. Accordingly, Bauknecht et al. (2005:166) contend that value-based strategies and suitable performance indicators are brought together in an adapted BSC which includes four value-based perspectives, namely, market, supply chain, customer, and business structure and process, thus bridging the existing gap between business models and the BSC.

2.4.2.6 The strategic value maps

Value mapping is a second-generation performance measurement and performance management approach that avoids many of the weaknesses of the existing frameworks (Jack, 2001:5) with first-generation performance measurement frameworks failing to capture all of the measurement needs in one approach.

If organisational performance measurement and performance management are to be effective it is essential that they both drive value creation in order to meet the needs of the stakeholders. If they are not adding value, then they are misdirected and energy and effort are being wasted. However, before an organisation is able to review and develop its performance measures the organisation needs to understand the value outcomes that it is trying to create and that these value outcomes are influenced by the needs of its stakeholders. According to Jack (2001:6), it is a fallacy that performance measures should be derived directly from strategy. Instead, the desired value outcomes and the measures of these desired value outcomes are derived from stakeholder and organisational needs

Value mapping is a tool with which to sort through the myriad of improvement programs that organisations undertake in an effort to distinguish those programs that will have the largest impact on stakeholder requirements. In addition, value mapping also supports performance measurement by requiring an assessment of the impact activities and initiatives in terms of value-based outcome (Jack, 2001:7–9).

Figure 2.14 depicts the strategic value-mapping model and elaborates on the relationship between stakeholder needs, value drivers, measurements and desired outcomes.

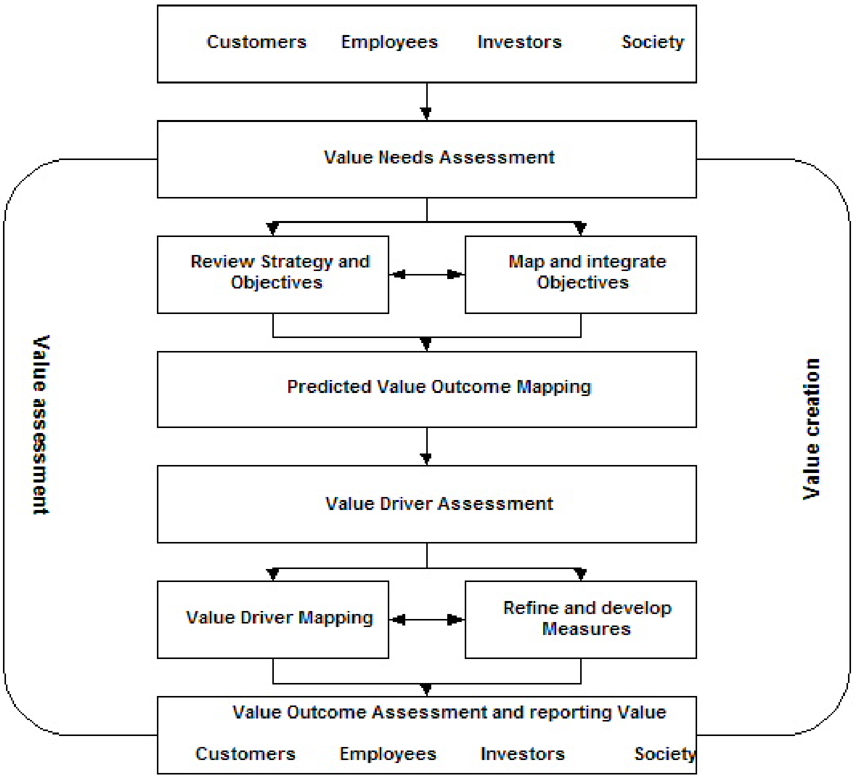

Figure 2.14:Strategic value mapping model

Source: Jack (2001: 8)

In addition to Jack's interpretation of the strategic mapping process, Harmon (2004:1) outlines the generic strategy map as designed by Kaplan and Norton. Harmon (2004:1) contends that the generic strategy map represents a refined methodology that seeks to align the balanced scorecard with the strategy of an organisation. In this map, as shown in figure 2.15, the four sets of BSC objectives are arranged in a hierarchical fashion, with financial objectives at the top. These financial objectives are affected by changes in customer objectives which, in turn, are affected by internal (process) objectives and changes in these internal objectives. The learning and growth objectives support and affect the internal business process objectives.

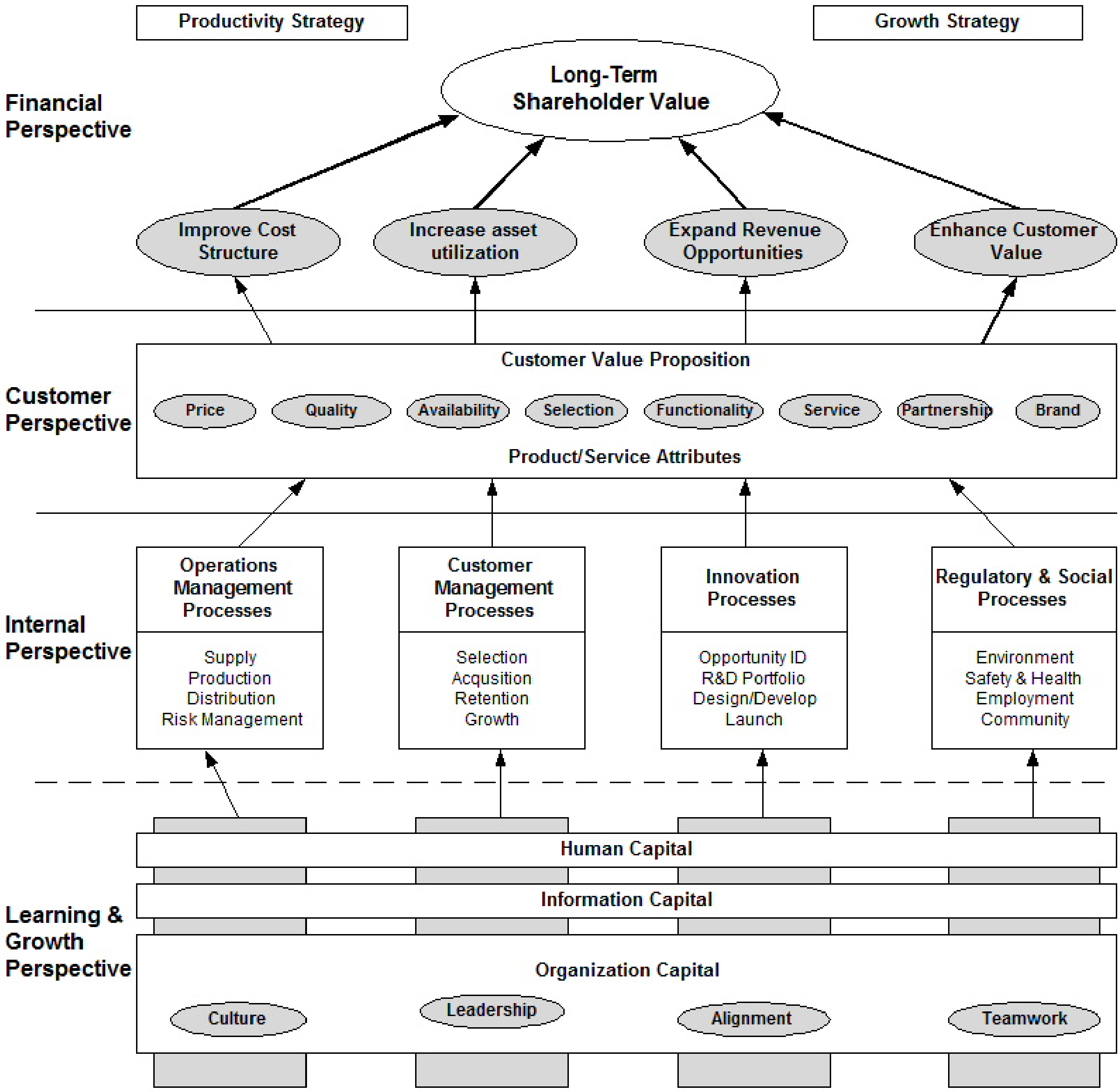

Figure 2.15: A generic strategy map

Source: Harmon (2004:2)

2.4.2.7 *The tableau de bord*

The BSC has widely been used as a strategic management tool for performance measurement and includes non-financial measures together with the traditional financial measures. However, although, the BSC has aroused a great deal of attention in the United States and in other countries, Bourguignon,Malleret and Nørreklit (2001:2) assert that the French-speaking community, in particular, in France, have not readily accepted the BSC. It would appear that these reservations on the part of the Frenchstem from the fact that French organisations have used the *tableau de bord* for the past fifty years. According to Bourguignon et al. (2001:2), arguments range from the BSC being merely another version of the tableau de bord to French resistance to American products.

Although these arguments may contain some truth, thus underpinning the cultural and socioeconomic differences between the originating countries, Bourguignon et al. (2001:10–12) point out that there are both similarities and differences between the two performance measurement approaches. The similarities refer to the fact that both these approaches aim at avoiding the monopoly of financial measures, thus assuming that anticipation is more important than reaction and recommending the selectivity of measures. The main differences may be found in the fact that the tableau de bord is not based on any specific model, unlike the BSC which is based on Michael Porter's competition model, and, instead, relies on the manager's own strategic representation (Bourguignon et al., 2001:10–11).In other words, in terms of the tableau de bord, the manager builds the whole model, from objectives to measures, based on his/her subjectivity. Another important difference may be found in the unequal emphasis placed on reward. Whereas the BSC links reward to performance measurement, the French tableau de bord places the emphasis on learning.

However, Bourguignon et al. (2001:10–7) do emphasise that the tableau de bord has undergone many changes and that today's tableaux differ considerably from the old ones. In fact, a new tableau de bord, developed by Daum (2002:8),is testimony of this progress. Daum's tableau incorporates all of the four elements of the BSC, namely, financial results, market/consumer measures, product development measures and process/resource measures.

In conclusion, it may be said that, although there may be differences in the way in which objectives and measures are derived, both management tools, the BSC and the tableau de bord, may be considered similar as regards their attempts to measure performance.

2.4.3 Performance measurement possibilities in the supply chain context

A supply chain does not remain constant and it must continually adjust to new circumstances. However, in order to derive the required performance from a supply chain, it is necessary that a company monitor and control its actions on a daily basis (Hugos, 2006:133). However, performance measurement is more complex than it may appear initially and measurements, that appear sound, may lead to inappropriate outcomes. For example, a company's measurement may be order fill rate. In order to achieve a good score, the company may find that orders are kept back until all units are available for shipment. Therefore, although order fill rates of almost 100% may have been achieved, the customer will still be unhappy as he/shewill have received the goods far later than anticipated (Coyle et al., 2003:482). The correct choice of measurements is, thus, of the utmost importance.

Stadtler andKilger (2008:49) emphasise that indicators have three functions, namely, informing −with the main purpose being to inform management and, thus,to support decision–making, steering, in terms of which indicators form the basis for target setting; and controlling which uses indicators for the supervision of operations and processes. Performance measurements are used in a wide range of operations and it is difficult to imagine trying to control an operation without the frequent use of measurements. According to Stadtler and Kilger, performance measurement frameworks require some sort of metrics or system of metrics, which are able to describe facts in a quantitative way

By their very nature supply chain performance measurements differ from the traditional business and logistics measurements as supply chain performance measurements span functions within both a single company as well as in organisations in terms of their combined performance (Coyle et al., 2003:495). According to Murphy (2004:2),organisations must implement measurements that are meaningful and which drive results, especially in key performances areas (KPAs). Performances indicators relevant to KPAs are also known as key performance indicators (KPIs). These KPIs should be aggressive, but attainable, as it is essential that the indicators selected are backed up with plans and initiatives that may lead to the realisation of the goals identified.

The supply chain drivers are depicted in figure 2.3. If a supply chain is to be successful, it needs to succeed in the specific areas of production, location, transportation and inventory. Specifically, supply chain performance and information flow in terms of efficiency and responsiveness was emphasised in paragraph 2.2.2. If the supply chain drivers are combined with the supply chain performance areas, it is possible to identify four categories of measurements(Hugos, 2006:137)

- Customer service
- Internal efficiency
- Demand flexibility
- Product development

Hugos (2006:137) contends that customer service refers to the ability of the supply chain to meet the expectations of its customers while internal efficiency measures the ability of the supply chain to generate an appropriate level of profit, whilst operating at a low level of cost. Demand flexibility assesses the ability of the supply chain to adjust to uncertainty in the levels of product demand. The last category, product development, encompasses the measurement of the timeous design and delivery of new products to the supply chain's markets.

Within the supply chain context, Hugos (2006:140–146) breaks these categories down into the following individual measurements:

- Customer service
  - i. Complete order fill rate and order line item fill rate
  - ii. On-time delivery rate
  - iii. Value and number of back orders
  - iv. Frequency and duration of backorders
  - v. Line item return rate

- Internal efficiency
  - i. Inventory value
  - ii. Inventory turns

iii. Return on sales
iv. Cash-to-cash cycle time

- Demand flexibility
  i. Activity cycle time
  ii. Upside flexibility
  iii. Outside flexibility

- Product development
  i. Percentage of total products sold that were introduced in the previous year
  ii. Percentage of total sales from products introduced the previous year
  iii. Cycle time needed to develop and deliver a new product

Coyle et al. (2003: 490–492) arrived at the same detailed measurements and others, although they identify the performance categories as cost, time, quality and other/supporting. In a more detailed explanation of the categories they associate time with the customer dimension and cost with efficiency. Quality may be associated with customer service and efficiency, whilst the other/supporting category may deal with measurements of, for example, information.

Simchi-Leviet al. (2009:368–381) propose to measure the perceived value to the customer of the customer's entire relationship with a company. They argue that customer value is based on customer perceptions and this requires that metrics start with the customer. Typical metrics include service level and customer satisfaction, as well as supply chain performance − an important contributor to customer value. Service level metrics include the ability to meet the required delivery dates of customers, while customer satisfaction metrics measure the performance of the sales department and personnel. Simchi-Leviet al. (2009:381–382) and Swink et al. (2011:42) refer to the SCOR model for the measurement of the supply chain performance. The performance perspectives referred to in this model include:

- Supply chain reliability

- Flexibility and responsiveness
- Expenses and
- Assets/utilisation

Specific metrics in these categories comprise:

- Supply chain reliability
  i. On-time delivery
  ii. Order fulfilment lead times
  iii. Fill rate
  iv. Perfect order fulfilment

- Flexibility and responsiveness
  i. Supply chain response time
  ii. Upside production flexibility

- Expenses
  i. Supply chain management cost
  ii. Warranty cost as percentage of revenue
  iii. Value added per employee

- Assets/Utilisation
  i. Total inventory days of supply
  ii. Cash-to-cash cycle time
  iii. Net asset turns

However, although performance measurement is not a new concept and dates back to the 1950s when it was introduced in a formalised manner, the supply chain specific performance measures have evolved over time (Coyle et al., 2003:484). Traditionally, organisational performance measurements were mainly financially oriented with little contribution from other business functions or processes. The collision of the historical cost accounting centred standards and the requirement to build competitive organisations based on the performance as regards core capabilities has led to the development of the balanced scorecard (Kaplan & Norton, 1996:7) − seesection 2.4.2.1.

2.4.4 Specific scorecards and alternative measures

Following the review of performance measurement possibilities in the supply chain context, specific performance measurement frameworks pertaining to the measurement of supply chain performance and information flow performance are explored in the following section.

Olugu andWong (2009:204–205) refer to traditional approaches to supply chain performance measurement (SCPM) such as Data Envelopment Analysis (DEA) and balanced scorecard models. However, DEA is not commonly used in supply chain performance measurement (SCPM) and requires advanced computational techniques such as linear programming (Mishra & Patel, 2010:104–105). In addition, DEA does not constitute a model of SCPM, but rather a computational method of analysis of arriving at metric values with which to measure performance. Accordingly, DEA will not be discussed in this study.

The measurement frameworks discussed include the more commonly referenced models such as the BSC models (Von Haaren &Malyshko, 2007:11; Santos et al., 2006:2–4; Swink et al., 2011:41; Hugo et al., 2004:106–107) and the SCOR model (Swink et al.,2011:42; Simchi-Levi et al., 2009:381–383; Webster, 2008:353–356).

2.4.4.1 Supply chain scorecard models

The balanced scorecard approach has been utilised in several areas of application, including supply chain management. Supply chain scorecards were developed as an adaptation of the BSC model to fit either an individual organisation or the entire supply chain (Hugo et al., 2004:102). Based on the BSC (see figure 2.10), four perspectives may be identified, namely (Santos et al., 2006:2–4):

- Financial
- Customer

- Internal processes and
- Learning and growth

There are variations on these four perspectives. Von Haaren and Malyshko (2007:11) prefer the following performance measurement perspectives:

- Financial
- Customers
- Internal processes
- Resources and
- Cooperation

The supply chain scorecards show the individual metrics associated with each perspective. Nevertheless, a closer inspection of the supply chain scorecards metrics proposed by the writers mentioned above reveals that the metrics are generally very similar in terms of each of the measured activities. However, depending on the focus of the business activities, additional metrics have been introduced in order to emphasise the individual business focus.

Von Haaren andMalyshko (2007:11) introduced metrics which are focused on the utilisation of warehouses and equipment as well as the efficiency of transportation, whilst Santos et al. (2006:2–4) include metrics from all the supply chain business processes. The table below presents the primary and support business activities, and the metrics selected for each business activity, as identified by Santos et al. (2006:2–4).

Table 2.3: The supply chain balanced scorecard according to Santos, et al.

Perspective	**Primary and support activities/proposed KPIs**	**Metrics**
Customer perspective	Sales/customer support	Quality – % non-conformity
		Forecast accuracy
		Market share
	Logistics	On time delivery
		Number of products/ distribution channel
		Damaged shipments
Financial perspective	Sourcing	Material acquisition cost
	Manufacturing	Non-quality cost
		Warehousing cost
		Manufacturing unit cost
	Warehousing	Cost of carrying inventory
	Logistics	Logistics cost
		Transportation cost
	Accounting processes	Cash flow
		EBDITA (earnings before depreciation, interest and tax)
		Income
		EVA (Economic added value)
		Operating ratio
		ROI (return on investment)
		Revenue per employee
		Return on asset
Internal business process perspective	Sourcing	Supplier on-time delivery
		Material inventories
		Material quality
		Supplier cycle time

	Planning	% of orders delivered according to plan
		Schedule changes
		BOM (bill of material) accuracy
	Manufacturing	Adherence to schedule
		% defective products
		Number of finished products /SKUs (stock keeping units)
		Manufacturing cycle time
		Setups/Changeovers
		Plant utilisation
	Delivery/storing	Finished goods inventory turn
		Stock keeping units
Innovation and learning perspective	Innovation	% new product development
	Social responsibility	Social programs invested
	HR	Absenteeism
		% employee training
		Employee productivity
		Motivation
		Employee turnover

Source: Santos et al. (2006:2–4)

As shown below Hugo et al. (2004:106–107) devised a supply chain scorecard based on the four perspectives of the BSC.

Table 2.4:The supply chain scorecard according to Hugo et al.

Customer Dimension						
Measure	Input Data	Frequency of measurement	Responsibility	Goal	Current performance	Resource allocation
Perfect order fulfilment						
Processing accuracy						
Forecasting accuracy						
Budget accuracy						
Delivery performance						
Customer satisfaction						
Product quality						
Business process dimension (incorporating time and asset utilisation)						
Measure	Input Data	Frequency of measurement	Responsibility	Goal	Current performance	Resource allocation
Supply chain response time						
End-to-end pipeline time						
Order cycle time						
Production flexibility						
Material labour capacity						
Inventory days						
Net asset turns						
Cash-to-cash cycle time						
Capacity utilisation						
Financial dimension						
Measure	Input Data	Frequency of measurement	Responsibility	Goal	Currentperformance	Resource allocation
Total supply chain cost						
Finished goods inventory turns						
Total delivered cost						
Cost of excess capacity						
Cost of capacity shortages						
Innovation						
Measure	Input Data	Frequency of measurement	Responsibility	Goal	Current performance	Resource allocation
New product introductions						
New process technology development						
Partnerships						

Source: Hugo et al. (2004:106–107)

2.4.4.2 The supply chain operations reference (SCOR) model

The SCOR model was developed and is maintained by the SupplyChain Council (SCC), a non-profit organisation formed in 1996 by AMR Research and numerous member organisations (Webster, 2008:352). SCOR was introduced to provide a standard framework for describing supply chain processes, and included associated terminology, metrics and best practices (Webster, 2008:352). Simchi-Leviet al. (2009:381) and Swinket al. (2011:42) describe SCOR as a process reference model that includes analysing the current state of a company's processes and its goals, quantifying operational performance, and comparing it to benchmark data. According to these writers, SCOR has developed perspectives and associated metrics for the measurement of supply chain performance. However, Swink et al. (2011:42) add that the SCOR model provide more than merely metrics as it also provides tools for charting and describing supply chain processes and identifies basic management practices at different levels of operation.

According to the Supply Chain Council (http://supply-chain.org), the SCOR model provides a unique framework that links performance metrics, processes, best practices, and people in a unified structure. In addition, the framework supports communication between supply chain partners and enhances the effectiveness of supply chain management, technology, and related supply chain improvement activities. Figure 2.16 depicts the SCOR model

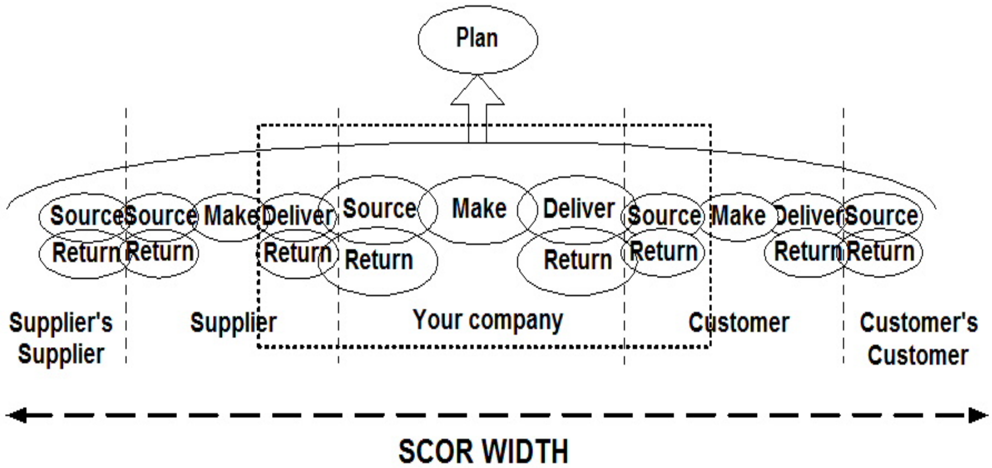

Figure 2.16: The SCOR model

Source: http://supply-chain.org

As emphasised by the Supply Chain Council (http://supply-chain.org) SCOR metrics are diagnostic metrics. SCOR recognises three levels of predefined metrics:

- Level 1 metrics are diagnostics for the overall health of the supply chain. These metrics are also known as strategic metrics and key performance indicators (KPIs). Benchmarking level 1 metrics helps establish realistic targets that support strategic objectives.
- Level 2 metrics serve as diagnostics for the level 1 metrics. The diagnostic relationship helps to identify the root cause or causes of a performance gap for a level 1 metric.
- Level 3 metrics serve as diagnostics for level 2 metrics.

The analysis of performance of metrics from level 1 through 3 is referred to as decomposition. Decomposition helps identify the processes that merit further investigation. (Processes are linked to level 1 and level 2 metrics.)

Several of the metrics in the SCOR model are hierarchical, just as the process elements are hierarchical. Level 1 metrics are created from lower level calculations while level 2 metrics are generally associated with a narrower subset of processes. For example, delivery performance is calculated as the total number of products delivered on time and in full, based on a commit date. In addition, metrics (diagnostics) are used to diagnose variations in performance against plan. For example, an organisation may wish to examine the correlation between the request dates and commit dates.

2.4.5 Conclusion

The many different business performance matrices and scorecards detailed in sections2.4.2 to 2.4.4 provide a glimpse only of the multitude of performance measurement tools currently in use, although those mentioned do represent the tools that are used the most frequently. The manifold adaptations of the balanced scorecard point to the fact that performance measurement is not only being applied to certain business processes, but that decision makers are also seeking to measure the progress of strategy implementation as well as that of non-strictly business processes. However, in view of the fact that it appears that no one tool exists which suits all types of enterprises, new performance measurement tools are constantly being developed.

Nevertheless, both information flow and information itself have been accepted as two of the most important drivers of supply chain performance. Despite the fact that some writers have, to a certain extent, dealt with communication or information, communication refers mainlyto public relations activities and their effect on the profit position and social acceptance of an enterprise. The efficiency with which information is transferred throughout the supply chain, for example, intra-organisation and inter-organisation information flows, which are critical to the success of supply chain management, have not been incorporated into any measures or any scorecard.

2.5 CONCLUSION

The supply chain has been depicted as a complex network of businesseswhich are forced, continuously,to undergo changes and adapt to new business conditions. In addition, writers have recognised that supply chains benefit from focusing on the entire supply chain rather than only on single enterprises within the supply chain. These benefits stem particularly from the optimisation of processes beyond the individual enterprise. However, such optimisation decisions may be taken effectively only if relevant information is allowed to flow freely and in real time between the function of an enterprise and between the member enterprises of a supply chain. The ability to process increasingly complex data structures, and to extract meaningful information from such data, has become one of the strategic advantages that enterprises seek to harness. In reality, enterprise resources are limited with these limits extending to which degree enterprises are able take advantage of favourable strategic choices.

Clearly, if it is not possible to transfer important information within acceptable time frames, then decisions regarding the main driver of supply chain activities, production, location, inventory and transportation will neither effective nor efficient in nature. Such decisions are the domain of supply chain management, which aims to align the supply chain strategy of an organisation with the overall business strategy of the organisation. Once a strategy has been formulated, it is essential that the appropriateness of the existing supply chain design be reviewed and, possibly, adjusted with the final supply chain design being executed in order to realise the desired goals. In order to assist the attainment of the supply chain management goals, supply chain performance must be measured and compared to requirements.

Organisational performance measurement has developed over a period of several years, from mainly financially oriented measurements to a balanced approach which combines traditional financial measurements with non-financial measurements from the internal process, the customer and the innovation and growth perspectives.

However, in all current performance measures, information flow, which almost all writers agree is essential to supply chain success, does not feature, with the exception of cases where information is exchanged with stakeholders in public relation scenarios.

It is, therefore, the intention of this research to contribute to the existing body of knowledge on supply chain performance measurement. This research study will concentrate specifically on the measurement of information flow efficiency in intra- and inter-organisation scenarios, with information flow efficiency as one possible measurement, amongst other possible measurements,which relates to the different objectives of the balanced scorecard as regards either the success or failure of supply chain management implementation. Once incorporated into a balanced scorecard, these information flow efficiency indicators and associated metrics will provide additional reasons for the deficiencies or success of other perspectives, including finance or the customer perspective, and should be considered as complementary to the indicators and associated metrics contained in these perspectives.

CHAPTER 3
INFORMATION, INFORMATION FLOW AND RELATED CONCEPTS

3.1 INTRODUCTION

Information and the flow of information always have played an important role in supply chain management (Reeker & Jones, 2002:1) with the bullwhip effect as the classic example underpinning this statement. The bullwhip effect is represented by the propagation and enlargement of small fluctuations of demand or inventory levels in either the final company or customer in a supply chain, extending back through the supply chain to the initial supplier. These fluctuations,as well asincreases in these small fluctuations in the beginning of the demand cycle,may be attributed to the fact that organisationsare in possession of incomplete information about the needs of the other supply chain members and, thus, respond to the imperfect demand projections with an disproportional increases in inventory which, in turn, creates an even larger requirement on the part of the company downstream (Trkmanet al., 2005:560). Trkmanet al. (2005:560)contend that if information is transmitted more rapidly between the organisations of the supply chain, i.e. directly from the customer to the manufacturer, then production peaks may be reduced by as much as 20%.

According to Reeker andJones (2002:1), information will play an important role in the manufacturing systems and supply chains of the future. Jones, Reeker andDeshmukh (2002:1) assert that the manufacturing aspect of the supply chain, in particular, has changed in two important ways. Firstly, automated data collection systems on the shop floor support real-time scheduling decisions, and secondly the Internet supports the movement towards global supply chain management decisions on an organisation level. However, in both cases, the availability of information in real-time is crucial in terms of the success of any supply chain decisions that may be taken. According to Manjappa, Del Angel, Shan, Zhao Becerra andThomson (2008:10), information is the main asset that organisationspossesswhich enables these organisationsto provide the necessary linkages across supply chains for both clarity of purpose among the partners in the supply chain and timely service to customers

Jones et al. (2002:1) point out that, although current technology may provide information in real-time, it is not able to assure that the information provided will be accurate and meaningful and that it will be used correctly. The dichotomy of information, in terms of both its provision and characteristics, arises from the fact that information is often obtained through the use of the optimisation algorithms implemented in software. However, despite the fact that algorithms are designed to complete computations fast, the processing decisions for the data require a common understanding amongst the supply chain members if they are to be meaningful.

Information, which is needed in order to arrive at meaningful decisions, has a direct impact on the performance of an enterprise (Jones et al., 2002:1; Madhani, 2008:239; Trkman et al., 2005:561) with information being required in order to make the correct decisions about the future state of the supply chain. Accordingly, information is required at different places in the supply chain simultaneously. However, as detailed in section 2.2.4, chapter 2, it is not possible to assume that either the information transfer between the supply chain members or information sharing will happen with ease and barriers to information sharing are a reality (Katunzi, 2011:107–109).

It is as a result of these barriers that the totality of information needed to describe a specific scenario may not be available and it is, therefore, understandable that organisations and supply chains may miss out on better decisions and improved performance as in the case of real time information sharing. It is for this reason that this research study aims to contribute to the existing body of knowledge on the role and importance of an efficient information flow both in supply chains as well as within and between member organisations, by measuring the efficiency with which information flows between supply chain members and then correlating these measurements with supply chain performance.

Apart from the human and systems difficulties involved in transferring information, information itself is not a straightforward concept. In fact, as shown in chapter 1, an all-encompassing definition of information is still lacking. A useful definition was found in terms of the origin and value of information but this definition does not incorporate either the technical or the etymological nature of information, or any of the pragmatic, epistemic, doxastic or modal properties of information.

If supply chain members are to be able to access information, then the information must be transferred from its point of inception to the next point(s) of use. Information is typically conveyed in physical symbols such as marks on paper, sounds, electrical pulses, light waves and others (Jones et al., 2002:1).

Based on the characteristics of information itself, as well as the various and complex methods of transferring information, it is clear that a detailed understanding of information, information flow and related concepts is required in order to attain the insights necessary to define the characteristics of the quantities of information flow that must be measured, as well as to define suitable measures for information flow efficiency.

3.2 BASIC CONCEPTS

3.2.1 Information as a concept

Chapter 1 provided a definition of information using a multitude of other definitions and concepts. The description of information arrived at then led to a categorisation of information based on both the types of information (see table 1.1) as well as the properties of information. In order to gain a better understanding of the way in which these different concepts fit into the overall concept of information, it may be useful to construct a concept map for information.

Concept maps are diagrams showing the relationships between concepts (encyclopaedia at http:/www.answers.com/topic/concept-map). The concepts are connected with labelled arrows, in a downward branching hierarchical structure. The relationship between concepts is articulated in linking phrases, for example, “gives rise to”, “results in” or “contributes to”. Based on the concepts linked to information it was possible to construct a concept map − see figure 3.1.

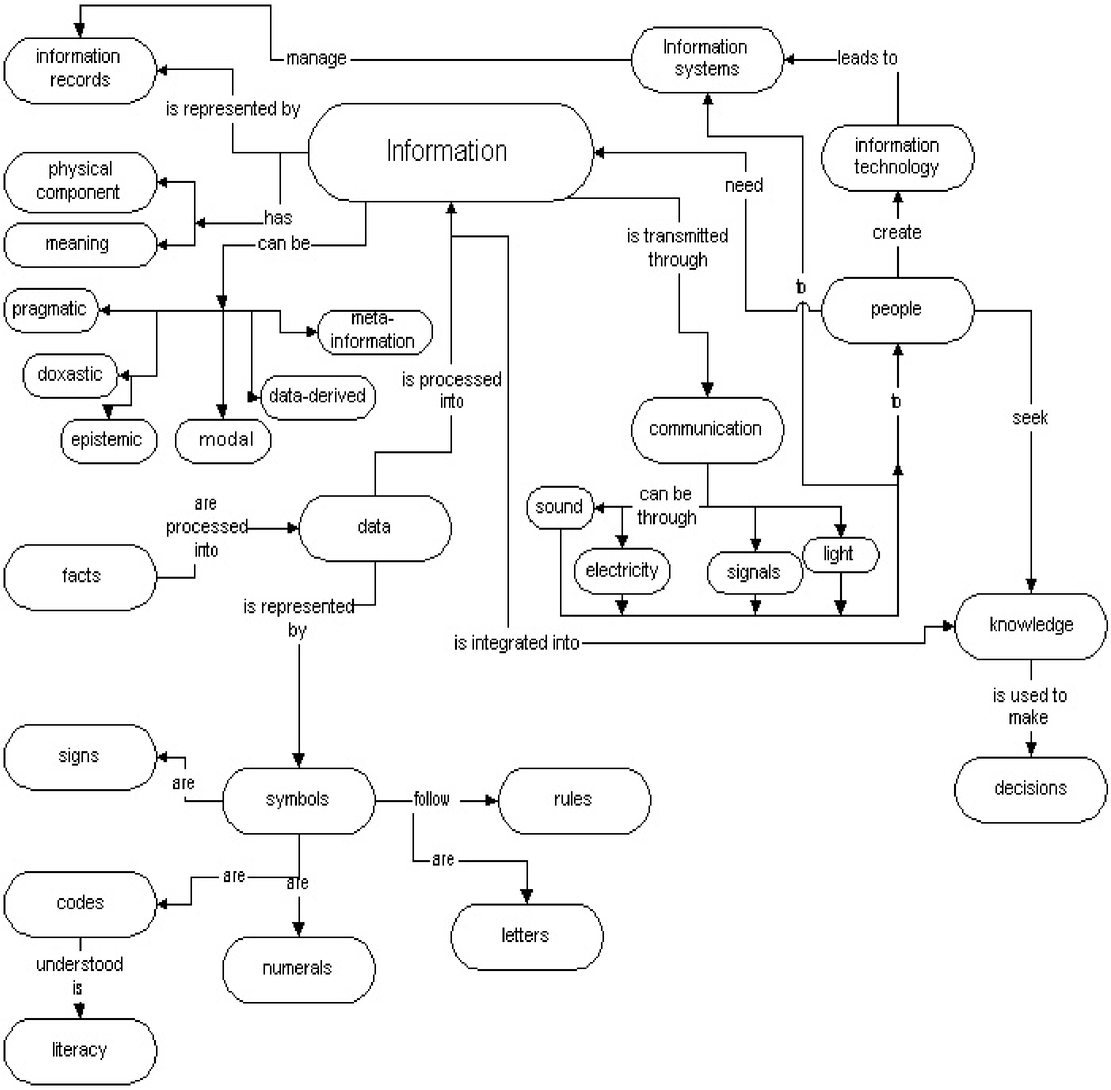

Figure 3.1: Information concept map

Source: Developed from example concept map at http:/www.answers.com/topic/concept-map (accessed 05.01.2011)

The concept map indicates that the main concepts linked to information are data, communication, knowledge, information systems and people. It also reveals that information is gained from the processing of data and that information may be transmitted via communication to other entities. Such communication may be conducted between two or more persons, between a person and an information system (e.g. computer), between an information system and persons or between two or more information systems.

Communication itself requires an information source, a transmitter, a receiver, a destination and a medium or channel through which to transmit information. This principle was established as early as 1948 by CE Shannon (Shannon, 1948:2–3).

Information may be integrated into a body of knowledge to create new knowledge. However, this integration process requires prior knowledge in order to be able to recognise the information content and to process the new information (Boisot & Canals, 2004:1–5).

Boisot andCanals (2004:1–5) contend that data is something that may be made public, but that only those who hold a "key" (or prior knowledge) are able to extract information and, thus, further meaning from the bare data. They also maintain that information is not equal to knowledge. This fact may be proven through the use of encryption. Although encrypted information may appear normal and may be understood in the sense in which it appears, it is only the entity that possesses the key to the encryption algorithm that will be able to extract the actual information transmitted. In addition, this information will be understood only if prior knowledge exists which is able to contextualise the information extracted correctly.

Stenmark (2002:2) describes information in the following ways:

- Facts organised to describe a situation or condition,
- A flow of meaningful messages
- Data with meaning
- Data with relevance and purpose
- A message meant to change the receiver's perception
- Text that answers the questions who, when ,what and where
- Data vested with meaning

These descriptions confirm that information is derived from the processing of data as well as from ascribing meaning to the information so derived.

It may be concluded from the above descriptions of information that information is not merely a physical or a technical quantity which may be described in terms of mathematical theory, but that it also has semantic, semiotic, pragmatic and etymological dimensions. Accordingly, information spans a wide horizon of disciplines. These will be explored in the following sections after a standard definition for information has been provided.

3.2.2 The standard definition of information (SDI)

According to Floridi (2005:353; 2011:5) and Primiero (2008:115), most analyses of information have supported a definition to the effect that information is equal to *data + meaning.* However, through rigorous analysis, Floridi (2005:353; 2011:5) proposes that this definition is insufficient to be applied within an information theoretical epistemology.

Primerio (2008:115–116), Floridi (2011:5–6)arrive at a more rigorous formulation that asserts that information may form part of the popular '*DOS*' (declarative, objective and semantic) concept only, and if and only if a symbol σ satisfies the following four conditions (Primerio, 2008:115–116; Floridi, 2011:5–6):

1. σ consists of *n data* (d), for $n \geq 1$
2. The data are *well-formed* (wfd)
3. The wfd are *meaningful* (mwfd = δ)
4. The δ are truthful

The first requirement indicates that it is not possible for *information to be dataless*, but it does not specify which types of δ constitute information. Floridi (2011:6) contends that there are four types of data, namely:

(1) *Primary data*. These data constitute the basic data which may be found in databases and which consists of either simple arrays of data, or the contents of a book. They are the data an information management system is generally designed to convey to the user;

(2) *Metadata*. These are secondary indications about the nature of the primary data and include essential properties of the primary data, such as location, format, updating, availability, and copyright restriction etc;

(3) *Operational data*. These are data unique to the usage of the primary data itself as well as the operation of the entire data system.

(4) *Derivative data*. This refers tothe data that may be extracted from (1) – (3), whenever these data are used as sources, that is, in search of patterns.

Floridi (2011:10) argues that it is not necessary for all data to be present simultaneously. In the special case in which there are no primary data available, this does not mean that, in fact, no primary data were embedded in the information. A negative answer, that is an empty search query, or silence as an answer, may still be interpreted as primary data which arebeing provided through explicit negative data.

The second condition requires data to be well-formed representations of the information required in a specific format, thus tying a specific format to data in order to be able to interpret the data as information.

The third condition requires data to be meaningful. Floridi (2011:6) emphasises that it is essential that data comply with the semantics of the chosen system, code or language in question. Semantic information, however, is not necessarily linguistic, but may also occur in terms of illustrations which are to be visually meaningful to the reader.

According to Floridi (2005:355–365), well-formed and meaningful data may still be of poor quality and such data can be imprecise, incorrect or inaccurate. Such data, if not truthful, may constitute misinformation only. However, misinformation, according to Floridi (2005:367), does not constitute information in any way. He, thus, considers this condition as vitally important if data are to become information. This view is also supported by Sequoiah-Grayson (2007:331–344).

However, as regards the information which is used in cognitive and computer science, Scarantino and Piccinini (2010:313) and also in a more general sense, Allo

(2007:331–344) considers false information to represent information. This, thus, implies that it is not necessary that the truth condition, as detailed above, be met. However, Allo (2007:331–344) adds that false information may never act as the stepping stone to the knowledge that epistemological theorising requires.

3.3 INFORMATION AS AN INTERDISCIPLINARY CONCEPT

3.3.1 Introduction

As shown in the previous section, information is not a straightforward concept, and no single definition exists that is able to describe the concept of information fully. Instead, the concept of information is always portrayed in terms of the particular field of study in which it is discussed (Floridi, 2003:1). For example, the natural sciences consider the physical component of information only, whichmay be used to describe the content of information as well as the information transfer rate mathematically. Nevertheless, despite the fact that such knowledge may be extremely useful in the telecommunications field, it says almost nothing about the semantics of information. It is also of particular significance fact that information has meaning and that this meaning must be absorbed, interpreted and transferred.

In another sense, information may be studied as part of linguistics, especially semiotics, which deals with the study of signs and symbols within the context of culture and communication, cognition and ecological interaction. In order to provide a satisfactory representation of the concept of information, as well as a more complete approximation of the term *information*, an object of this study, the different theories and schools of thought as regards information will be briefly discussed in the following sections.

3.3.2 Information within the natural sciences context

As regards the natural sciences, the concept of information has been governed by CE Shannon’s definition of information and communication. CE Shannon published his paper “A mathematical theory of communication” in 1948 at the Bell

Labs. In this paper, he provides an exact mathematical definition of the concept of information (Adriaans, Van Benthem, Gabbay, Thagard, & Woods, 2008:171).

Shannon's theory is based on the fact that information, in the form of messages and chosen from a finite set of possible messages, may be transmitted from a sender to a receiver through a defined channel (see figure 3.2). Denoting the probability that a sign *i* from a finite alphabet is transmitted with the probability *p(i)*, then the information content when receiving sign *i* is

$$IC(i) = -ld(p(i)).$$

The information content*IC(i)* of a sign is reversely proportional to the logarithm of the probability of transmitting sign *i*. The quantity ld in the above equation denotes the logarithm to the base 2, which results in information being measured in bits (binary digits) (Reucher, 2006:5).

However, the statistical choice of a specific symbol from a finite alphabet may also be described by the term uncertainty. This means that, while the receiver of a communication system − as depicted in figure 3.2 − is waiting to accept the next sign, the receiverwill be uncertain which sign the sender will actually produce (Schneider, 2005:2–3). However, once the symbol appears, it is known and the uncertainty decreases and, thus, information will have been received. Information may, therefore, be expressed as a decrease in uncertainty. Shannon's theory takes into account the possible different probabilities with which the individual symbols of the finite alphabet appear in messages, thus resulting in different uncertainties as regards the symbols being sent. Shannon arrives at the following formula for uncertainty (Shannon, 1948:11, Adriaans et al., 2008:176):

$$H = \sum_{i=1}^{M} P_i \log_2 P_i \quad (bits\ per\ symbol)$$

This formula makes it possible to measure the amount of information transferred,with this measurement being expressed in number of bits per symbol or message. This number represents the decrease in uncertainty which results from the receipt of this symbol or message.

Another important development in Shannon's work concerns the transmission of information through a noisy channel with the noise in a channel further increasing the uncertainty with which a particular symbol is received. This uncertainty continues to exist after the symbol has been received. Denoting the uncertainty before the transmission with H_{before} and the uncertainty after the receipt of the symbol with H_{after}, it follows that the rate of transmission, R, equals

$$R = H_{before} - H_{after}$$

In terms of this theory, the transmission rate will drop if noise is present in the transmission channel. However, without noise, the uncertainty after the transmission of a symbol will fall away, and the transmission rate will equal the uncertainty that existed before the transmission of the symbol.

The above formulae deal with the possibility of measuring both information and information transfer or flow. Accordingly, this theory may have a direct impact on this research study and will, thus, be revisited in a later chapter.

Shannon's theory of information and his treatment of information as a decrease in uncertainty have provided a satisfactory measure of the physical transmission of symbols over a communication channel. In view of the fact that communicated information always has a physical dimension, this model is relevant, although the physical part is only a carrier for what is *meaningful*, and this, in turn, lacks a satisfactory theoretical basis (Reeker & Jones, 2002:5). Gernert (2006:145) argues that Shannon and Weaver (1949) had clearly delineated the limitations of their theory by stating that the proposed measure of information does not take the meaning and usage of the message into account.

According to Reeker andJones (2002:5), information becomes meaningful information only, also often referred to as *semantic information*, once the transmitted symbols or words, etc. have been interpreted. This interpretation process depends largely on conventions, sensory capabilities, experience, language, adopted standards and other personal traits. The following sections will discuss the term information in a human−social context.

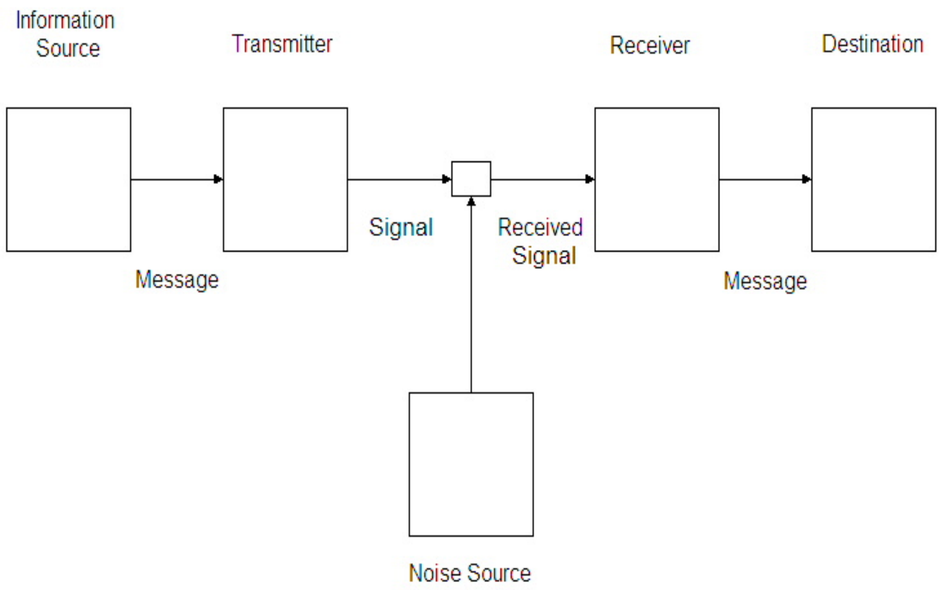

Figure 3.2: Schematic diagram of a general communication system

Source: http://www.tnt.uni-hannover.de/js/edu/vorlesungen/InfoTheor/download /shannon1948.pdf (Shannon, 1948:2)

3.3.3 Information as a human−social concept

3.3.3.1 Information in a semiotic context

Semioticsmay generally be characterised as the science of symbols and systems of symbol with the production of symbols, the structure of symbols, and the cognition of symbols being the focus of this science. Furthermore, semiotics also deals with communication and culture, processes of cognition and orientation and interaction between living forms (Zimmermann, 2004:705–710).

Beim Graben (2006:170) and Patokorpi (2011:43) argue that the classic information theory established by Shannon and Weaver, although highly useful and appropriate to the telecommunications field, does not take into accounteither the content and the value or the meaning or quality of information. According to them, information is required in order to change the status of knowledge in an agent. In most cases it is not possible to extricate this purpose from the possibility and ability on the part of the receiver to act upon the change in knowledge.

As a general rule, symbols may be assigned the following three components, namely, a structural component (morphology/syntax), a meaning of the symbol, and pragmatic component (purpose of action in reality context).

This partitioning of symbols into three components, as proposed by the semiotic, may also be applied to natural speech systems. In this context of natural speech systems, verbal utterances may mean “devotion” (comfort), they may be used simply to“air some feelings”orthey may be considered as (direct or indirect) an order for action (“Please close the window”) (Zimmermann, 2004:705–710).

During the communication process, non-verbal symbols (if it is possible to recognise them) are as important as the verbal information itself.

In terms of information technology the core question for the linguistic science is the following: “Which methods are available, or must be developed,in order to process and make accessible to an information retrieval system, the information which is available in the coding of a natural language, so as to ensure that all relevant, and only relevant, sources of information are returned for a given problem?”.

This problem is also manifested in the natural languages, in terms of which verbal utterances are fixed in words or sentences. As regards electronic dictionaries, it is essential that basic word forms and derivatives, word agglomerations and sentence structures be recognised.

The semantic or meaning of words is also of interest in linguistics. The semantics of information will, thus, be discussed in the following section.

3.3.3.2 The semantics of information

In general, semantics involves the study of meaning. As such, semantics is opposed to syntax with semantics referring to what something means, while syntax represents the formal structure in terms of which something is expressed (Dodig-Crnkovic, 2005:2). According to Dodig-Crnkovic (2005:2), semantics, thus, concerns the relation between the expression of language and its meaning. In terms of information, objective semantic information is assumed to have a declarative or factual value, that is, it is supposed to be correctly qualifiable alethically.

The main issue in semantic information pivots on the requirement that information be truthful. Floridi (2005:366) argues that well-formed and meaningful data may still be of poor quality. However, even if data is imprecise, incorrect or inaccurate,it will still constitute data but, if the data is not truthful, then it will constitute misinformation only. Floridi (2005:366) further emphasises that, although the word "information" may be used as a synecdoche to refer to both "information" and "misinformation", exchanging false information about a state x, in actual fact, does not denote the exchange of any information at all, but rather the exchange of meaningful and well-formed data with semantic content only. As a result, it is essential that any definition of information should include a necessary truth-condition (Dodig-Crnkovic, 2005:6). According to Dodig-Crnkovic (2005:6), Floridi's quantitative theory of *strongly semantic information* (semantic information with a truth condition) is based on truth-values as opposed to the classic quantitative theory of *weakly semantic information* of Bar-Hillel and Carnap (D'Alfonso, 2011:66). Although the classic theory assumes that truth-values supervene on information, this principle has been found to be too weak and generates the well-known Bar-Hillel and Carnap paradox (D'Alfonso, 2011:65).

This paradox infers that the sentence "A triangle has four sides" contains more semantic information than the contingently true statement that "The earth has only one moon".

As a solution, Floridi’s concept of strongly semantic information contains truth from the outset and, thus,both avoids the paradox and is consistent with the common usage of the word information.

However, a dilemma becomes apparentin deciding between the two definitions of information with the weaker definition accepting meaningful data as information, and the stronger one claiming that information must be true in order to qualify as information (Dodig-Crnkovic, 2005:6–7).

However, Dodig-Crnkovic (2005:6–7) argues that meaningful data need not necessarily be true in order to constitute information as partially true information, or even completely false information,may lead to an outcome which is both adequate and relevant for inquiry. If truthlikeliness admits degrees, then the history of enquiry is one of steady progress towards the truth. Accordingly, in that sense, models may generate information for improving our knowledge about the empirical world.

3.3.3.3 Other diverse views and theories on information

3.3.3.3.1 Fred Dretske’s naturalist theory of information (Dretske, 1983)

According to Truyen (2002:6), Fred Dretske (1983), in “Knowledge and Flow of Information”, sets out a novel theory of knowledge based on Shannon’s theory of communication. Truyen (2002:6) reports that Dretske restates the technical point about equivocation in defining the relation between the information on the sender’s side − I(s) − and the information on the receiver’s side − I(r). In fact, a reduction of possibilities takes place when a message is composed while the decision mechanism on the sender’s side may alter the probability that a particular token will be transmitted. For example, suppose a choice of eight names exists but, if a certain name is to be transmitted, this name is exchanged for another one. This name will then appear twice as likely as any other name. In Dretske’s view (Adriaans et al., 2008:33–37), there is a difference between I(s) and I(r) and this difference may be named $I_s(r)$. There are two ways of defining $I_s(r)$:

$$I_s(r) = I(r) – noise$$
$$I_s(r) = I(s) – equivocation$$

In the first formula the information transmitted from s to r is defined as the information at r without noise, and in the second formula as the information without the part that is not transmitted to r. It would, thus, appear that noise and equivocation are the same on the receiver's side. However, on the sender's side, it is not clear whether the processes are relevant to communication theory. Truyen (2002:7) points out that Shannon's theory involved the transmission of signals and the transfer of data, irrespective of any decision made on the sender's side.

Dretske (1981:1-288) developed other principles regarding the amount of information generated by a certain state of affairs and the amount of information carried by a particular signal as well as the informational content of a signal. However, according to Truyen (2002:9), these definitions may be used for comparative purposes, but are otherwise too awkward to be used in practice. He also argues that, unlike Dretske, it is not possible to make abstractions about the manner of processing data on the part of the receiver in order to obtain information. However, different information will come about as a result of the receiver's prior knowledge. Accordingly, information is not a given, but is created in the communication process, during which agents, who have information needs, process data accordingly.

3.3.3.3.2 The situation theory of information

In terms of situation theory, there is recognition accorded to the partiality of information as a result of the finite, *situated* nature of the agent (human, animal, machine) with limited cognitive resources. Any agent must employ necessarily limited information extracted from the environment in order to reason and communicate (Devlin & Rosenberg, 2006:8).

According to Devlin and Rosenberg (2006:8), situation theory takes its name from the mathematical device which is introduced in order to take into account that partiality of information. A situation may be conceived of as a limited part of reality. Such parts of reality may beeither spatio-temporal in nature, or else thought of as fictional worlds, contexts of utterances, problem domains, mathematical structures or databases. In addition, there is a distinction made between individuals in terms of which situations possess structure that plays an important role in the theory, whereas individuals do not.

A fundamental assumption underlying the situation-theoretic approach to information is the assumption that information is not intrinsic to any signal or to any object or configuration of objects in the world; but that information arises from the interactions of agents with their environment (Devlin & Rosenberg, 2006:10).

According to this approach, it is not the elements of language only that function as carriers of meaning but, as in the case of the real things of the world, non-linguistic signs may also convey meaning.

3.3.3.3.3 Bar-Hillel and Carnap's theory of semantic information (D'Alfonso, 2011:63)

This particular theory of semantic information measurement is of interest to this research study as the theory provides measures for information. The semantic information theory was influenced by the work of Bar-Hillel and Carnap, who developed a definition for the information content of a statement in a given language in terms of the possible states this information content rules out. The basic notion is that the more possibilities (possible states of affairs) a sentence rules out, the more information it contains, that is, information is the elimination of uncertainty. The information content of a statement is, thus, relative to a language (D'Alfonso, 2011:63; Dodig-Crnkovic, 2005:5).

According to Dodig-Crnkovic (2005:5), Bar-Hillel and Carnap suggested two measures of information. The first such measure of the information content (*quantity of semantic information*) of a statement S is termed the *content measure,* cont(S), and it may be defined as the complement of the a priori probability of the state of affairs expressed by S:

$$\text{cont}(S) = 1 - \text{prob}(S).$$

However, the content measure is not additive and violates other natural intuitions about information. Another measure, termed the *information measure (or informativeness)*, inf(S) in bits is given by:

$$\mathrm{inf}(S) = \log_2(1/(1-\mathrm{cont}(S))) = -\log_2 \mathrm{prob}(S)$$

prob(S) again is the probability of the state of affairs expressed by S, and not the probability of ‘S’ in some communication channel. According to Bar-Hillel and Carnap, cont(S) measures the substantive information content of a sentence S, whereas inf(S) measures the surprise value, or the unexpectedness, of a sentence H.

However, Dodig-Crnkovic (2005:5) emphasises that the information measure violates a common intuition that the information of S, given by an evidence E, must be less than or equal to the absolute information of S. In fact, according to the two measures above, in a case in which evidence E is negatively relevant to statement S, the information S relative to an evidence E is higher than the absolute information of S. This paradox has already been touched upon in section 3.3.3.2 and the solution shown. The main intention of this section is, thus, to introduce the measurements of information.

3.3.4 Information as a value concept

Weissinger (2005:6) contends that some writers are in agreement that, as a concept, information has an evaluative sense, even if they differ on exactly what this evaluative sense is. He contrasts the factual with its non-factual sense, with the latter being described as attitudinal and understood in terms of a thing’s perceived benefit or harmfulness to an individual. Accordingly, the values an individual holds are, in fact, attitudinal states and it is these attitudinal statesthat cause one’s engagement in either preservation or acquisition activities.

In a more idealistic sense, Weissinger (2005: 6) explains that information may be regarded as the very structure of thought and, thus, it is possible to define information as both the content of thoughts and the standard by which such thought is evaluated. Valuation is, therefore, understood as a person's ability to assess a thing's likeness to a standard critically in order to determine its purpose and whether it satisfies that purpose.

Hefurther indicates that it is possible to develop a normative system that is able to rate certain types of information on a series of scales of "betterness" or "worseness", as determined by the individual, organisation, society, or culture. Furthermore, information has instrumental value, and is usually communicated in an organised or formalised pattern to increase its potential utility. Weissinger (2005:7) argues that, since the value of information is instrumental, utility is the major criterion of the social value of information. Moreover, information may be good for any number of purposes, for example, as intelligence, news, a message, recreation, a joke, a narrative, knowledge, and so forth because the subjective settings of purpose may differ.

Weissinger (2005:7) also points out that other writers have produced a list of attitudinal states that exceed the simple states mentioned above. These values listed range from honesty, love, generosity, creativity and happiness to freedom. On reflection, it may be recognised that these values belong to different groups of virtues which are, in fact, character traits and which overcome certain passions and which obscure judgement. Creativity is a form of technical goodness. A creative person not only has the ability to do well but also, performs the kind of activity associated with excellence. Happiness is a form of hedonic good, associated with pleasure and notions such as enjoyment.

In conclusion, meaningful information embedded in, inter alia, proverbs and oral narratives, has value because of both its purpose and its benefit.

3.3.5 Conclusion

The preceding sections attempted to provide a composite overview of the concept of information. It was demonstrated that information theory has its roots in the natural sciences approach, as demarcated by CE Shannon. Shannon's information theory is based on the purely physical character of information transferred in a communication channel and is based mainly on the reduction of uncertainty, once symbols or data have been sent.

However, this view does not account for the meaning that is attached to, nor the structure of, the message or data, nor does it account for whether or not the message or data are actually true.

In general, writers agree that information is a consequence of meaningful data which is in the process of being interpreted by a knowledgeable person.

Depending on the specific theory, that is,the weakly semantic or the strongly semantic theory of information, writers' opinions range from truth not being a requirement to alethic neutrality being a precondition for the formation of information from data.

However, as regards this research study thetheories of information discussed above must be viewed in the context of a real supply chain. The question then arises as to the way in which the information theories may be interpreted and how they influence this research.

The information flowing within the company of a supply chain and between the supply chain members was discussed in detail in chapter 2. In answering the question posed above, it will be assumed that, in a particular case, the completion data about a manufacturing order has become available. This data may have become accessible either by word of mouth, or through a computerised information system. The data indicated that the order in question would be delayed and would only be completed one month later than originally envisaged. Based on this data, a knowledgeable order administrator in the specific manufacturing company of the supply chain would become aware that this manufacturing order was linked to a specific customer. In view of the fact that he is acquainted with this customer's preferences, he would now be in a position to interpret the customer's reaction to the delay and to make decisions regarding the future treatment of the order. It is, thus, clear that this information should be true, otherwise future decisions and consequences may prove disadvantageous. In this sense, the extracted information is also valuable, specifically as regards both the customer and the order administrator.

It is essential that this research study consider all elements of information and that a measurement of information flow in terms of physical characteristics only will not suffice.

However, the simultaneous interpretation of all the theories of information, as detailed above,would be difficult and unyielding. Accordingly, the following sections will deal with categorising the concept of information into more convenient and manageable objects.

3.4 THE CATEGORISATION OF INFORMATION

3.4.1 Introduction

If it were possible simply to express all the information that is important in characterising a system's behaviour, including a supply chain, in bits, this would provide a numerical value that could be used to measure and control system performance and to effect improvements (Reeker & Jones, 2002:4). Reeker and Jones (2002:4) argue that in a purely physical system numerical measures of energy output alone may be sufficient to characterise the overall system and to measure energy efficiency.

However, as shown in the previous sections, information does not consist of a physical component only and, indeed, includes semantic, semiotic and epistemic elements. Without these elements it would not be possible to convey information successfully. The elements necessary in transferring information were specifically elaborated on in section 3.2.2 in the discussion on the concept of the standard definition of information.

Accordingly, Reeker andJones (2002:5–7) propose a different categorisation of information in terms of which information is arranged into a *physical component* as well as a *meaningcomponent.*In addition, Truyen (2002:12) offers another proposal for characterising information in terms of a layered information model. On the other hand, Beim Graben (2006:170–175) and Gernert (2006:144) refer to syntactic, semantic and pragmatic information categories, which may, however, be related to the above categorisations.

However, information has already been categorised in chapter one, in terms of the epistemology of information.

In order to provide an understanding of the way in which information may best be categorised, the different categories applicable to information will be discussed in more detail in the following sections.

3.4.2 Information categorisation according to a physical and a meaning component

Reeker andJones (2002:5–7) proposed a classification of information,according to its dimensions, into potential and mediate information. This will be discussed in the following sections.

3.4.2.1 Potential information

Reeker andJones (2002:5–7) are of the opinion that Shannon's information yielded a highly satisfactory measure of the physical transmission of symbols across a communication channel. According to them, the model is relevant as communicated information always has a physical dimension despite the fact that this physical dimension is a carrier only for what is actually meaningful. The physical information that is sent out is not meaningful until it is interpreted at the point at which it reaches the recipient. However, before that time, it is nothing more than data, or *potential information*.

3.4.2.2 Mediate Information

As regards their categorisation of information, Reeker andJones (2002:5–7) contend that the meaningful part of information (often referred to as *semantic content* or *knowledge*) requires a theoretical construct, which they term *mediate* *information.* Themediate information directs the process in terms of which the potential information becomes meaningful. This mediate information,which is required to convert potential information into meaningful information, is partially a set of conventions that were used by the speaker in the belief that the listener would interpret the information using the same conventions. Such conventions are either based on sensory capabilities or consist of experiences with the world and the language, or areadopted from standards, informal or formal.

3.4.2.3 Meaningful Information

According to Reeker and Jones (2002:5–7), meaningful information consists of two parts, namely, potential information and mediate information. As outlined above, mediate information is required to attach meaning to potential information. The transmission of meaningful information, as shown in the case of a simple linguistic utterance and as depicted in figure 1.2, requires not only that a certain amount of potential information be transmitted, but it also requires a “hidden channel” of mediate information that is previously known to both the sender and the receiver. This may be compared with the scenario where a speaker had encrypted something and sent a message of which the key was the mediate information sent by another channel.

3.4.3 Layered information model

Truyen (2002:13–15) approaches the concept of information from an information systems and information retrieval point of view. In his proposal, he contends that the information contained in, for example, documents must be reformatted in order to adapt it to machine use.

Accordingly, binding sections, which are often included in exposés, do not count as vital information, but must be translated into tools that the user may apply to navigate through the information stored. Truyen and his colleagues have developed a layered information model for the analysis of the content of documents before translating the content into machine-stored information. This model is depicted in figure 3.3.

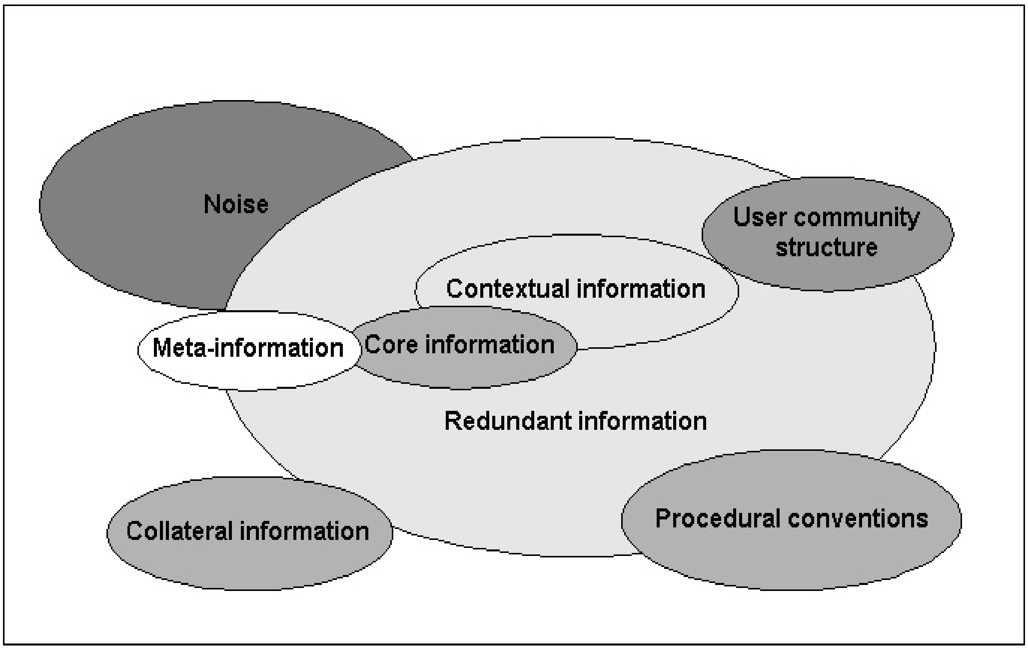

Figure 3.3: Layered information model

Source: Truyen (2002:13)

In his information model,Truyen (2002:14–15) distinguishes between the different information categories as follows:

- *Core information*. This type of information is often restyled into a text in terms of which verbs tend to be replaced by concepts, names, and attributes. Core information represents the pure content of the information itself.

- *Redundant information*. Redundant information refers to a trivial type of additional information, which may also be considered as prior knowledge about a certain subject matter.

- *Contextual information*. This information entails additional information, unique to the core information, which may consist of, for example, chronological background information relating toa certain period of time appearing in the core information.

- *User community*. There is often, embedded in the core information, information about the community that uses the specific core information. Accordingly, information for scholars may be represented and stored differently as compared to information relevant to books.

- *Procedural information*. Many publications also include some indications on the way in which the document should be used. This information is referred as procedural information. In the context of a computer user interface, this information is separated from the “pure content” in order to enhance its usability for different users with, possibly, different skills.

- *Meta information*. This information provides information about a document or publication itself. It comprises information such as, inter alia, the originator, the publisher, the purpose of the document, and its relation to other publications.

- *Collateral information*. Collateral information includes information, which may possibly have an association with other information chains, that is, DNA research and archaeology. Initially this type of information does not have any importance in relation to the core information, as this type of information is not necessarily known. It may, however, become incremental information over time.

- *Noise*. Noise originates from superfluous information and functionality in terms of computer interfaces. A specific type of noise is created when an interface requires more steps to achieve a certain task than to reach decisions. This, in turn, leads to the generation of superfluous information during each unnecessary step.

According to Truyen (2002:16), the above types of information are, intertwined in the total information which is passed between human or non-human agents. This information requires processing not only in human minds, but also in animal brains, plants, and robots and computers. However, although information, or even, in simpler terms, data, may reside in different storages, i.e., brains, books, CDs and ROMs, the data or information will become information again and again, only with each access, each use of it and each query made to it. Accordingly, Truyen (2002:16) concludes that it is essential that a genuine information theory consider information both as input and as the result of processing by knowledgeable agents who continuously try to adjust their beliefs to changing situations.

3.4.4 Conclusion

Two main categorisation models were discussed in the above sections.Reeker andJones (2002:5–7) clearly differentiate between a physical and a mediate component of information. The physical component may be transferred by various means, i.e., sound waves, whereas mediate information comprises a "key" which enables the encrypting and decrypting of the actual information transferred, and which directs the process of interpretation of the information sent through the communication channel.

Truyen's model (2002:13), as depicted in figure 3.3 above,sorts information into categories based on their relation to the core message to be transferred. His model is relevant specifically to information systems that process information digitally, and in respect of which the storage and renewed representation of information to a different user at a different knowledge level are of particular concern.

Both models are relevant to this research study, which is principally concerned with the measurement of the efficiency of the information flow in supply chains and member organisations. As outlined in the example discussed in section 3.3.5, it is not possible for this study to focus on the physical part of information and its transfer only and the study must also take into account the totality of information transferred, including its meaning and value.[1] In this study, the transfer process is

[1] This study focuses on information flow. However, there will be no information flow if information is not transferred from one party to another. Information flow and information transfer are, thus, closely linked and, therefore, considered to be almost synonymous.

of particular importance as it encompasses information transfer and, thus, the information flow between persons, persons and information systems and between information systems. In order to retain a relevant, but simplistic, view of information transfer or flow, information will be considered as a single integrated concept, although this includes the effect of the information on its recipient. The basic model, as proposed by Reeker andJones (2002:5–7),is the most appropriate to this study, as it takes into account information which is being sent through a single channel and limits the unnecessary increase of variables to be observed during the research.

The following sections will consider the flow or transfer of information and related concepts such as communication and knowledge transfer in more detail.

3.5 INFORMATION FLOW AND COMMUNICATION

3.5.1 Introduction

Organisations are often considered to be part of multi-company, multi-echelon networks, such as supply chains. SCM aims at the integrated control of such networks and this, may, in turn provide significant benefits. The utilisation of information technology is considered to be an imperative requirement for managing these networks, and has also been associated with significant supply chain improvements (Auramo, Inkiläinen, Kauremaa, Kemppainen, Kärkkäinen, Laukkanen, Sarpola,& Tanskanen, 2005:2).

Wu et al. (2004:1) emphasise that information flows are between persons and, in social organisations,such information flows are important to issues such as productivity, innovation and, generally, in acquiring new and useful ideas. They also contend that the way in which information spreads determines the speed with which individuals are able to act and plan their future activities.

The flow of information is,thus, extremely important to the success of a supply chain. However, as mentioned above, information technology plays an important role in SCM and, therefore, the use of information technology requires an interaction with humans.

As regards SCM, it is possible to distinguish three distinct mechanisms of information flow or transfer (Mizuta & Nakamura, 2005:2):

- Information flow between persons
- Information flow between persons and information systems and vice versa
- Information flow between information systems

In order to understand the mechanisms governing the transfer of information or communication and the closely related concept of knowledge transfer, these concepts will be discussed in more detail in the following sections.

3.5.2 Information flow or transfer and communication

3.5.2.1 Basic concepts

People seek and use information constantly as part of their daily lives with information relating to work, leisure, health, money, family and other categories being sought from a vast array of sources, including digital media (Johnstone et al., 2004:1). The use of digital media is becoming ubiquitous, especially in offices. Nevertheless, digital information is not the only source of information. As indicated by Mizuta andNakamura (2005:2), person–to–person and computer mediated communication function as important information transfer mechanisms in organisations. A more in-depth discussion of the individual modes of communications will be contained in the following sections.

3.5.2.2 Person-to-person communication

In modern society, in which the use, creation and dissemination of information are vitally important activities, a person’s communication competence has acquired a new meaning in the information and knowledge society and the effective use of information has become a tool both for increasing competition and for the control of knowledge and resources. New information, which creates new knowledge, is acquired through communication only (Chreptavičiene, 2004:2).

According to Ekman andLankoski (2003:4), face-to-face communication relies heavily on factors other than primary messages to transmit meaning, for example people use body language and tone of voice to convey meaning. Caplan (2001:3) suggests that interpersonal communication is a rule-governed form of interaction (e.g. turn-taking, conversational norms, facial expressions). In his view, it is incumbent on participants to attend to both verbal and non-verbal cues constantly, as well as to the content of the messages. Interpersonal communication involves messages designed for some particular other and, thus, participants in such communication are engaged in rule-governed, highly involved, and reciprocal message processes.

The anatomy of the communication process has been described in chapter 1 and is depicted again in figure 3.4 below. This anatomy of the communication process is founded on both the basic theory of communication of CE Shannon as well as the expanded view of Reeker andJones (2002:10), who include the mediate portion of information as regards attaching meaning to the message sent.

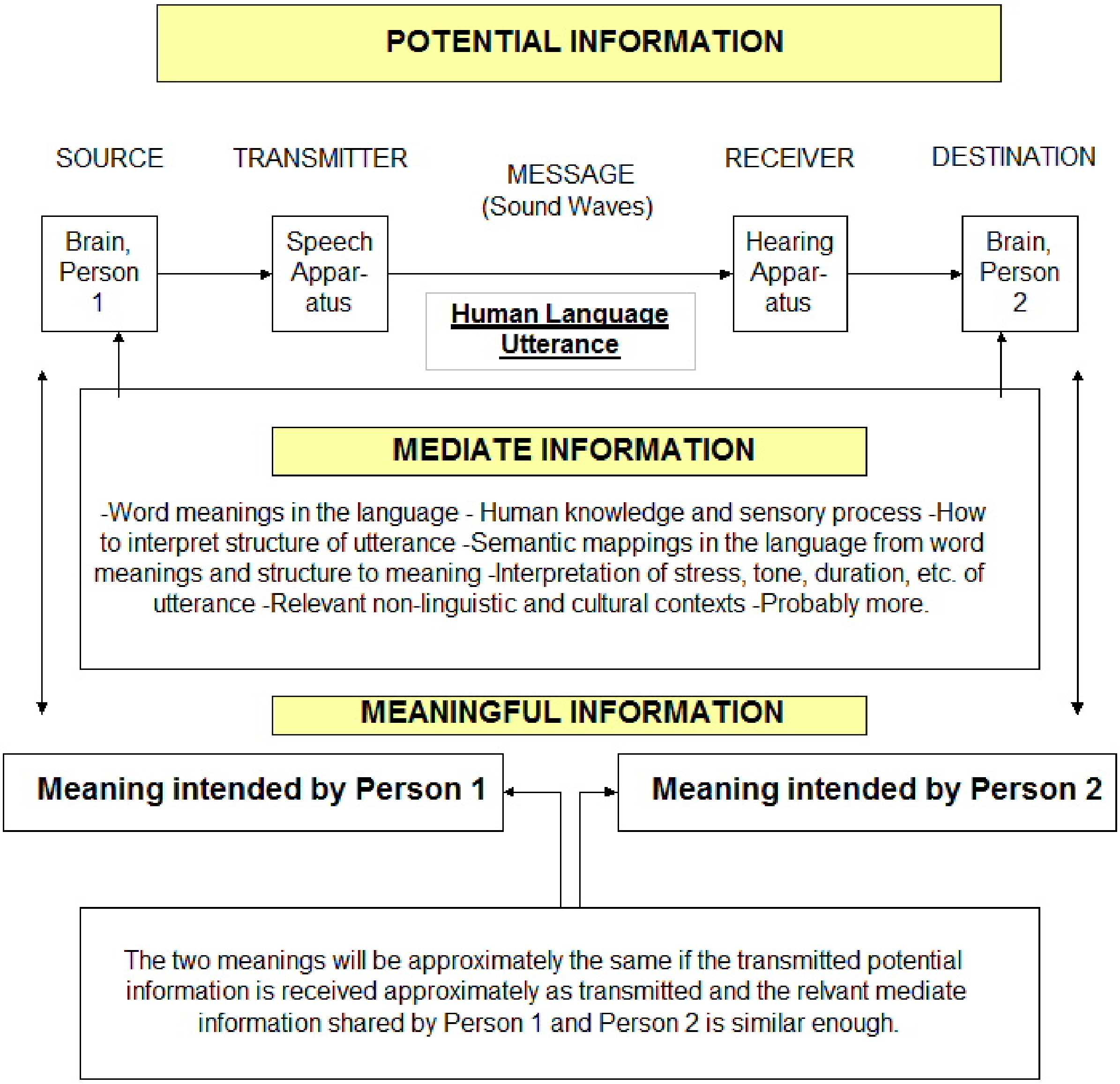

Figure 3.4: The conveyance of knowledge process

Source: Reeker and Jones (2002:10)

3.5.2.3 Computer mediated communication (CMC)

Electronic communication and information transfer are enjoying increasing popularity (Avrahami & Hudson, 2006:1). The advent of the Internet, in particular, has meant that computer-mediated communication, described as synchronous and asynchronous communication, using text messages and real-time pictures sent via computer, has increased both the breadth and depth of connectivity between individuals with global communication becoming available by the touch of a button (Grooms, 2003:2). Long distance communication has become a fact of life for an increasing number of persons, and more and more relationships are being formed and maintained online, including supplier-purchaser relationships (Bos, Olson, Gergle, Olson & Wright, 2002:1). According to Bos et al (2002:1), these “at a distance” collaborators have an increasingly varied range of computer-mediated communication tools at their disposal. Piltz (2001:3–6) lists the following basic applications of CMC:

- Electronic messages
- Electronic mail (e-mail)
- Electronic discussion forums
- Computer conferences (text and video)

Bos et al. (2002:1) maintain that CMC offers new possibilities for communication, although it is essential that the communication media be selected carefully, based on the type of communication task envisaged. Nevertheless, it would appear that there are several types of tasks that seem unaffected by the communication media while a few of these types of tasks, particularly those with a high affective component or in terms of which either context or interpersonal trust is extremely important, will be influenced, if not inhibited, by CMC.

The mediated person-to-person(s) communication may be modelled as depicted in figure 3.5.

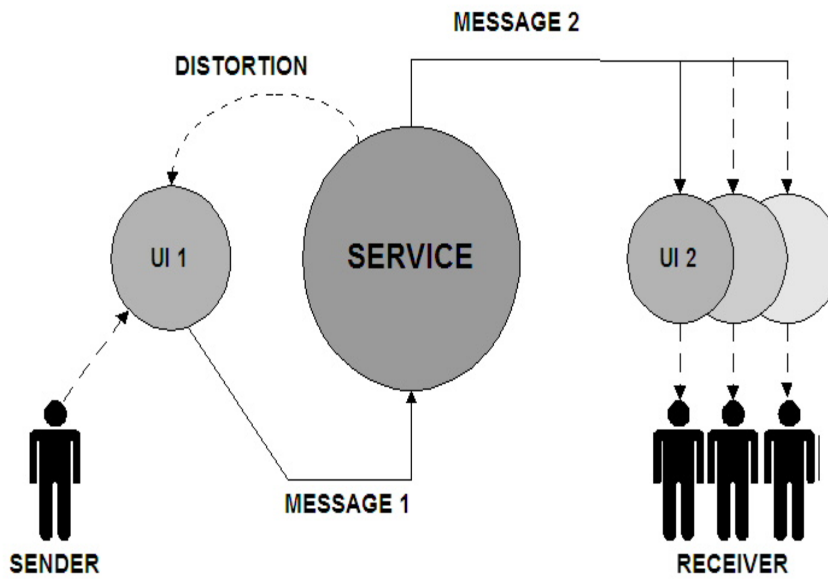

Figure 3.5: Mediated person-to-person(s) communication model
Source: Ekman andLankoski (2003:9)

The modeldepicted above is similar to the communication model presented in figure 3.4, although the model in figure 3.5 has been extended to include the technical structures necessary for the mediation process. This mediated communication model includes both the user interfaces (UI1 and UI2) and the service. According to Piltz (2001:3), the user interfaces of the computer-mediated communication process are represented mainly by keyboards and monitors, to which microphones and cameras may be added with computers providing the service. This excludes mass media such as television.

The main difference between the real person-to-person communication and the mediated communication may be found in the fact that the mediated communication lacks the direct, cognitive perception of the communication partner, as well as the situational, physical and psychological context (Piltz, 2001:3). Ekman andLankoski (2003:4) contend that, in normal person-to-person communication, the sender has full control over what he/she sends and what is received. However, in mediated communication, the message sent is never the same message that has been sent. In figure 3.5, this situation is depicted by the fact that there are two messages, namely, message 1 that is sent to the service and message 2 which is passed on by the system. The distortion influences the translation process from message 1 to message 2, thereby altering the message which has been sent. Such distortion may also appear in user interface 2, thus further influencing the message received. The complexity of user interfaces and services influence the characteristics of the CMC system.

According to Piltz (2001:6–8), the basic characteristics of CMC include the following:

- *Individual and mass communication*

  CMC exhibits elements of both individual and mass communication. Electronic messages and e-mails may be assigned to individual communication, whereas discussion forums and computer conferences may be classified as both individual and mass communication, as they mayeither be public or anonymous and are simultaneously interactive.

- *Written communication*

  With the exception of videoconferences, CMC media, allow written communication only. Accordingly, it is not possible to transfer non-verbal messages as they appear in the direct person-to-person communication. Therefore, the set of signs that may be transmitted with this type of CMC is limited to the standardised character set, as described by ANSI.

- *Asynchrony*

  In face-to-face communication, telephony and video-conferences, both or all the communication partners have to be available at the same time. However, in the case of e-mail and discussion forums, the communication partners are able to read their messages or respond to messages at their leisure, and they do not need to be present simultaneously. The following aspects of face-to-face communication are a result of the asynchrony:

- Individual control: The individual communication partner retains control over the time, length and autonomy of his/her communication.
- Flexibility and ability to reach: This includes the use of different terminals and the ability to read mailboxes from any terminal.
- Turn taking: The continual change in the roles between the communication partners, as in face-to-face communication, is not necessary.
- Speed of message exchange: In face-to-face communication, synchronisation is required between the messages sent during a communication with the speed of the message exchange occurring at the speed of speech. In the case of asynchronous CMC, the speed of the message transfer may be increased to the speed of reading.

- *Storage of communication contents*

The storage of the communication content is a specific characteristic of CMC. In contrast to telephonic or face-to-face communication, e-mails are stored immediately, respective to both the sender and the date of transmission. A similar principle is used in discussion forums, where submissions are archived centrally.

Although not all forms of CMC are, fundamentally, different kinds of communication, there are, however, computer-mediated communication phenomena that do not represent new extensions of ourselves, nor is it possible to classify them in terms of the traditional notions of “mass” and “interpersonal” communication systems (Caplan 2001:1). However, emerging technology is continuously enriching the characteristics and possibilities of CMC and bringing them closer to face-to-face communication and its characteristics.

3.5.2.4 Information system-to-information system communication

Business-to-business (B2B) e-commerce is emerging as a new market with tremendous potential. Organisations are trying to link their services across organisational boundaries in order to trade electronically in goods (Sayal, Casati, Dayal & Shan, 2001:1). However, this form of trading requires communication between information systems and the execution of transactions between the, often heterogeneous, systems of different organisations. In order to achieve successful interoperability between systems, industry standards, which provide guidelines as to the way in which the electronic interaction should be carried out, have been developed. However, when interacting with a trading partner, an organisation must not only be able to send and receive messages and carry out conversation according to a specific standard, but also be capable of coordinating the internal business processes with the external interactions. The alignment of internal and external business processes requires an integrated supply chain in terms of which each supply chain partner has installed a fully integrated ERP and SCM solution, as depicted in figure 3.6 below.

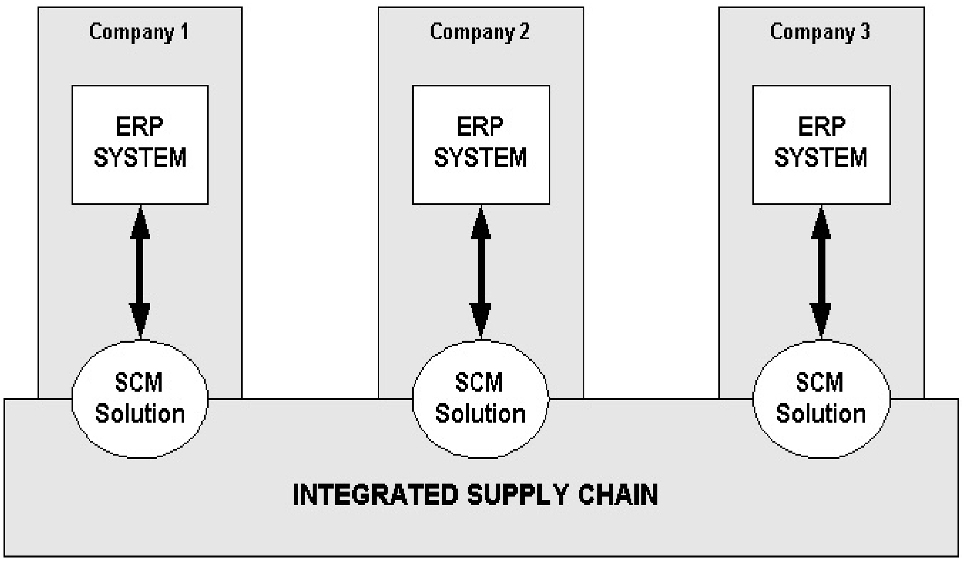

Figure 3.6: Complementary application of ERP and SCM systems in an integrated supply chain

Source: Buxmann, Ahsen, Diaz andWolf (2004:297)

The ERP system provides primarily inbound oriented functions, while the SCM solution focuses on both intra- and inter-organisational processes. However, in many cases, both ERP and SCM systems are integrated into one single system.

However, fully integrated supply chains rarely exist because organisationsoften have legacy systems installed which are interfaced with other, sometimes standalone, SCM and ERP systems, thus preventing full and real-time integration (Inovis, 2007:4).

According to Barchi andTongil (2007:7), advancement in information technology and the acceleration of globalisation have created the problem of supporting the inter-operation of the various data formats and communication protocols used by the different trading partners in business communities. Standard communication protocols and unified data format automate both speed up information transactions and enrich the quality of the information flow. However, as is evident today, these standards are still far from merging into one universal standard; for example, there are countless disparate formats and standards of documentation, spreadsheets, databases, accounting software, and ERP packages in existence (Barchi & Tongil, 2007:7).

However, despite the existence of disparate systems, communication between systems is being used, mainly in the form of electronic data interchange (EDI) and web-based interactions (Zhu, 2004:168–178).

The main standards will be discussed in the following sections:

- *EDI*. EDI refers to the direct electronic transmission, computer to computer, of standard business forms, such as purchase orders, shipping notices, and invoices between two organisations. Within a supply environment, documents are transmitted electronically, thus eliminating the need to generate hardcopies and distribute these hardcopies manually. EDI increases the speed of the information flow, while simultaneously decreasing the potential for data errors

(Burt et al., 2009:185–186). The basic components of EDI include a standard EDI form, a translation capability and a mail service (the network). The translation software translates company-specific database information into the standard EDI document format, which will then be sent by the mail service to a third party provider, responsible for the network, to the receiver. At the receiver, the information transferred is translated into company-compatible information and dealt with appropriately (Swink, Melnyk, Cooper & Hartley, 2011:299). Before the mid-1990s, the high implementation cost of EDI constituted a major barrier to its wide-spread implementation, as EDI required significant investment by organisations in dedicated hardware and specialised software (Monczka et al., 2010:457). The WorldWideWeb, however, is a huge network with standard protocols, allowing for quicker, inexpensive B2B transactions (Burt et al., 2009:186–187).

- *Extensible Markup Language (XML).* XML has evolved over the last several years from the HTML (hypertext markup language), which uses tags that define a Web page's format. In the case of XML, the tags define both the Web page's content and the meaning of the text (Webster, 2008:87). An XML parser interprets the tags according to a schema indicated in the message header. However, unlike EDI, which demands strict compliance with a predefined message length and field order, the information in an XML document may appear and be in whatever order or length the sender desires. Although it would appear that standards regulating the use of XML are nearing resolution, the main issue that may be insurmountable in terms of supply chains, is the willingness to share strategic information among the members of the chain (Burt et al., 2009:198).

- *RosettaNet.RosettaNet Partner Interface Processes® (PIPs®)* define business processes between trading partners. PIPs fit into seven clusters, or groups of core business processes, that represent the backbone of the trading network. Each cluster is broken down into segments − cross-organisational processes involving more than one type of trading partner. Within each segment are individual PIPs. PIPs are specialised, system-to-system, XML-based dialogs. Each PIP specification includes a business document with a interface specificvocabulary, and a business process with the choreography of the message dialog (http://www.rosettanetorg/).

- *BizTalk*. BizTalk is a Microsoft initiative that seeks to provide software and business communities with the necessary resources for learning about and using XML for enterprise application integration (EAI) and B2B document exchange, both within and across enterprises (http://msdn.microsoft.com).

- *Open Applications Group (OAG).* OAG is a consortium comprising many of the prominent stakeholders in the business software and components industry throughout the world. The Open Applications Group is focused on building process-based business standards for eCommerce, Cloud Computing, Service Oriented Architecture (SOA), Web Services, and Enterprise Integration (http://www.oagi.org).

- *ebXML*.ebXML is a joint initiative of the United Nations Centre for Trade Facilitation and Electronic Business (UN/CEFACT) and the Organisation for the Advancement of Structured Information Standards (OASIS). The original project envisioned and delivered five layers of substantive data specification, including XML standards for business processes, core data components, collaboration protocol agreements, messaging and registries and repositories (http://www.ebxml.org/).

- *Object Management Group (OMG).* OMG task forces develop enterprise integration standards for a wide range of technologies, including: Real-time, Embedded and Specialised Systems, Analysis & Design, Architecture-Driven Modernisation and

Middleware and a range of industries, including business modelling and integration, finance, government, healthcare, legal compliance, life sciences research, manufacturing technology, robotics, software-based communications and space (http://www.omg.org/).

- *Open EDI Reference Model (ISO14662).* ISO/IEC 14662:2004 specifies the framework for coordinating the integration of existing International Standards and the development of future International Standards for the inter-working of Open-edi Parties via Open-edi and also provides a reference for those International Standards. As such, it serves to guide the work necessary to accomplish Open-edi by providing the context to be used by the developers of International Standards to ensure the coherence and integration of related standardised modelling and descriptive techniques, services, service interfaces and protocols (http://www.iso.org/).
- *Open Financial Exchange (OFX).* OFX is a unified specification for the electronic exchange of financial data between financial institutions, business and consumers via the Internet (http://www.ofx.net/).

It is clear from the above listing of available services that it is extremely important to choose the correct standard for a particular industry. The necessary criteria to consider include:

- Control over an installed base of customers
- Simplified implementation
- Improved flexibility
- Set-up time and complexity
- Intellectual property rights
- Ability to innovate
- Experience

- Backward compatibility
- Symmetric versus asymmetric standards

Despite the fact that some industries have been successful in establishing standard brokers within their domains for example, RosettaNet, Chemical Industry Data Exchange (CIDX), Petroleum Industry Data Exchange (PIDX), and Odette File Transfer Protocol (OFTP), inter-operability is still an issue when data exchange is required across different industries. In addition, many Electronic Data Interchange (EDI) and Extensible Markup Language (XML) standards have been localised for regional requirements around the world which, in turn,exacerbates the complexity to this problem (Barchi & Tongil, 2007:7).

3.5.3 Conclusion

Information plays a significant role in the success of supply chain management. In the real supply chain world, information is transferred in communication processes in three distinct *modi operandum*. In the first instance, information is transferred from person-to-person. This type of communication involves face-to-face contact involving the spoken word as well as non-verbal communication, such as body language. In the second instance, information may be entered into an information system, or computer, via a keyboard or scanner. This informationmay be interpreted according to certain rules and be made visible on a workstation in a different department, via a monitor or printer. This type of communication is termed computer-mediated communication and it involves user interfaces and service providers. In the third instance, information may be transferred between systems following a certain protocol, which must be understood at both ends, namely, transmitter and receiver. In all cases it is important that the receiver understand the information in the way in which it was intended by the sender, thus providing for a common frame of understanding, and an elimination of noise.

The flow and accumulation of information,which leads to new knowledge, will be discussed briefly in the following section.

3.6 INFORMATION FLOW ANDKNOWLEDGE

3.6.1 Introduction

The terms knowledge and knowledge management are widely used throughout theory.

Pedroso andNakano (2007:2) emphasise that both information flows and knowledge are particularly critical in supply chains, where products and services are characterised by high technology content and consumers who are both knowledgeable and demanding. According to Pedroso and Nakano (2007:2), consumers must be made aware of new technologies and developments so asto enable them to be familiar with and to consume these new developments and technologies. It is essential that to understand fully new features, and applications as well as the limitations of new products and services, otherwise they may either be utilised incorrectly or consumed, causing complaints and poor product image. Information flows and knowledge are of the utmost importance in product development as well as in demand creation and propagation throughout the supply chain.

According to Wadhwa andSaxena (2005:13–14), knowledge,unlike information which provides meaningful facts and data only, enablesthe making of predictions, causal associations and/or predictive decisions. The management of knowledge through systematic sharing in supply chains is an important strategic issue, which may significantly affect the overall performance of the supply chain (Wadhwa & Saxena, 2005:13–14) and will be discussed in the following sections.

3.6.2 Knowledge

3.6.2.1 The basic concepts of knowledge

Resatsch andFaisst (2003:2), Wadhwa andSaxena (2005:14), and Garcia-Perez andMitra (2007:374) define knowledge as “a fluid mix of framed experiences, values, contextual information and expert insight that provides a framework for evaluating and incorporating new experiences and information”. Knowledge originates in the mind of individuals (Zins,2007:479), whereas in organisations it may be embedded in routines, processes, practices and norms. Knowledge actively enables performance, problem solving, decision making, learning and teaching by integrating ideas, experience, as well as the intuition and the skills with which to create value for the individual, the employees, the organisation, its customers and stakeholders.

The above discussion raises the question as to how knowledge is formed. Hey (2004:13) proposes that knowledge is created by the accumulation of information. Information is, thus, a necessary medium for eliciting and constructing new material. He also contends that knowledge is derived from an organised body of information. However, it appears that that part of knowledge, which is more easily definable, involves the accumulation and assimilation of multiple pieces of information, providing structure to the knowledge by forming relationships between the pieces of information, and internalising and personalising that knowledge by bringing it from the outside 'in' to the mind. Nevertheless, once inside, it is difficultboth to pin down and to see. In addition, Boisot andCanals (2004:2) assert that prior knowledge only wouldmake possible a contextual understanding of the information received.

The fact that information is required in order to construct new knowledge, and that data leads to information, suggests that a hierarchy exists between these concepts. Bellinger, Castro andMills (2004:1) presented the transition from data to information, knowledge and wisdom (DIKW). The DIKW hierarchy will be discussed in the following section.

3.6.2.2 *The data-information-knowledge-wisdom (DIKW) hierarchy*

The DIKW hierarchy may be depicted in a knowledge pyramid, as depicted in figure 3.7.

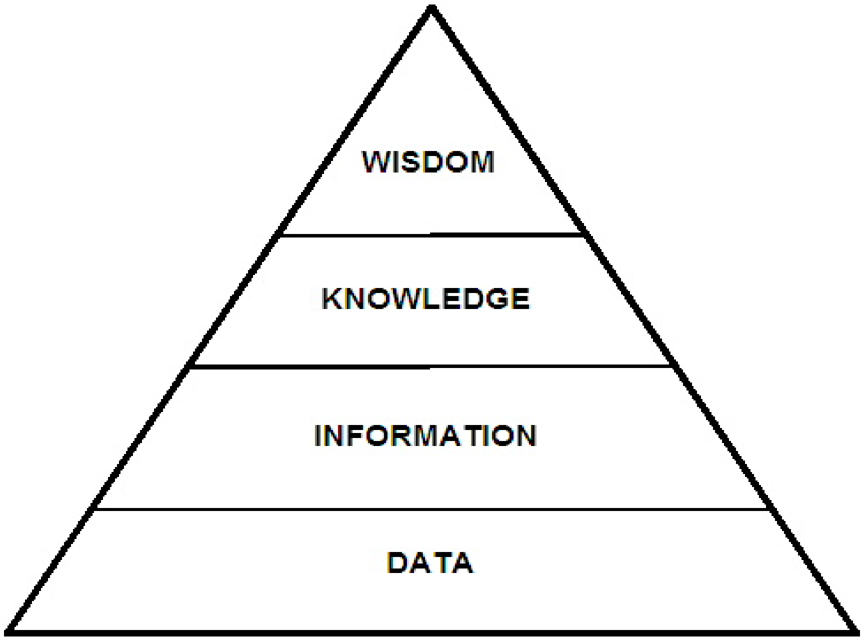

Figure 3.7: The knowledge pyramid

Source: Hey (2004:3)

The knowledge pyramid sets out the basic dependency levels between the individual concepts data, information, knowledge and wisdom. However, Hey (2004:2) reports that other writers include understanding and intelligence before arriving at wisdom.

Hey (2004:3) and Bellinger et al. (2004:3) outlinesuch a different perspective of the knowledge pyramid as presented in figure 3.8, comprising a linear chain rather than a pyramid.

According to this view, the researching of data and the absorption of the resultant information relate to the experience that we have had in the past and are, indeed, still having. However, the construction of knowledge and the formation of wisdom are required to produce novel concepts in the present and future. The diagram also shows the change in context, from a simple gathering of data to connecting the parts, formulating a whole and joining different wholes together.

These principles are extremely relevant to the supply chain management process. Firstly, data is gathered about the status of the various individual, demand satisfying activities. The data may be structured and accumulated and, together with other knowledge about the customer, leads to customer specific information. Together with the data and information from related processes, such as materials management and distribution management, it is then possible to construct knowledge about the status of the company processes. Joining the knowledge of one company with the knowledge from other supply chain partners will lead to an overall view of the entire supply chain performance.

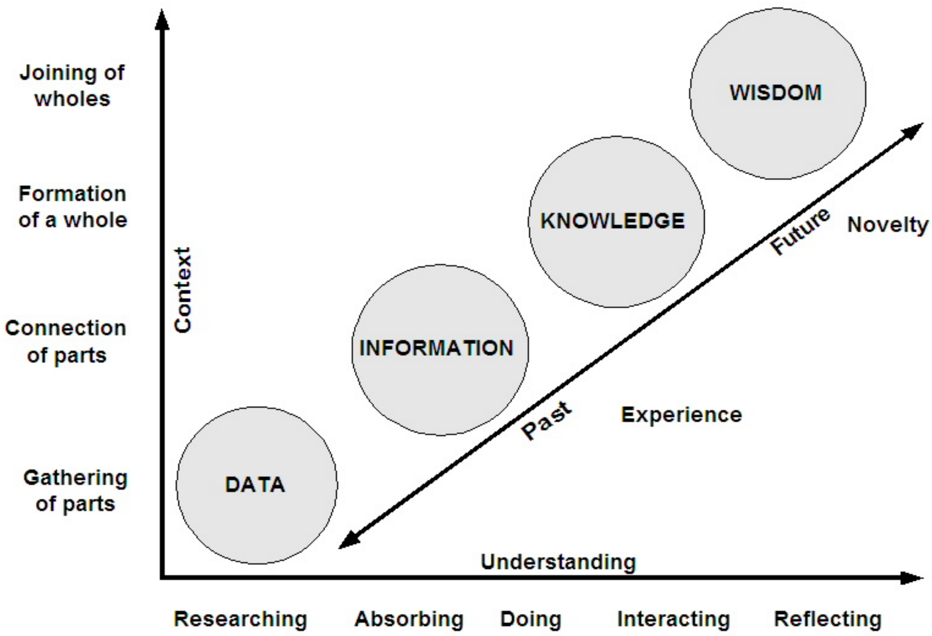

Figure 3.8: A different perspective of the knowledge pyramid
Source: Hey (2004:3)

The following section will discuss different types of knowledge in the hope that this will lead to a deeper understanding of the concept of knowledge.

3.6.2.3 *Types and styles of knowledge*

Mittelmann, Häntschel, Ehrhart, Hahn andWienerroither (2001:4) argue that knowledge may be found in *individual* form, bound to a person. However, it is also available in *collective* mode, in terms of the procedures, routines, practices and rules of an organisational unit or working group.

Knowledge may also exist as either an *internal* or an*external* species. The internal knowledge may be considered to exist within an organisation, whereas external knowledge may exist with the consultants or other cooperating partners of an organisation.

Resatsch andFaisst (2003:3–5) contend that knowledge may be divided into another two types, namely, *explicit* and *tacit*. Experts, who possess topic specific, as well as cognitive, skills that contain patterns of thought or notions, beliefs, institution and mental models, hold tacit knowledge. Explicit knowledge may be articulated in an artefact of some type outside of a human being, and may be transferred to other persons. Explicit knowledge is rational and includes theoretical approaches, manuals and databases. The above typology of knowledge is illustrated in the knowledge cube depicted in figure 3.9.

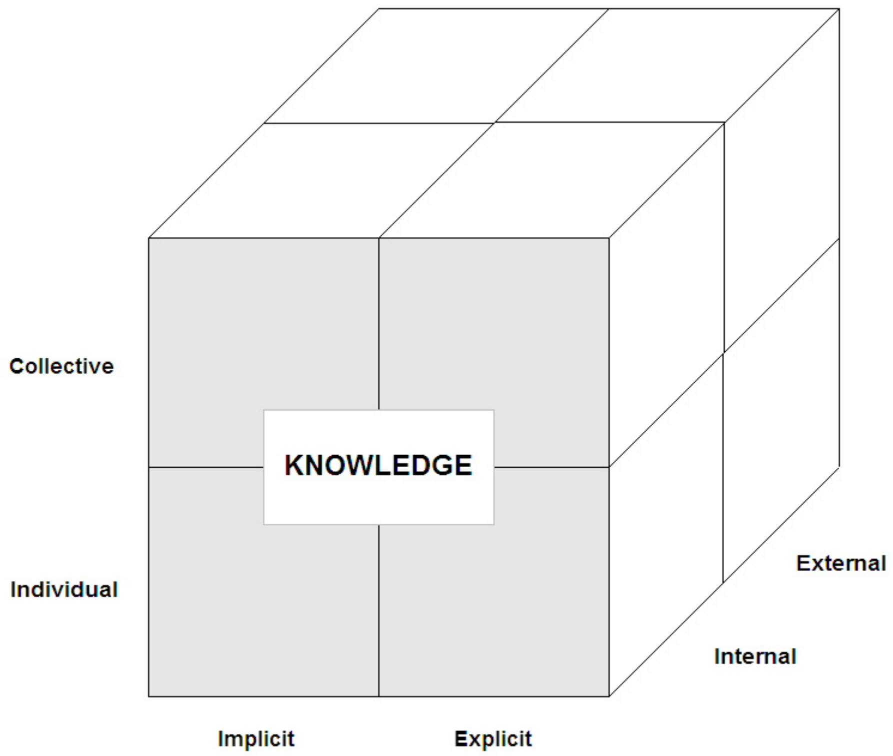

Figure 3.9: The knowledge cube

Source: Mittelmann et al. (2001:4)

The explicit and tacit oriented perspective lends itself to the categorisation of knowledge into four styles, namely, dynamic, system-oriented, human-oriented and passive, as shown in figure 3.10.

Resatsch andFaisst (2003:4–5) emphasise the use of these four styles to characterise organisations. According to them, passive style organisations do not manage knowledge in a systematic manner and do not truly exploit knowledge. Organisations of the system-oriented style place greater emphasis on codifying and reusing knowledge, which is, in turn, increased by the use of advanced IT systems to facilitate the complexity of accessing and using knowledge. The management capabilities of such organisationsare enhanced by group and standard training programs. Human-oriented style organisationsplace the emphasis on acquiring and sharing tacit knowledge and interpersonal experience. Knowledge within such organisations originates from internal networks with good relationships among organisational members. These organisations tend to seek radical learning abilities and prefer procedures such as storytelling as a way in which to share knowledge. The dynamic style is an aggressive and integrative way to manage tacit and explicit knowledge dynamics. The organisationscharacterised by style achieve the best overall performance of all the types of organisations.

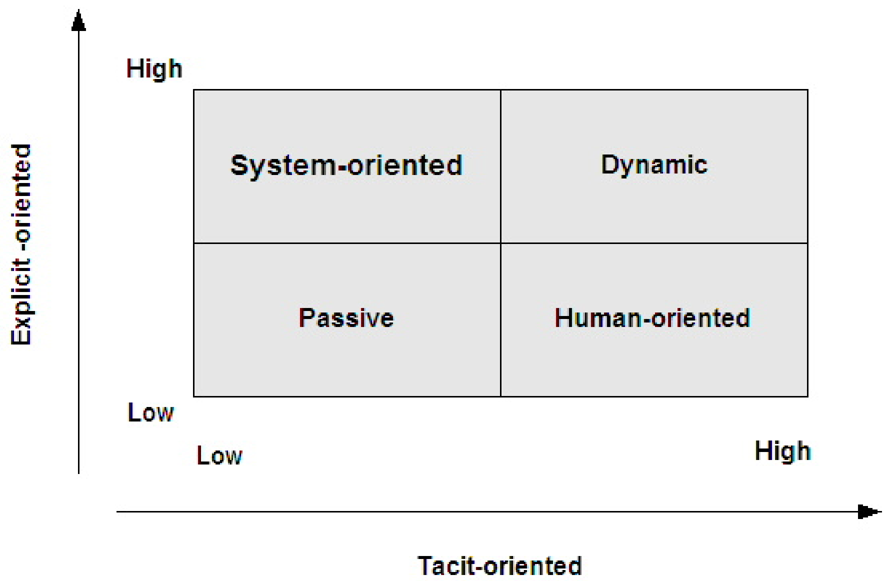

Figure 3.10: The four styles of knowledge

Source: Resatsch andFaisst (2003:4)

It is important to note that the explicit–oriented level considers the degree of codifying and storage of organisational knowledge needed if a person is to use it and access it and this, in turn, also renders knowledge easily transferable. The tacit-oriented level considers the acquisition and sharing of organisational knowledge. It is this type of knowledge that resides in the minds of an individual and is difficult to track.

3.6.3 Conclusion

Section 3.6 discussed the concepts of information flow and knowledge. Knowledge is formed by accumulating information in a contextual sense by applying prior knowledge. This process leads to knowledge innovation − one of the most important assets for most organisations. Organisations have found that, in order to remain competitive in a climate of increasingly sophisticated customers, increased competition and the availability of technology, they have both to engage into activities aimed at harnessing the existing knowledge stock, but also to renew the knowledge within the knowledge stock so as to stay abreast of developments within a specific market These requirements have led to the increased use of information technology in order to store and redistribute knowledge.

3.7 CONCLUSION

This chapter dealt with the concepts and complexities of information, information flow, communication, and knowledge.

The introductory section emphasised the fact that efficient information transfer plays an important role in the successful operation and integration of the supply chain and its related activities. The way in which information spreads determines the speed with which individuals are able both to act and to plan their future activities.

A composite overview of the concept information was provided. Information was defined and categorised in different contexts. The concept of communication as a means of transferring information between different media was introduced. In order to transfer or communicate information it is important to understand that information comprises both a physical and a mediate component. The physical component consistssolely of the physical possibility of transferring the information, whereas the mediate component includes the meaning of the words, tone of the voice, as well as non-verbal signs, especially in person-to-person communication. It was also emphasised that both information and the data creating the information must be well-formed, meaningful and truthful.

However, supply chains do not communicate solely in terms of person-to-person communication. Current technology also promotes person-to-computer and computer-to-person communication, agglomerated in the term computer-mediated communication. This type of communication differs from the person-to-person communication in that interfaces are required that allow the human user to translate the entered information into a computer-compatible format as well to translate the computerised information into a human-understandable format.

Modern technology also makes provision for the transfer of information between computers and information systems with such transfers requiring a clear understanding of the meaning of the messages sent. This is accomplished by protocols and laid down standards that regulate the way in which electronic information transfer should be carried out.

In order to improve communication and data transfer in supply chains, supply chain managers often embark on the use of information systems tailored to supply chain activities. The nature of such systems will be discussed in the following chapter.

CHAPTER 4
THE ROLE OF MANAGEMENT INFORMATION SYSTEMS (MIS) IN THE SUPPLY CHAIN

4.1 INTRODUCTION

If they are to remain successful,it is essential thatsupply chains become more and more efficient and more responsive to the needs of increasingly demanding customers, as business survival and prosperity continue to become more problematic. For example, competitive pressures have led to former competitors forming mergers to create global conglomerates, the continued downsizing of corporations to concentrate on core business and to improve efficiencies, efforts to reduce trade barriers, and the globalisation of capital.

All these facts point to an increased internationalisation of business organisations and markets, as well as increased complexity. In addition, business issues and decisions are also becoming more convoluted and must be made in real time (Turban et al., 2007:3). This increased demand as regards flexibility requires that more and more information be disseminated and analysed in shorter periods of time.

Recent developments in information technology (IT) have made it possible to store vast amounts of data and information, and to design algorithms to sift through the data and information quickly so as to return the information necessary for the making of effective decisions. Both IT and communication networks play a significant role in designing supply chains that have a competitive advantage (Hugos, 2006:169).

IT assists particularly in the provision of information and its transfer by storing information and making it available on request. These tasks are carried out by information systems (IS), which are designed specifically to collect, manipulate and disseminate data and information and to provide a feedback mechanism (Stair & Reynolds, 2003:4).

According to Ventana Research (2006:4), organisations have struggled with information challenges for years with billions of dollars being spent on addressing this issue by acquiring cutting-edge information technology. Today, advances in IT have reduced both the cost and complexity of these IT systems. However, it is essential that company executives be able to take advantage of the rapidly changing conditions and make the best use of the available resources. Gaining greater access to useful information has been one of the most significant reasons why organisations invest in IT and information systems. Organisations require information for the following reasons (Ventana Research, 2006:5–6):

- Financial reports
- Management reports
- Alerts
- Visibility
- Decision support
- Planning and budgeting

Such reports are often created on a regular basis, that is, monthly or weekly, or on an ad hoc basis for specific analyses. Information systems that provide such information have been implemented in many different forms. The main implementations include stand-alone spread-sheet systems, extended spread-sheet systems incorporating central databases, fully-fledged enterprise resources planning systems, decision support systems and supply chain execution systems (SCE). Any of these systems should provide benefits to the users in terms of powerful analysis capability and easy reporting facilities as well as adequate security features.

If the above facts are taken into account, it may be concluded IT has had a profound effect on the performance of supply chains and that IT is a critical enabler of effective supply chain management (Simchi-Levi et al., 2009:14–15). Progress in information technology enables organisations to share information − one of the most critical factors in building integrated supply chains. The flow of information in business organisations and, particularly, in supply chains affects productivity and innovation because it determines the speed with which individuals are able to act and plan future activities (Wu et al., 2004:1). Any delays in response to any information transferred or delays in transferring information between supply chain members will, ultimately, affect the efficiency of the supply chain. Ideally, all the participants in the supply chain would support real-time, online communication, and information sharing. McLaren et al, (2004:1–15) found that, by implementing information systems, organisations will integrate both internally and externally. In addition, the level of information integration plays a decisive role in the way in which organisations and supply chains communicate.

It is clear that information systems impact on the efficiency of the information flow in both organisations and supply chains and, therefore, the concepts of and associated with information technology and information systems require elucidation. These will, thus, be discussed in the following sections.

4.2 BASIC CONCEPTS

4.2.1 Information technology (IT)

4.2.1.1 Origin and definition

Information technology is derived from the French word *informatique* and *informatika*in Russian and encompasses the notionof information handling. According to Chidnandappa andDharnendra (2006:1–2), IT is a new science involving collecting, storing, processing and transmitting information.

The online encyclopaedia Merriam-Webster defines IT as “the technology involving the development, maintenance, and use of computer systems, software, and networks for the processing and distribution of data”.

According to Oz andJones (2008:15), information technology may be defined as “all technologies that collectively facilitate construction and maintenance of information systems”. In a more day-to-day interpretation, information technology is often referred to as “the application of computers and telecommunications to the collection, processing, storage and dissemination of voice, graphics, text, and numerical information" (Tansey, 2003:3). Tansey (2003:4) contends that the main uses of information technology comprise the following:

- Storage and easy retrieval of information: databases
- Analysing information: spreadsheets, accounting packages
- Internal communications (within business): networks
- External communications (with other businesses and customers): e-mail, booking systems, etc.
- Presentation of information: word processing and desktop publishing
- Computer-aided design (CAD)
- Computer-aided manufacture (CAM): robots, process control
- New and better products: video recorders, washing machines, etc.

These main uses may be divided into categories which, in turn, lead to the components of information systems − see nextsection.

4.2.1.2 The components of information technology

According to Chidnandappa andDharnendra (2006:2–4), it is possible to discern the following components of information technology:

- Computer technology
- Communication technology
- Reprographic, micrographic and printing technologies

4.2.1.2.1 Computer technology

Computer technology encompasses computer, software, artificial intelligence, microchip technology, ROM and storage technology, machine-readable databases and computer networks.

The computer hardware of modern microcomputer systems includes a central processing unit (CPU), internal memory storage, disk drives and other devices for the transfer of data and programs in and out of memory, and telephone or network connections for linking computers with other computers. The internal memory storage may be divided into three categories, namely, random access memory (RAM), read-only memory (ROM) and disk space such as hard disks.

Apart from the internal memory and processing chips, computers also contain input and output units (I/O devices), which transfer data in and out of the computer. Such devices include typewriter-type keyboards, mice, printers, telephone lines, microphones, loud speakers, scanners, monitors and voice recognition software.

Computer software consists of programs, which are stored in external or internal memory storage. These programs contain instructions which, when executed, allow the user of the computer to carry out manifold activities, such as writing letters, performing calculations on a spreadsheet, playing games or music, or creating new programs.

Computer programs fall mainly into two categories, namely, operating systems programs and application programs. Operating system programs manage the internal functions and activities of the computer. They carry out the coordination tasks of reading and writing the data between internal units, such as hard disk, RAM and CPU, between internal and external equipment, such as keyboards and printers, performing basic housekeeping functions, and facilitating the use of application programs. As a result of the fact that a computer requires an operating system program, it follows that the application program must be compatible with the operating system program. In order to accomplish the required compatibility between the two types of programs, the operating system program offers an application-programming interface (API) to the application program developers.

Computer networks allow computers to communicate with each other and this, in turn, enables dispersed computer users to exchange information between them, for example, by electronic mail (e-mail) or the internet.This also reduces the time and cost of transferring information, regardless of the physical location of the computers.

The construction of a computer network requires certain hardware which,either physically or virtually, connects the individual computers with each other. In the simplest form, a simple cable may link two computers if they are situated in close proximity to each other. Long-distance connections between computers may be accomplished via the telephone line or even wireless systems. A modem is one common type of hardware that manages the telephonic transmission of digital data. Networking software is required to enable computers to communicate with each other.

Networks may be of limited nature, such as Local Area Networks (LANs), which are mainly used in organisations to connect employees with each other and to enable them to share data with each other, or else public networks, such as the World Wide Web (WWW or Internet). The WWW renders accessible to Internet users hypertext documents, which reside on hypertext transfer protocol (HTTP) servers throughout the world. These hypertext documents or web pages are identified by uniform resource locators (URLs), and are written in hypertext mark-up language (HTML). The codes embedded in the web pages may instantly access other documents on the WWW. The Internet became a mass media phenomenon with the development of "web browser" programs that permit personnel computers to access a wide variety of information and programs on the WWW. The Internet has also changed the way in which commerce is conducted. The Internet enables virtually all users to buy certain goods and trade via the Internet The development of this electronic commerce (e-commerce) has shifted the speed with which business transactions are carried out, and poses new challenges to the legal, as well as the supply chain management, community.

4.2.1.2.2 Communication technology

Communication technology may be classified into the following groups (Chidnandappa & Dharnendra, 2006:3–5):

- *Audio technology*

  As a result ofdramatic improvements and inventions, older gramophone records have been dwindling in importance and far more sophisticated cassettes and tape recorders have emerged. Today, random access memory devices are slowly replacing the older tape based units, although these older tape based units are still widely used for creating back-ups of large, server based data. Modern FM (Frequency Modulation) receivers are replacing the outmoded AM (Amplitude Modulated) radio receivers. This audio technology may be used in libraries and information centres for the provision of a wide variety of information.

- *Audio visual technology*

  Motion pictures, television and videodisc are the main representatives of this technology. Videodisc is a new medium containing pre-recorded information, which allows the user to reproduce this information in the form of images on the screen of a television receiver at will while videodisc technology offers high quality storage, image stability and speed of recall.

- *Facsimile transmission (fax)*

  Facsimile transmission has been boosted by the adoption of methods of data compression made possible by compact, reliable and inexpensive electronics. During the initial stages, the average speed of facsimile transmission was 3.4 minutes per page. However, this technology was slow and was replaced by micro facsimile. Satellite communication and fibre optics have increased the potential of facsimile transmission.

- *Electronic mail*

  E-mail is the electronic transmission and receiving of messages, information, data files, and letters or documents by means of point-to-point systems or computer-based messages systems.

4.2.1.2.3 Reprographic, micrographic and printing technologies

The technology of reprography has made a big impact on the document delivery system. Most research libraries have reprographic machines and provide photocopies of any document on demand. By using reprographic and micrographic techniques, it is possible to condense bulky archives and newspapers and, thus,solve storage problems. Such techniquesalso serve the purpose of preserving, they help in resource sharing and the save the time of users.

- *Micro forms*

  Microforms is a term referring to all type of micro-documents, whether they are transparent or opaque, or in roll or sheet form. The varieties of microforms include microfilm, microfiche, ultra fiche, microopaques, cards.
- *Roll-film (microfilm*)

  Microfilm is a continuous strip of film with images arranged in sequence. It is available in 100 feet rollswhich are 35 mm wide.
- *Microfiche*

  This is flat film with large number of images arranged in rows and columns. Standard sized microfiche of 4x6 inches accommodates 98 pages.
- *Printing technology*

  Thousands of years ago, people recognised the need to keep records of their daily activities. Paper was invented and the art of writing and record keeping came into being. However, lasers and computers have now entered the field of printing. There are three categories of computer printers, namely, line printers, dot matrix printer, and laser printers with laser printers being the most popular today.

Information technology supports the internal operations oforganisations in a supply chain as well as collaboration between these organisations. In the context of supply network innovation, information systems are the primary conduit for information flow. Information systems will be discussed in the following sections.

4.2.2 Information systems (IS)

4.2.2.1 The basic concepts of information systems

As outlined above, an information system comprises any organised combination of people, hardware, software, communication networks and data resources that stores and retrieves, transforms and disseminates information within an organisation (O'Brien & Marakas, 2006:6). This concept of data and information processing is depicted in figure 4.1 (Hogan, Carnahan, Carpenter, Flater, Fowler, Frechette, et al., 2001:344):

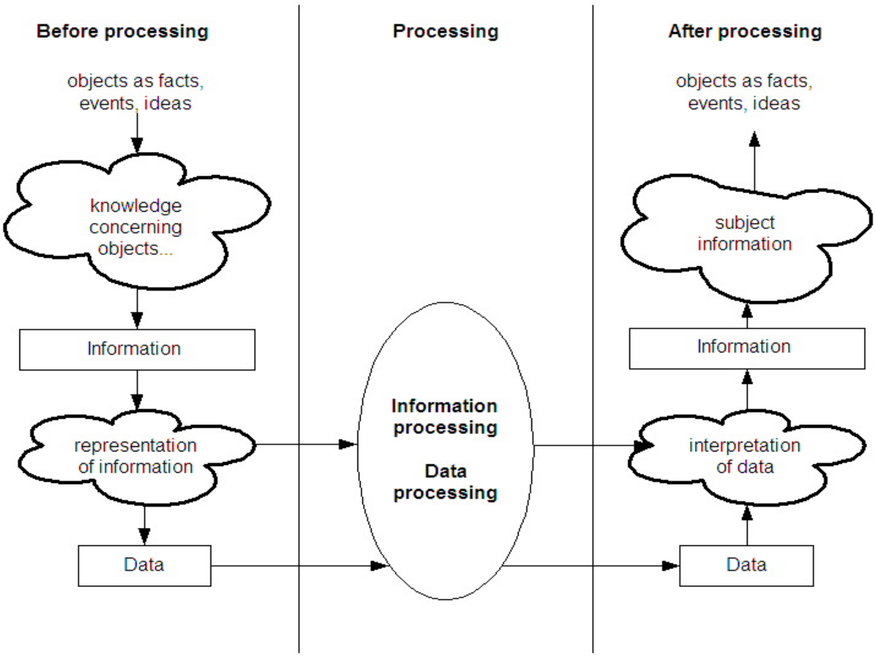

Figure 4.1: Concepts of information and data processing

Source: Hogan et al. (2001:344)

Figure 4.1 above illustrates the concept of processing data into information, storing data and information and representing data and information on request using an information system. This theory may be applied to different types of information systems.

The following, two concepts are embedded in "information systems", namely, the concepts of *information* and *systems*. The concept of information, which is one of the main topics of this research work, has already been discussed in-depth in chapter 3. However, the concept of "systems" will be briefly discussed in the following sections.

4.2.2.2 Systems

4.2.2.2.1 Basic concepts and definition

According to Oz andJones (2008:12), a system may be defined as “an array of elements or components that interact to accomplish goals”. In other words, the elements themselves and the relationship between them determine how the system works. In addition, systems include inputs, processing mechanisms, outputs and feedback.

Bellinger (2004:1), on the other hand, defines a system as “an entity which maintains its existence through the mutual interaction of its parts”.The main emphasis in this definition is on “mutual interaction”. This, in turn, implies that something is occurring between the parts, over time, which maintains the system. Accordingly, a system differs from a simple collection of elements or parts as, in a system, element A of the system influences element B of the same system, but element B also influences element A.

Examples of systems include cells, organisms, persons, communities, solar systems and the universe.

In any discussion about systems and the interactions between the elements of these systems, the notion that these interactions produce results, which are greater than the sum of the results of the individual actions of each element in isolation, is of key importance. This effect is termed *synergy*.

Systems exist in many different forms and shapes and for vastly different purposes. Other examples of systems include, inter alia, a carwash, a coffee shop, a school, a movie with some of these systems depending on their environment, for example, the carwash, while others, for example,mechanical systems, do not depend on their environments. Based on their interaction with the environment, systems may be classified into different categories. This classification of systems is the subject of the next section.

4.2.2.2.2 Classification of systems

As mentioned above, systems may be classified according to their interaction with the environment. Bellinger (2004:2–3) proposes that systems may be isolated, closed or open. However, Reynolds andStair (2003:10) and O'Brien andMarakas (2006:24–25) extend this list of system characteristics to include an organisational point of view, and add classification items such as simple and complex, stable and dynamic, adaptive and non-adaptive, and permanent and temporary.

As regards computer systems that process inputs through a set of instructions contained in a program and produce desired outputs such as reports, it is clear that such systems may be simple or complex, permanent and stable and, in most cases, non-adaptive in nature. It is the latest software only which is used in artificial intelligence, and which is capable of learning, that may be considered as both dynamic and adaptive.

For the sake of completeness, Bellinger (2004:3–5) mentions Boulding's classification of systems. This classification is based on the viewpoint of the economist Kenneth Boulding(Bellinger, 2004:3–5)and includes the following six general classes:

- *Parasitic system* − a system in which the positive influence from one element to another provides a negative influence in response to the first.

- *Prey/predator system* − a system in which the elements are essentially dependent on each other from the perspective that the quantity of the one element determines the quantity of the other element.

- *Threat system* − a system in which one element does not do something if the other element does not do something else.

- *Exchange system* − elements of this system provide goods and services to other elements in exchange for money or other goods and services.

- *Integrative system* − a system in which some elements work together in order to achieve a desired common objective or goal.

- *Generative system* − a system in which two people come together to create something,although neither of them have any idea when they began the process.

4.2.2.2.3 System performance and standards

It is important to know how well or how badly a system performs, particularly as regards information systems, in terms of which the processing of massive amounts of data may require resources for long periods of time. O'Brien andMarakas (2006:16) maintain that system performance may be measured in several ways. Firstly, they mention efficiency as a performance measure. Efficiency is a measure of what has been produced divided by what was consumed in production. The second measure they propose is effectiveness, which measures the degree to which a system achieves its goals. One way of calculating this measure is to take the number of goals achieved and divide this figure by the total number of goals required.

However, in order to evaluate system performance, a system performance standard is required with which the efficiency and effectiveness measures may be compared.

4.2.2.2.4 System variables and parameters

Systems and their elements are not always under the direct control of a decision maker. For example, the price a company charges is under the direct control of the companyconcerned, whereas the cost of raw material may not be under the company's control. The quantities or items that may be controlled are termed system variables, while those items that cannot be controlled are termed system parameters. It is important to differentiate between the variables and parameters when designing and modelling systems (Stair & Reynolds, 2003:11)

4.2.3 Types of information systems

4.2.3.1 Introduction

The above discussion on general systems provided a basic definition of the concept of systemsand, in particular,an explanation of the classification of systems as well as the interaction between the elements of a system. As discussed above, the systems theory may also be applied to computer and information systems.

Oz andJones (2008:22–26), Reynolds andStair (2003:18) and Murphy andWood (2004:62) propose that the information systems used in business organisations may be categorised into transaction processing systems, supply chain management information systems, decision support systems, customer relationship systems, business intelligence systems and geographic information systems. Some businesses employ special systems such as artificial intelligence and expert systems.

4.2.3.2 Management information systems (MIS)

Oz andJones (2008:9–14) describe a management information system as an information system, which provides managers with predefined management reports which contain the information required to aid decision making. According to Geerders (2004:1–5), the MIS are consistent, modular and flexible tools for the systematic acquisition, analysis and archiving of data and information from a variety of sources. In particular, MIS should, ideally, provide an understanding of relevant processes on the basis of available, historic information as well as providing information about a current situation, especially for early-warning, forecasting changes and impacts as well as forecasting the consequences of policy decisions and measures.

Generally, MIS generate outputs, either on demand or automatically, and periodically in the form of textual or graphical reports. Such reports may be transmitted to the relevant users in either digital or printed form. Another group of reports may be generated to assess the possible consequences of certain measures or activities, such as the availability of new manufacturing capacity.

On the other hand, Geerders (2004:1–5) maintains that MIS are costly assets and require detailed planning, design, implementation and operation in order to ensure success.

4.2.3.3 Decision support systems (DSS)

Murphy andWood (2004:62) contend that decision support systems aid managers in making decisions by providing information tools for analysis and models. These tools and models enable the users to store information, access and report historic information, analyse and manipulate information, as well simulate future, proposed situations.

Simulation involves a model which consists of a series of mathematical relationships and algorithms, which describe a specific, real-world problem. By using such models, the users will be able to predict an outcome by changing the values of parameters and input variables and entering these new values into the model. The results of the simulation will approximate reality the best if the model provides a comprehensive descriptionof the real-world problem.

However, despite the fact that simulation is a powerful analytical tool to predict results to changes in the real-world problem cheaply, a poorly constructed model, bad data, inaccurate assumptions and even overly complex models may lead to sub-optimal, or even unworkable, solutions.

4.2.3.4 Transaction processing systems

A transaction processing system captures and processes the data which describes business transactions, updates organisational databases and produces a variety of information products (O’Brien & Marakas, 2006:220–222). Transactions arean integral part of doing business andinclude sales, purchases, deposits and payments as well as transactions arising from production processes.

According to O’Brien and Marakas (2006:220–222), the primary objective of a transaction processing system is the efficient processing and control of such transactions. The actual processing of transactions by the computer system may be carried out in either batch or real-time mode (O’Brien & Marakas, 2006:220–222; Oz & Jones, 2008:13). As regards batch processing, the data relating to the transactions is stored for processing at a later time, whereas real-time processing mode processes transactions at the time at which they occur.

Examples of transaction processing systems include payroll systems, the computer-to-computer transmission of business data in a structured format via EDI, automatic identification technologies such as barcode enabled transaction processing, and point-of-sale systems that record the sale of specific items at the till (point-of-sale).

The enterprise resource planning (ERP) system is a special type of transaction processing system. Generally, the ERP system integrates the manufacturing and business finance functions of an organisation. In many cases, the ERP system also includes purchasing, production planning and inventory modules. In order to maintain these functions, the ERP system captures transaction from the different functions of the business, and updates databases simultaneously in the business function modules that are affected by the transactions captured. Accordingly, the main benefit of an ERP system is its consolidated capability of updating and reporting the effects of multiple transactions across all business functions(Cuenca, 2004:243–248).

4.2.3.5 Artificial intelligence (AI) and expert systems (ES)

Artificial intelligence is a subfield of computer science which is devoted to the development of programs that enable computers to display behaviour that may be characterised as intelligent (Thomason, 2009:1; O’Brien & Marakas, 2006:10).

This, in turn, implies that AI systems display behaviour that humans associate with intelligence or solve problems that humans believe an intelligent being only would be able to solve.

Richter (2004:12–15) contends that, in order to achieve intelligent behaviour, AI systems need a way in which to represent knowledge and methods for reasoning. AI systems generally differ from procedural programs in that AI programs do not follow a prescribed order of steps, although knowledge is represented and reasoning methods are provided.

AI systems are used mainly in the areas of mathematical reasoning, natural language understanding, vision, robotics, machine learning neural networks and general knowledge based systems (Richter, 2004:15–17).

However, as regards SCM and, specifically, logistics, AI systems have been employed to manage certain parts inventories of the US Air Force. IS, utilising AI which is dedicated to a specific domain, are termed experts systems (ES). ES provide specific solution for specific problem areas such as the example cited above. Other examples involving ES include systems focused on specific issues regarding highway traffic, predicting urban traffic flows and managing traffic congestion (Murphy & Wood, 2004:68–69).

4.2.3.6 Conclusion

In conclusion, information systems acquire and store data which may, in turn, be used to extract information. Generally, IS may be divided into management information systems (MIS), decision support systems, transaction processing systems and systems employing artificial intelligence. In practice, organisations choose IS packages suited to the size and requirements of the company concerned, while the main implementations of IS are undertaken in terms of the financial functions. However, rapid growth in the use of IS has occurred specifically in the use of application specific software such as, inter alia, financial management, asset management, logistics, enterprise resource planning, customer relationship management, inventory planning, supply chain management, and warehousing, particularly as regards an operational and execution related emphasis. The following section will focusmainly on the characteristics of IS.

4.2.4 Characteristics of information systems

4.2.4.1 Introduction

As mentioned earlier in section 4.2.2.1, an information system consists of a set of interrelated elements or components that collect (input), manipulate (process) and disseminate (output) data and information and provide a feedback mechanism designed to meet a specific objective.

Information systems and technologies are a vital component of successful business and organisations (O’Brien & Marakas, 2006:4).For this reason, the remainder of this chapter will deal with computer-based information systems (CBIS).

According to O’Brien andMarakas (2006:26–28) and Oz andJones (2008:18), CBIS consist of hardware, software, databases, telecommunications, networks, people, procedures and information products that are configured to collect, manipulate, store and process data into information. An overview of a CBIS is depicted in figure 4.2 below.

However, once an IS has been established, it is essential that the data and information contained in the system be protected from unauthorised access. In particular, the data and information need to be protected in order to ensure the confidentiality, integrity and availability of information system assets, including information and data that is to be communicated (O’Brien & Marakas, 2006:455–457). In addition, it is often necessary to extend security measures to cover a complete network.

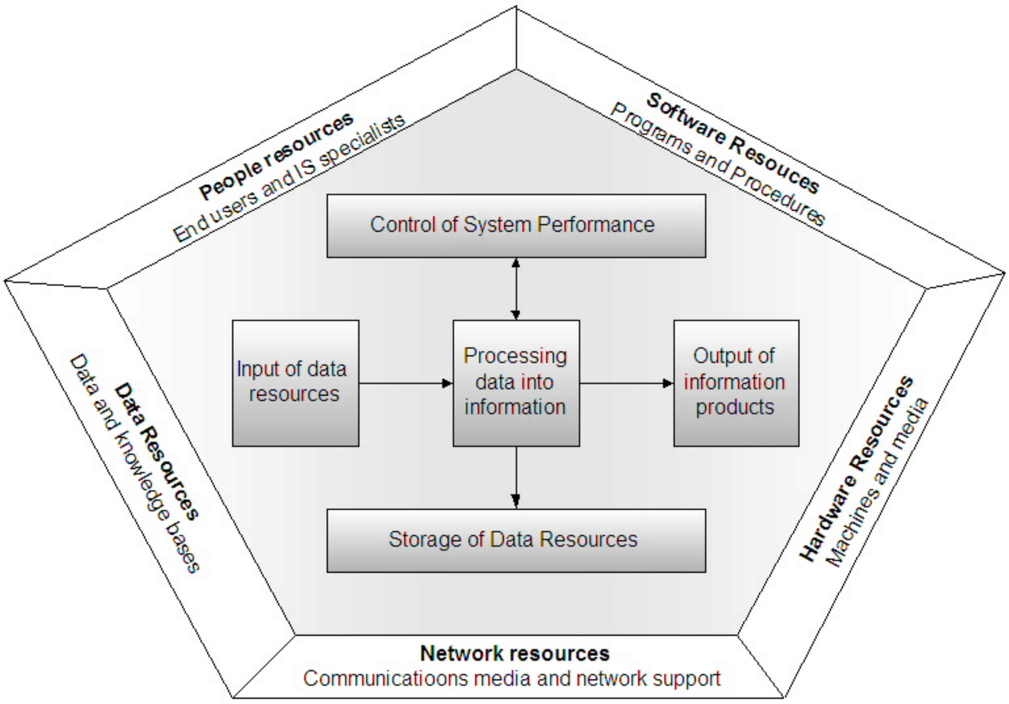

Figure 4.2: The basic components of an information system

Source: Adapted from Bagad (2009:1–6)

The following sections discuss the most common components of an IS, including software, networks, databases, people, procedures and feedback, especially from the point of view of information retrieval and the necessary interfaces with humans as well as specific security principles.

4.2.4.2 Components of an IS

4.2.4.2.1 Hardware

(i) Overview

Hardware consists of equipment which performs input, processing, output, storage, telecommunications and networks. Accordingly, hardware represents the physical aspects of computers which are required to support the information and information processing needs of an organisation electronically. Lin(2) (2006:4) distinguishes the following six categories of hardware, namely

- input device
- output device
- storage device
- central processing unit (CPU)
- telecommunications device
- connecting device.

These devices will be discussed in more detail in the following sections.

(ii) Input techniques

Lin(2) (2006:14) contends that input devices are tools with which to capture data and commands. Input may be manual, that is,by means of a keyboard, or electronic with the aid of scanners. Typical input devices include

- keyboard
- point-of-sale (POS)
- microphone
- mouse
- pointing stick
- touch pad
- touch screen
- barcode reader
- optical mark and character recognition (OMR and OCR)
- Scanner
- RFID reader

(iii) Processing techniques

According to Oz andJones (2008:20) and Stair and Reynolds (2003:14), processing involves the conversion or transformation of data into information. Accordingly, processing may involve calculations, the comparison of data, the sorting of data, the conversion of data and the storing of data for future use. Processing requires central as well as peripheral processing units, which carry out specific instructions, as dictated by the operating system. Accordingly, the CPU orchestrates the interactivity between the input, output, storage and other peripheral devices. In addition, the CPU, in conjunction with the operating system, also monitors and directs the activities of application software, which is often required to perform specific and user defined tasks.

(iv) Output techniques

According to Lin(2) (2006:15–16), output devices may be characterised as equipment that is used to see, hear, or otherwise accept the results of information processing. The most common types of output devices include:

- Monitors
  i. Cathode-ray tube monitors (CRTs)
  ii. Flat-panel displays
  iii. Liquid crystal display (LCD) monitors
  iv. Gas plasma displays

- Pixels – the dots that make up an image on the computer screen
- Printers
  i. Inkjet printers – form images by forcing ink droplets through nozzles
  ii. Laser printers – form images using an electrostatic process in the same way in which a photocopier works.
  iii. Multifunction printers – scan, copy, fax, as well as print

- Loudspeakers – produce audible sound

(v) Storage

Storage devices are units that store data, either temporarily or permanently. Temporary storage is commonly found in a computer's memory, with the information beingassigned to a memory location for later retrieval, whilst specific software is in execution. Once the software terminates, the storage locations are cleared and become available for the next process. However, the permanent storage of data and information requires either a technology in terms of which the state of the memory location is not altered, or else technology such as magnetic or optic material, which may be altered to maintain the information or data written to it. The former technology is used to realise flash memory and memory cards, whereas the latter technology has been utilised in the creation of high-density floppy disks, hard disks, CD-ROM/R/RW and DVD-ROM/R/RW[2] discs.

(vi) Telecommunication devices

Stair &Reynolds (2003:17) define telecommunication devices as units that carry electronic signals and transmit these signals to other telecommunication devices, which receive the transmitted signals and convert them into data that a computer is able to accept. Lin(2) (2006:19) differentiates between the following 5 basic telecommunication devices:

- *Dial-up access*: on demand access using a modem and a regular phone line. Such devices are cheap, but generally slow (2400bps[3] – 56kbps).
- *Cable carrier*: requires a cable and special cable modem. These devices function at approximately 512kbps – 200Mbps.
- *DSL (digital subscriber line):* this technology uses the digital portion of regular copper telephone line to transmit and receive information. A special modem and adapter card are required. This device operates in the bandwidth of 128kbps – 30Mbps.
- *Wireless (LMCS):* access is gained by connection to a high speed cellular such asa local, multipoint, communication system (LMCS) network via a wireless transmitter/receiver. This device operates at 30Mbps or more.
- *Satellite:* newer versions of telecommunications devices are characterised by two-way satellite access, thus obviating the need for

[2] ROM = read-only memory, R = recordable, RW= rewritable, CD = compact disc, DVD =
[3] bps = bits per second, kbps = kilobits per second, Mbps = megabits per second

phone lines. Operating speeds of several hundreds of Mbps are achieved.

O'Brien andMarakas (2006:194–196) also elude to terrestrial microwave technology, cellular telephone and pager systems that use several radio telecommunications technologies and optical fibre cable technology supporting operating speed of up to 10 terabits per second

(vii)Connecting devices

Connecting devices enable the hardware devices to connect and communicate with each other. Lin(2) (2006: 23–24) lists the following devices:

- *Ports:* Parallel connectors are used to plug a printer into a system box; serial connectors are used to connect mice and keyboards; USB (universal serial bus) accommodates mice, flash memory cards and other expansionary equipment.
- An *expansion bus* moves information from the CPU and RAM[4] to all the other hardware devices.
- *Expansion slots* are long narrow sockets on the motherboard into which expansion cards may be inserted.

4.2.4.2.2 Software

According to Oz andJones (2008:134), software consists of sets of instructions that govern the operation of the computer. Lin(2) (2006:8) maintains that computer programs contain the instructions that the hardware executes in order to perform an information processing task. Both Oz and Jones (2008:134) and Lin(2) (2006:8) agree that there are two basic categories of software, namely, application software and system software.

[4] RAM = Random Access Memory

Application software is used for specific information processing needs, such as word processing systems, a payroll system, a customer relationship management system or a project management system.

On the other hand, system software controls the way in which the various technology tools work together along with the application software. A computer operating system, which controls the basic computer operations and manages how the hardware devices work together and controls the interactions of the hardware devices with the application software, is an example of system software.

4.2.4.2.3 Networks

Oz andJones (2008:183–188) consider networks to be an interconnection of computers or devices within a building, a country or the world, in order to enable electronic communication and to share data information between members of the network. Lin(3) (2006:5) points out that virtually any kind of information and data may be stored and retrieved from a central location in the network. In addition, a network combines the power and capabilities of diverse equipment providing a collaborative environment in which to combine the skills of various people, regardless of their physical location.

According to Lin(3) (2006:9) and Parsons and Oja (2012: 248), a network is made up of several physical elements, including computers, printers, scanners, and other devices. The manner in which the different items are connected is referred to as the network topology. According to Parsons and Oja, (2012:250-251) and Lin(3) (2006:11)Networks may be arranged in different topologies, for example, bus topology, star topology, ring topology, tree topology and wireless topology − see figure 4.3.

Networks are commonly referred to as "area networks". Different area networks may be distinguishedLin(3) (2006:7-8):

- Local Area Network (LAN): connects network devices over an extremely short distance. For example, a building may sometimes contain a few small LANs, although a LAN may also sometimes span a group of buildings nearby.

- Wide Area Network (WAN): is a geographically dispersed telecommunications network
- Metropolitan Area Network (MAN): interconnects users in a geographic area or region larger than a LAN, but smaller than a WAN

The different configuration of networks is depicted in figure 4.4.

Parsons and Oja (2012:251-252) contend that networks are accessed and communicated with in a predefined way, using a protocol. The most popular protocols include token ring, Ethernet and fibre distributed data interface. Networks also require transmitting and receiving devices, which are commonly found in the form of network adapters, modems, repeaters, microwave transmitters, infrared laser transmitters, cables, hubs, routers and gateways.

As regards networks, a distinction is often made between client-server networks − versatile, message-based and modular infrastructure based network − and a peer-to-peer network which enables a computer to function both as a server or a workstation (Lin(3), 2006:35).

The Internet is the world’s largest network. It uses two of the most influential technologies, namely, the transmission protocol/Internet protocol (TCP/IP) suite and the World Wide Web (www).

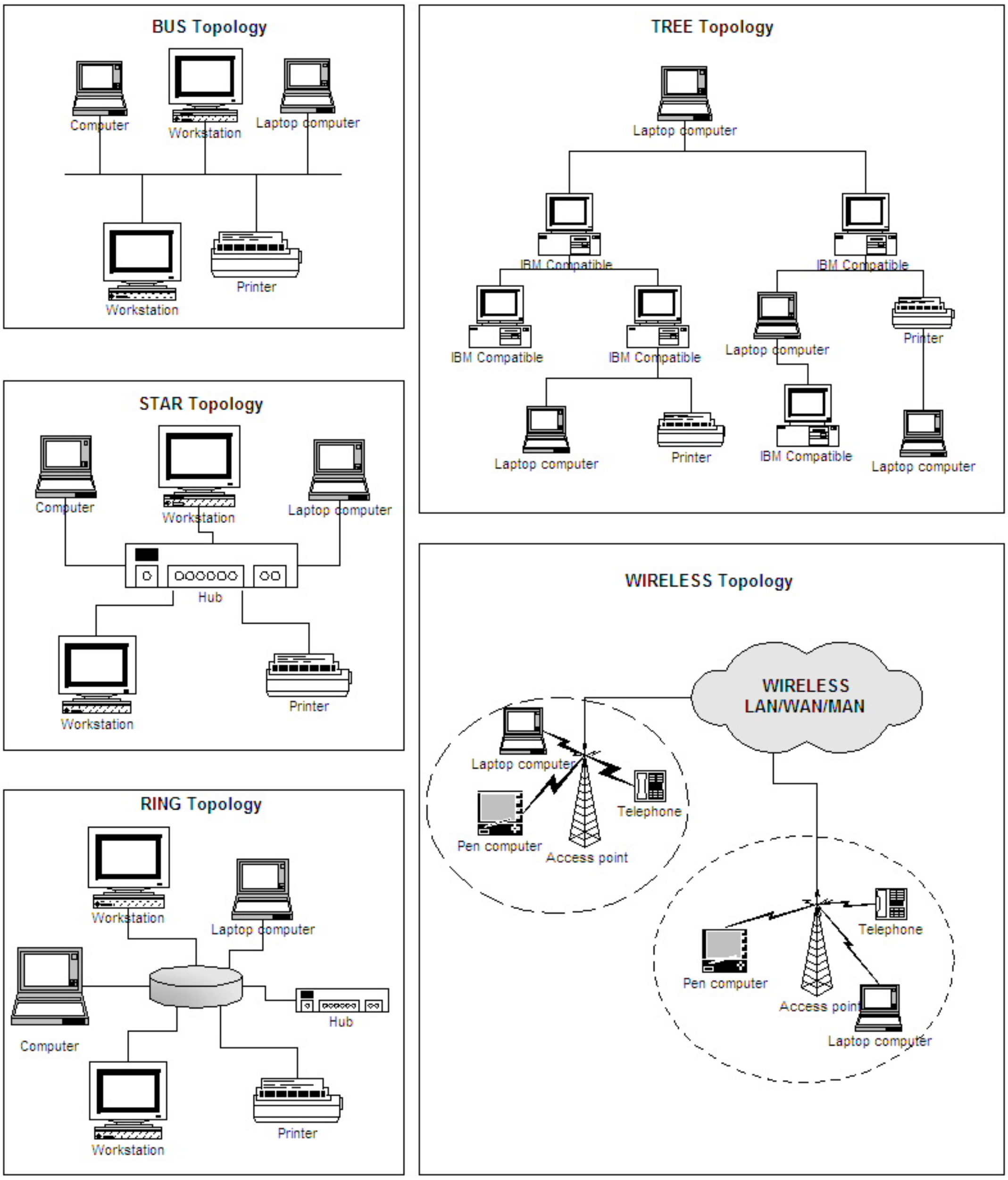

Figure 4.3: Network topologies

Source: Lin(3) (2006:11)

The TCP/IP group of networking protocols is used to connect computers to the Internet with TCP providing transport functions and ensuring, inter alia, that the amount of data transmitted is the same as the amount received. The IP part of the TCP/IP protocol provides addressing and routing mechanisms. The World Wide Web is a client-server based environment, in which information is managed through websites on servers. Access to the websites is provided through the use of client software, such as browsers.

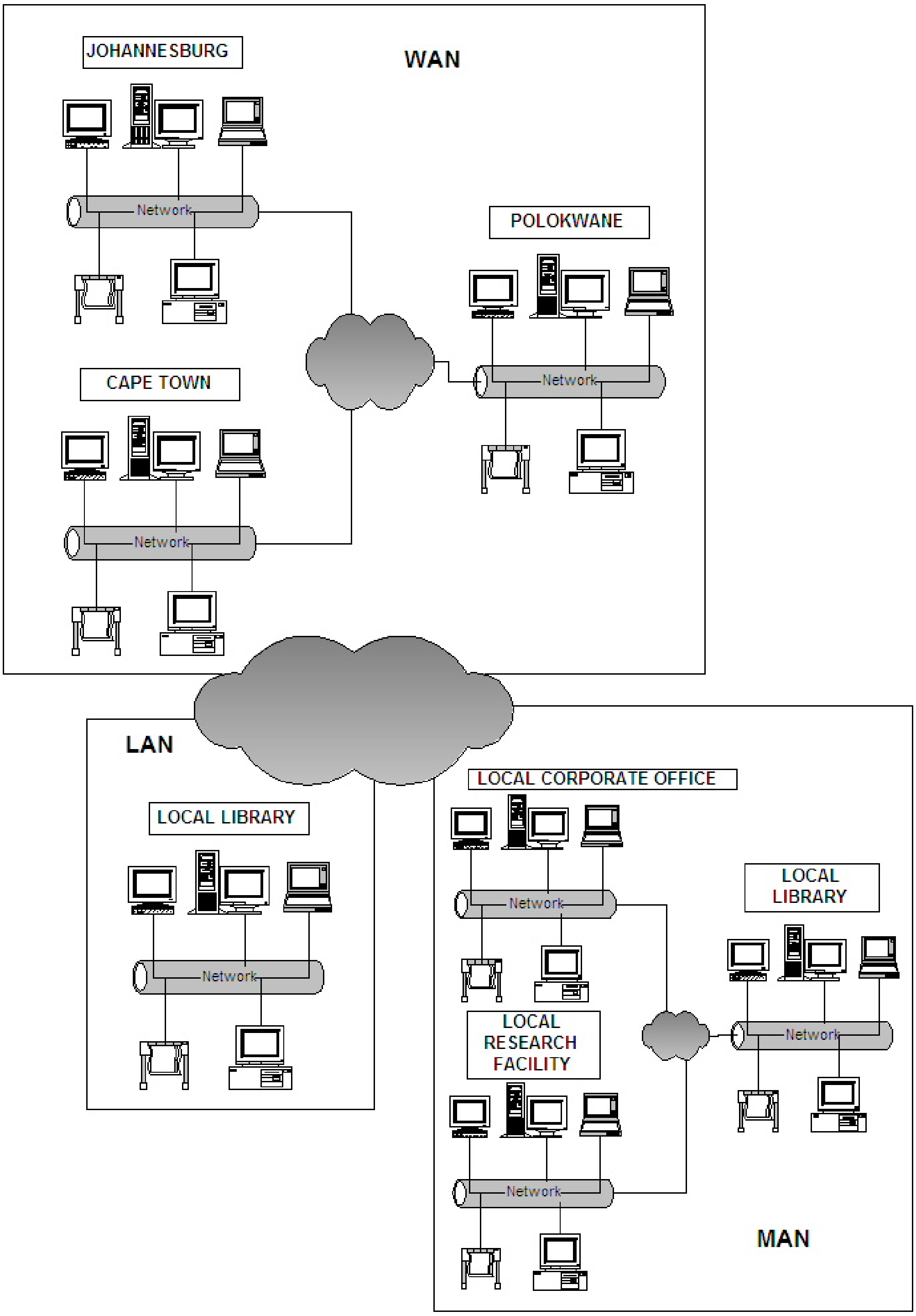

Figure 4.4: Types of networks

Source: Lin(3) (2006:8)

4.2.4.2.4 Database management

A database is an organised representation of facts and information. A database may, for example, contain an organised collection of information pertaining to customers. Such a customer database collects the same information from each customer, that is, name, postal address, code, telephone number and delivery address. Accordingly, such a database is constructed from a constant number of columns and an increasing number of rows, each time a new customer is added. Databases are one of the most important and invaluable parts of a CBIS (Stair & Reynolds, 2011:14).

4.2.4.2.5 Human-to-computer interfaces and information retrieval

The interface technology has changed since the introduction of the World-Wide-Web. The content of information available from information systems, including the Internet, has changed dramatically from a purely structured text or database display to content that includes, inter alia, images, statistics, videos, music computer codes, real time sensors (Marchionini, 2006:2). In addition, the content of information changes frequently and is becoming increasingly more conditional. To this end, information retrieval systems should be designed to be closer to the end user in terms of the information needed, the required intellectual responsibility and control exerted by the user, the span of the lifecycle of the information, the support of adjusting informationby the end user and information sharing.

The above list of requirements of interfaces to the computer system, coupled with the increasing computer literacy of users, present unique demands to interface design. Accordingly, it is essential that designers find ways of closely coupling the system backend to the user interface to enable users to interact with information rather than with systems(Marchionini, 2006:2-3).

4.2.4.2.6 People

According to O’Brien andMarakas (2006:27), people represent the essential ingredient for the successful operation of any CBIS. Information systems personnel include all the people who manage, run, program, and maintain the system while users are those people who retrieve and use the information from the system in order to obtain results.

4.2.4.2.7 Procedures

Procedures include the strategies, policies, and rules for using the CBIS. For example, some procedures describe when a certain program is to be run, whereas others describe who may have access to a certain database to run, and who may have access to maintain the database. Other procedures deal with the methods and plans to be implemented in the case of disaster and extended system downtime (Stair &Reynolds, 2003:17).

4.2.4.3 Information systemsecurity

According to Ayen (2002:3), information security deals specifically with measures to ensure the confidentiality, integrity and availability of information system assets, including the information and data to be communicated. If these requirements are extended to include networks, it becomes necessary both to protect network services from unauthorised modification, destruction, and disclosure, as well as to provide the assurance that the network is performing its critical functions correctly and that there are no harmful side effects to using these network facilities. Ayen (2002:6–24) recommends the following security principles and measures:

- *Confidentiality*

  Confidentiality protects against the disclosure of information to parties other than the intended recipients. Measures to achieve confidentiality include data access control and cryptography. Crytography encodes information by using an algorithm and certain secret information known only to the originator and the intended recipient of the information.

- *Integrity*

  Integrity refers to the receiver of information being able to determine that the information received has not been altered in the transmission process by anything/anybody other than the originator. Integrity mechanisms often use the same underlying technologies as confidentiality schemes, but they usually require additional information to be added to the original communication content for the integrity check, rather than encoding the information.

- *Authentication*

  Authentication involves establishing the validity of a transmission, message, or originator. As such, authentication will allow the receiver to have confidence that information that is received originates from a specific, known source. Ways of ensuring authentication include the use of passwords, digital certificates, digital signatures and biometrics.

- *Availability*

  Availability assures that the information and communications services will be ready for use when expected by the user. However, it is essential that information be available to authorised persons when needed. Specific examples of ensuring availability include firewalls, intrusion detection mechanisms, anti-virus protection, redundancy measures and backups.

- *Non-repudiation*

  Non-repudiation refers to the prevention of later denial that a specific action had occurred, or that a particular communication had taken place.

  Specific measures to ensure non-repudiation include the addition of time stamps to communications and the maintenance of log files.

4.2.4.4 Conclusion

Information systems, either manual or computerised, require inputs of data/information. These systems then process the inputs to provide the required information and produce outputs which may be understood by the user(s). In most cases, information systems are of computerised nature, as the human ability to store, retrieve and process information is limited in capacity and requires vast amounts of time. CBIS are generally controlled by operating software, whereas application software generates the required information by accepting specific inputs and processing these inputs.

Information systems may be classified into different types of IS, including transaction processing systems, decision support systems, management information systems and expert systems.

Cables or wireless technology interlink several IS to form either local or wide area networks. Networks generally provide several users with access to uniform information. In addition, networks are able to make optimal use of ancillary equipment such as printers and scanners, as well as diverse people skills, independent of the physical location of these people.

However, the operation of networks also requires tight security measures in order to protect data from either unauthorised change or erasure. Another important point that needs to be considered is facility availability and network maintenance.

Despite security issues, networks provide a unique and important opportunity of connecting different IS, and sharing information, especially within supply chains. For this reason, specific management information systems, decision support systems and transaction processing systems have entered the field of supply chain management with the aim of improving the visibility of supply chain related information and, thus, supply chain performance. The information systems utilised in SCM, as well as specific supply chain information systems, will be discussed in the following sections.

4.3 INFORMATION SYSTEMS IN SUPPLY CHAINS

4.3.1 Introduction

The information systems for supply chain management must address the fundamental activities in the supply chain, namely, buy – make – move – store – sell.

According to Oz andJones (2008:23), each of these activities may be linked to a specific module in the supply chain management system. It is as a result of the linkage of these activities to different modules and the capability of information systems to compute the effects of changes in these activities, that information systems allow the modelling of supply chains. The goal of modelling the supply chain is to capture the interdependency of the different activities that constitute the supply chain and to evaluate the consequences of local decisions on the entire supply chain. Govil andProth (2002:22) contend that the evaluation of the consequences of local decisions requires both algorithms and event triggers that will assist managers in accomplishing this type of evaluation.

Within this framework of supply chain modelling, supply chain information systems may assume the form of management information systems, providing the necessary information to supply chain managers, or decision support systems, and, thus, assisting supply chain managers in making decisions, or expert systems, by elaborating on possible scenarios and offering possible routes to solving complex problems, or a combination of the above scenarios and decisions.

According to Cuenca (2004:242–243), systems that are able to perform the above-mentioned tasks have been in development for the past 40 years, since the advent of the first computer. From a historical point of view, the first development in systematising the information flows about the production process became visible when the first, commercially available, materials planning software, termed MRP, appeared on the market Cuenca (2004:243–245) further elaborates that the MRP systems were soon developed into MRP II software, which was capable, not only of material planning, but also updated associated entries in an integrated production system. At the same time, distribution requirements planning (DRP) systems were developed on the basis of MRP in order to solve distribution relevant issues.

Further software development brought to light enterprise resource planning (ERP) systems, which may be installed throughout the entire organisation and which include all the fundamental activities as detailed above. ERP systems are set up to approximate the actual flows of material through the organisation, including the associated financial values. Accordingly, ERP systems attempt to integrate all the sub-processes across the entire organisation, in order to provide integrated, comprehensive and consistent information, especially event dates, to all the users (Cuenca, 2004:243).

In order to achieve real time updating of the ERP systems, the so-called manufacturing execution systems (MES) were utilised. MES typically interface with manufacturing machinery both to retrieve the occurrence of events, in this case, the occurrence of the start and completion of manufacturing processes, and to export the times and dates of such events to the ERP systems. MES also report on the general activities and states of the manufacturing equipment in real time which, in turn, enables managers to reaact in an appropriate manner to certain events.

Later developments in supply chain information systems include advanced planning and scheduling systems (APS), which enable organisations to improve customer service dramatically and to reduce costs (Van Eck, 2003:1). Other system improvements include the development of customer relationship and supplier relationship management (CRM & SRM) modules.

Based on the information above, supply chain information systems may be represented as depicted in figure 4.5 below.

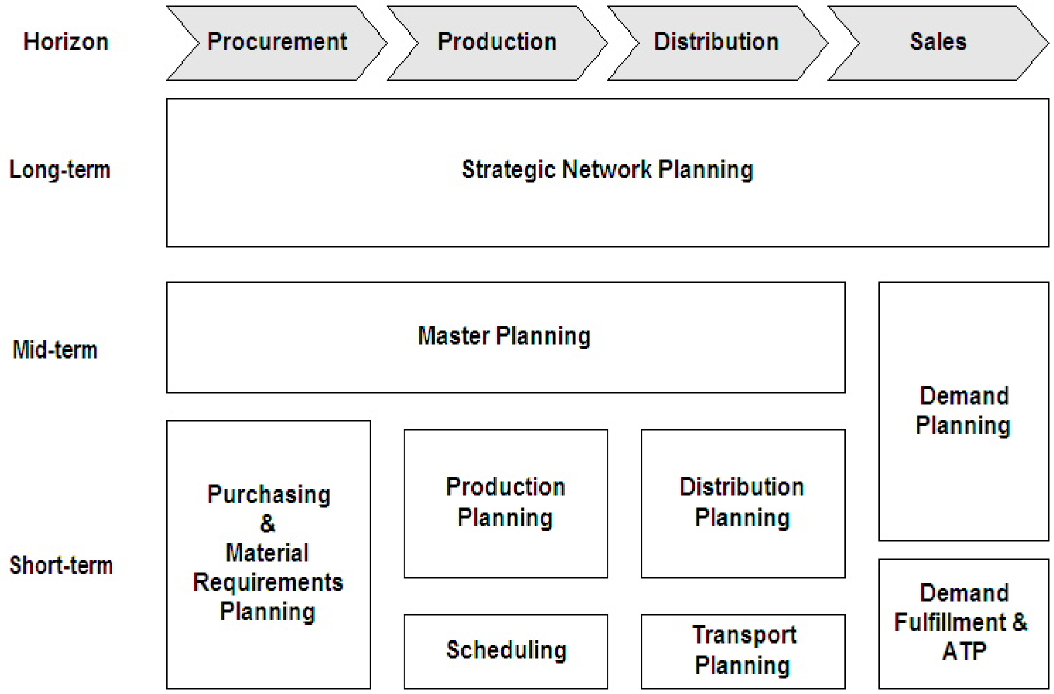

Figure 4.5: A supply chain planning system and software modules based on APS.

Source: Stadtler andKilger (2008:109)

Figure 4.5 clearly depicts all the necessary activities in the supply chain, from procurement to demand fulfilment.

In order to gain a better understanding of the nature and evolution of supply chain information systems, the different types of modules,as explained above, will now be discussed in more detail in the following sections.

4.3.2 Material requirements planning (MRP) systems

MRP, one of the first systems developed in the 1970s, could plan manufacturing situations in unlimited capacity models (Li, 2008:9–10). MRP combines the explosion of the bill of materials (BOM) with the concept of backward scheduling in order to arrive at the latest possible starting time for an order, based on lead times. MRP starts at the end item and progresses further down the BOMs by subtracting the lead times for each item of a BOM from the end item finish date in order to arrive at the latest start date of the manufacture of, or the purchase date of,the lowest level item. The timing and quantities to be ordered for each level of BOM depends on the requirements for parts by the parent item.

According to Knod andSchonberger, (2001:464–466), planned order release calculations must proceed from the first level to the second level, to the third level, and so on. This type of cascading through the levels of the BOMs achieves level-by-level netting of material requirements. This task is, however, further complicated by the fact that the same material may be part of a lower level item, but, at the same time, be required by another parent item. Moreover, these same materials may be part of other parent items. In total, it is essential that independent demand be combined with dependent demand in order to arrive at an overall requirement for a specific material. The end items are driven mainly by the master production schedule (MPS), which provides the necessary input into MRP. Figure 4.6 details the inputs and outputs of an MRP system.

Figure 4.6 clearly depicts the open order status, on-hand balances, planning factors, independent demands, end item requirement per planning bucket and the product structure as mandatory inputs into an MRP system. Running MRP produces planned order releases, rescheduling notices and management reports.

However, MRP systems, as described above, are one-way directed efforts. Valid material requirements are calculated based on the logic of the parent demand. Orders may be released accordingly but, once launched, the planning parameters actually encountered may differ significantly from those used to create the schedules. In addition, re-scheduling relies on notices, which must still be carried out manually and this mayconstitute a sizeable task, taking into account multilevel BOMs with hundreds or thousands of materials. Accordingly, MRP systems were further developed into distribution requirements planning systems and MRP II systems, which extend the logic of MRP further into the distribution requirements, in the first case, and also into closed loop manufacturing resource planning systems, as discussed in the following sections (Knod & Schonberger, 2001:475).

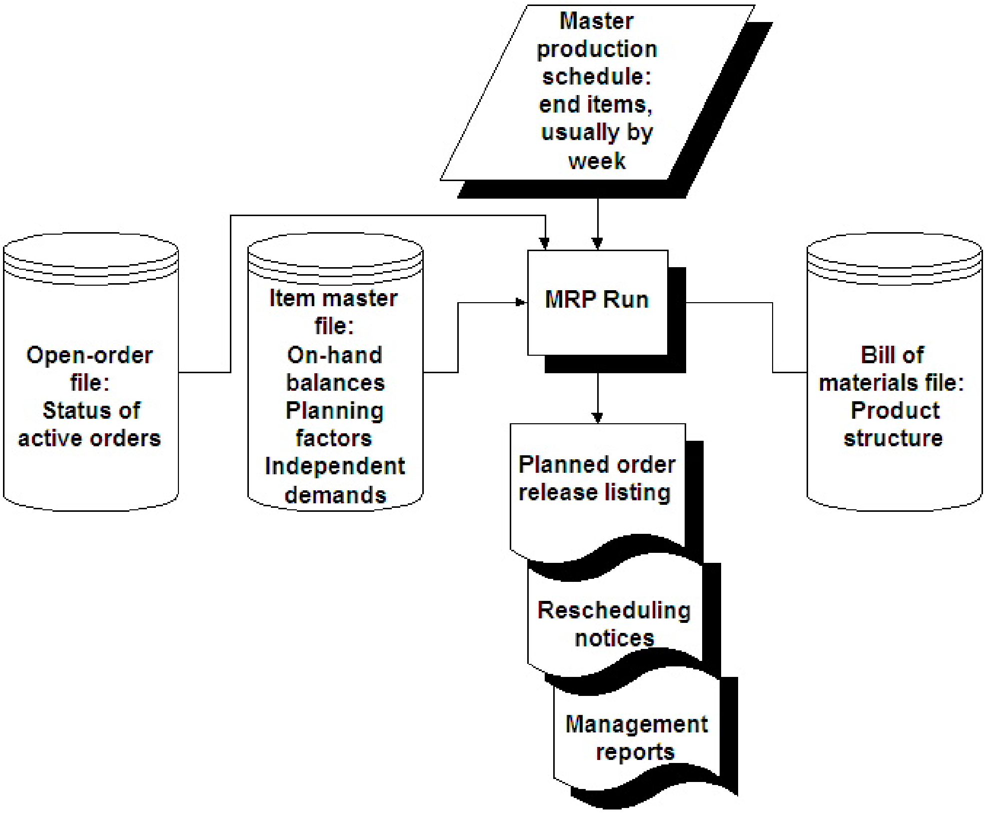

Figure 4.6: MRP system, with inputs and outputs

Source: Knod andSchonberger (2001:466)

4.3.3 Distribution resource planning (DRP)

A distribution network may consist of several, consecutive inventory points. According to Van Eck (2003:10), distribution networks may include a factory, a central distribution centre and national sales warehouses. Accordingly, the coordination of the different activities (i.e. sales forecast, orders, transport and inventories) is essential. By developing the principles of MRP into the realms of transportation and distribution planning, DRP systems emerged to handle the abovementioned activities.

Van Eck (2003:10) contends that DRP systems are information systems that support the co-ordination of distribution networks. The purpose of these systems is to record material flows and distribute this information to all points in the distribution network. Thus, DRP enables the coordination of decision making between the members of the distribution network.

4.3.4 Manufacturing resource planning (MRPII) systems

According to Gil, Serna & Badenes (2010, 183), MRP II systems are a direct extension of MRP I systems. They calculate capacity requirements in addition to the material requirements. On the basis of a required production program, MRP II back-schedules and back-calculates, from the delivery date, both the material requirements and the capacity requirements. This process provides early information of possible bottleneck operations or resource constraints in terms of machinery, people and material (Gil, Serna & Badenes: 2010, 183).

4.3.5 Enterprise resource planning (ERP) systems

ERP systems constitute an extension of the MRP II system. ERP systems are strongly integrated amalgamations of all the necessary functions of an organisation and have the capacity to unite all the internal transactions of an organisation (Cuenca, 2004:243–244). ERP systems specifically integrate the five most important business processes of an organisation, namely, finances, logistics, manufacturing, human resources and sales and marketing. Figure 4.7 depicts a typical structure of a common ERP system although it excludes human resources planning.

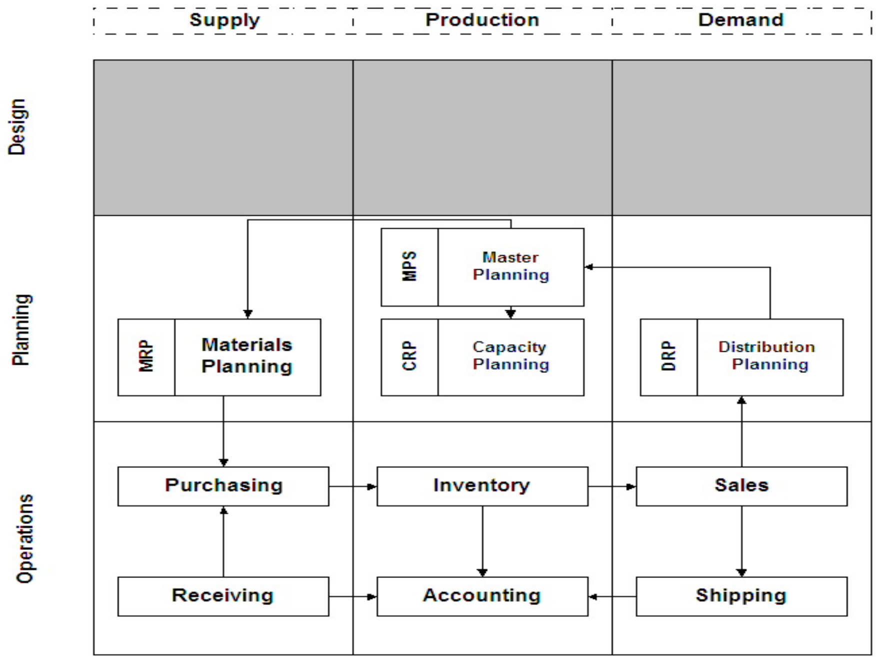

Figure 4.7: Structure of an ERP system

Source: Adapted from Taylor (2004:113)

Van Eck (2003:10) argues that ERP should be considered as the backbone of an organisation. It enables a company to standardise its information systems by providing a streamlined dataflow between the different business processes. ERP systems consist of different modules, which provide the necessary graphical user interfaces (GUI's) required for the business process represented by the specific module. Depending on the activation of various modules, ERP systems may be tailored to the needs of an organisation. Generally, ERP are able to handle tasks ranging from manufacturing transaction recording to balancing the books in accounting and reporting (Van Eck, 2003:10).

Accordingly, by using integrated ERP systems, it is possible to move the correct information to the right people at the right time. Those ERP systems that connect directly with the ERP systems of suppliers and customers, thus improving the efficiency of the information flow across the boundaries of organisations, are clearly especially useful (Cuenca, 2004:246). However, although ERP systems have the capacity to calculate capacity requirements, rescheduling is handled mainly by rescheduling notices, as is the case in MRP and MRP II systems, which must be acted upon manually. Relief from the tedious and time-consuming reprocessing of rescheduling notices was the basis for the concurrent development of the advanced planning system (APS) which, when coupled with ERP systems, is able to insert new start and end dates into the production orders and reschedule accordingly.

Another shortfall of ERP systems may be found in the updating of information. In many cases, information on the status of work done will only be fed back to planning personnel long after the event and, thus, updating of the system databases will occur only at that time. Clearly, the practice of updating system information after the event may not be sufficient in the interests of efficient communication with customers and order promising as well as ascertaining product availability. Thus, more organisations are deciding to use manufacturing execution systems (MES), in addition to APS. MES have the capability of extracting pertinent information from the shop floor in real-time and conveying this information in the ERP systems. MES are the topic of the following section (Greeff and Ghoshal, 2004:324-328).

4.3.6 Manufacturing execution systems (MES)

According to Tata Consulting Services (2002:1), manufacturing execution systems (MES) were developed to counteract the problems encountered in large manufacturing plants. In complex process plants, execution does not always run according to plan, no matter how good the plan. These difficulties may be the result of forecasting errors, capacity bottlenecks and process inefficiencies. However, these difficulties may give rise to a wide information gap, which is unacceptable, considering the fact that customers expect the timeous filling of their orders at competitive prices. Manufacturing execution systems were, thus, developed to bridge this gap.

MES control the operations that enable the realisation of plans and help to close any gaps in execution by providing links between shop floor instrumentation, control hardware, planning and control systems, process engineering, production execution, the sales force and the customers (Tata Consultancy Services, 2002:1).

Figure 4.8 below illustrates the relative position of an MES in the information systems hierarchy.

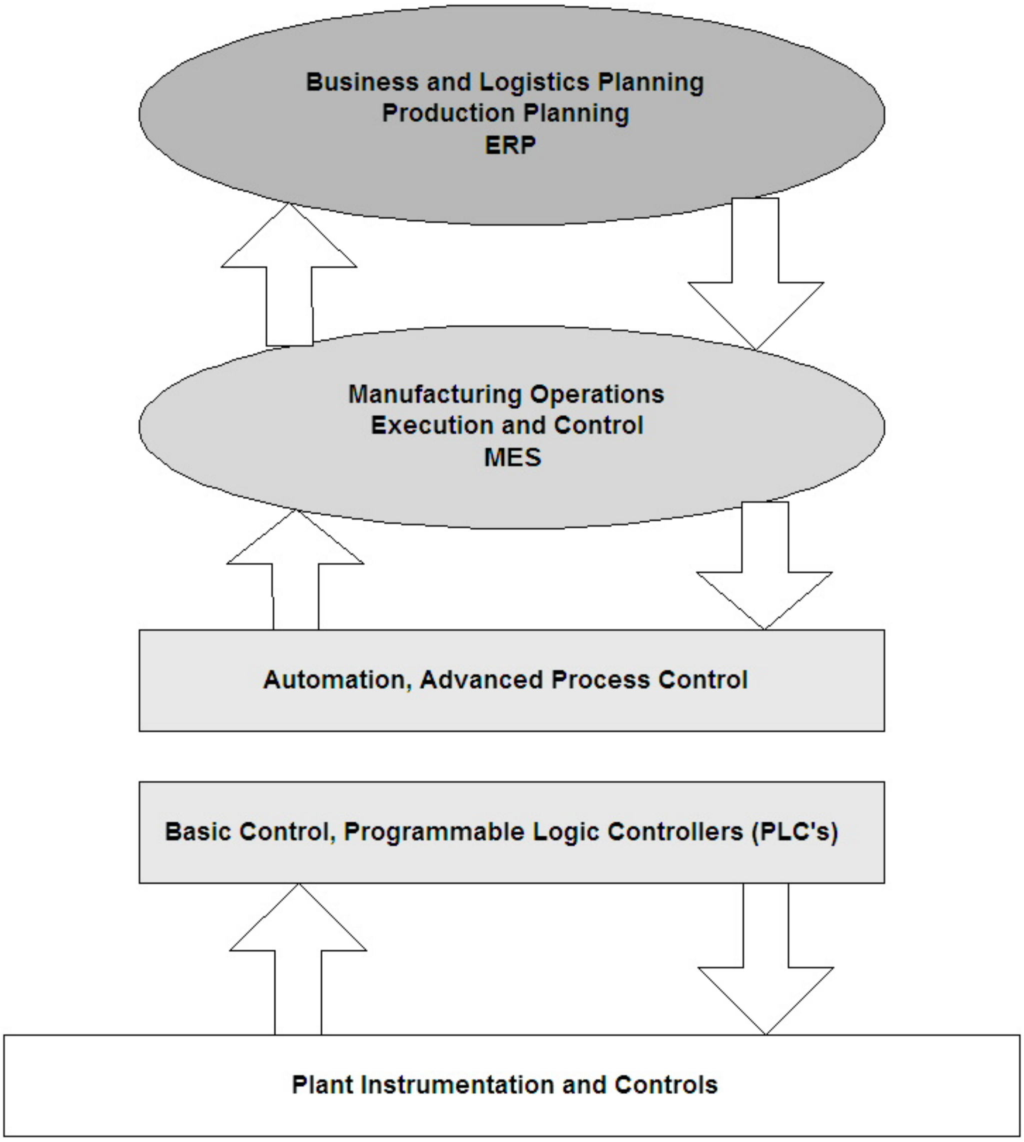

Figure 4.8: The relative position of an MES in the information system hierarchy

Source: Tata Consulting Services (2002:1)

As depicted in figure 4.8, MES integrate seamlessly with ERP systems, transmitting real-time data from the lower information level systems to the ERP system. MES deal typically with changes in the operations plan during execution, allowing for real-time updates and assessments of the impact of such changes in plans. MES also allow for more efficient resource management and resource allocation, including scheduling, equipment monitoring, preventative maintenance and direct and indirect cost allocation.

As indicated above, organisations tend to utilise the advantages of APS, in addition to MES,to enable more precise planning activities. APS will be covered in more detail in the next section.

4.3.7 Advanced planning and scheduling (APS) systems

Advanced planning systems evolved in an attempt to improve the performance of existing ERP systems or to act as umbrella systems combining all the existing systems within an entire supply chain (Van Eck, 2003:11). Accordingly, APS represents a revolutionary development in organisation and inter-organisation planning. APS typically utilise advanced mathematical heuristics and algorithms, which allows for the solution of constraint planning and scheduling situations. APS take into account a wide variety of possible constraints (Van Eck, 2003:11), including:

- material availability
- machine or labour capacity
- customer service level requirements
- cost
- distribution requirements
- sequencing of set-up and change-over efficiency
- inventory safety stock level requirements.

In an effort to achieve constraint resolution APS firstlyarrangethe orders on hand into a master production scheduling (MPS) fashion, then APS explode material requirements through MRP and, finally, APS resolve capacity and other constraints with the aid of closed-loop capacity requirements planning (CRP). According to Taylor (2004:116), APS may be set up to incorporate and model an entire supply chain network. APS is, thus, ableto solve supply chain constraints and communicate the solution to the different ERP systems of the supply chain members.

The structure of APS is depicted in figure 4.9. The structure is closely related to the one presented in figure 4.7, which depicts an ERP system. In contrast to the ERP system, APS support the levels of planning and design,but not operational requirements.

As an extension to ERP, APS and MES, many software manufacturers include new modules such as customer relationship management (CRM) and supplier relationship management (SRM). These will be the topics of the following sections.

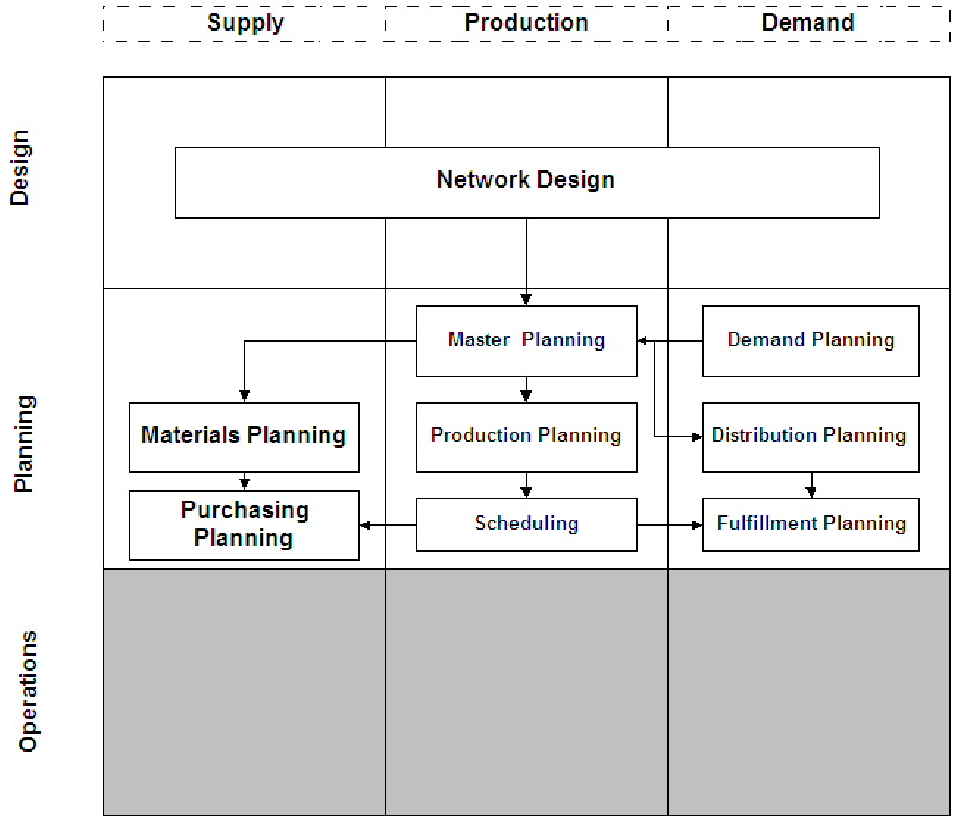

Figure 4.9: Structure of an advanced planning system

Source: Taylor (2004:115)

4.3.8 Customer relationship management (CRM) and supplier relationship management (SRM)

Supplier relationship management (SRM) involves the establishment of a working relationship between the supplier and the customer in terms of which both supplier and customer are enabled to act more efficiently than if each one were to act independently. According to Scala Business Solutions (2004:20), SRM entails the following activities:

- *Supplier lead time*. The amount of time normally required tomanufacture and ship the goods, that is, the period from the time the supplier receives the order to the time the customer actually receives the goods.
- *Supplier measurement*.The activity of measuring the supplier's performance in terms of delivery reliability, lead-time, quality, service and price.
- *Vendor managed inventory*.A supply chain performance improvement program, in terms of which the supplier has access to the customer's stock data and is responsible for maintaining the stock level required by the customer.
- *Continuous replenishment*.The supplier commits to replenishing the daily sales made by the customer, without receiving replenishment orders. This activity lowers associated stocking cost and increases stock turnover.
- *Supplier contract management*.Supply contracts define the relationship between customer and supplier and may include pricing, quantity decisions, delivery schedules and other details. Once established, contract performance may easily be monitored and it is possible to identify potential supply problems.

Many modern ERP systems, including SAP and others, cater for these activities in their purchasing and logistics modules, and no separate modules are required.

However, as regards customer relationship management (CRM), the situation is different. Traditionally, marketing strategies focused on the four P's (price, product, promotion and place) to increase market share with the main concern being the increase in the volume of transactions between buyer and seller. However, as a result of the fact that ERP systems were developed during the time in which the above marketing strategies were in force, ERP systems typically require only the information needed to support this type of marketing strategy (Gray & Byun, 2001:7).

Nevertheless, CRM is a business strategy which extends beyond increasing transaction volume. CRM attempts to maintain a relationship with customers, which promotes mutual benefit as well as repeat buying.

The three main components of CRM are customer, relationship and management. Gray andByu, (2001:8–9) explain these components as follows:

- *Customers*. The customer is the only source of a company's present profit and future growth. However, customers are knowledgeable and it is difficult to maintain customer loyalty in a climate of fierce competition. In addition, it may be difficult at times to differentiate who the real customer is, because buying decisions are often made by the participants of the decision-making process. Information technologies may assist in distinguishing and managing the customer. CRM, thus, constitutes a marketing approach that is based on customer information.

- *Relationship*. A relationship between a customer and the selling company requires bidirectional communication and interaction. Relationships may be either longterm or shortterm, continuous or discrete and repeating or one-time. Attitudes and behaviours also determine the nature of the relationship. Although a customer may have a positive attitude towards a company, the customer's buying behaviour may be highly situational and favour the products of competitors. CRM involves managing this relationship in such a way that it is both profitable and mutually beneficial.

- *Management*. The customer information collected is transformed into corporate knowledge that enables activities that take advantage of both the information and of market opportunities. Specific software to support the management process includes:

    i. field service
    ii. e-commerce ordering
    iii. self-service application
    iv. catalogue management
    v. bill presentation
    vi. marketing programmes
    vii. analysis applications

All of these techniques and procedures are designed to promote and facilitate the sales and marketing function.

4.3.9 Supply chain management (SCM) systems

SCM systems depend mainly on successful supply chain planning results and coordination. According to Van Eck (2003:18), the supply chain planning function uses a forecast and factors which are in actual demand, after which a constrained operations plan for manufacturing and distribution is generated. The output of the supply chain planning process constitutes a constrained multi-plant, master plan, which also takes into account material availability and the capacities in all the available plants. For some industries, transportation requirements, set-up sequencing and economic order sizes are also taken into account. Taylor (2004:227) contends that a combination of an APS, which is connected to the individual ERP system, is the most efficient way of carrying out supply chain planning − see figure 4.10. The supply chain planning team uses the APS to explode the requirements, run MRP and schedule the orders and material, capacity and transportation requirements of the entire supply chain as well as to transmit the optimised plan to the ERP systems of individual supply chain member. Any changes in demand will be handled in a similar manner.

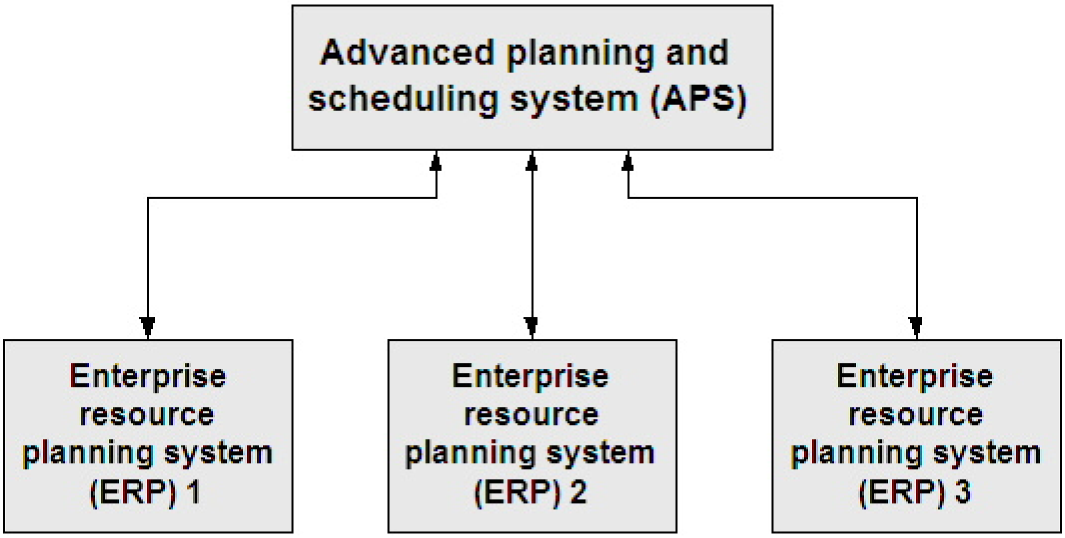

Figure 4.10: Supply chain planning system

Source: Adapted from Taylor (2004:227)

4.3.10 Business process management (BPM)

Although business process management (BPM) and business process optimisation (BPO) are not information systems in their own right, they are, nevertheless, a prerequisite for the correct functioning of many of the information systems encountered in the supply chain and,thus, warrant being mentioned in this section.

Business process management involves the management of an interrelated series of activities that convert business inputs into business outputs (Scala Business Solutions, 2004:10). A typical characteristic of business processes is that they operate across functional boundaries. BPM also entails organising resources and responsibilities around core processes and core tasks instead of around general business tasks and business functions. Scala Business Solutions also point out, that as explained above, the supply chain crosses not only functional, but also organisational, boundaries. Accordingly, business processes management needs to work across multiple functions and organisations. It is, thus, clear that informationsystems that support the supply chain, such as the ERP and APS systems, need to follow these business processes so as to be able to take advantage of the information contained in and flowing from the individual information systems. It is, thus, essential that information systems be synchronised with the actual business processes with BPM and BPO, therefore, playing an integrative role in supply chain management.

4.3.11 Conclusion

In conclusion, the information systems in the supply chain may be categorised by application. In this respect, it is, thus, possible to differentiate between management information systems, decision support systems, and expert systems. From a historical perspective, the emergence of supply chain information systems is closely related to the evolution of information technology. The first systems developed dealt with the solving of complex inventory problems.

This development continued with the implementation of more complex mathematical algorithms to resolve constrained storage, material requirements planning and transportation problems and, as computational power further increased, complex planning scenarios and closed loop finite capacity scheduling problems were resolved. Today, software vendors offer entire organisation planning solutions as well as advanced planning and scheduling systems that integrate into the ERP systems which enable the implementation of constrained capacity planning,the automatic updating of order dates and other important supply chain events. Furthermore, manufacturing execution systems integrate with production machinery and control equipment to provide the real-time posting of events taking place on the production floor in the ERP systems. In order to promote customer relationships and supplier relationships, special modules were created. In conjunction with APS, ERP and MES, entire supply chain solutions were developed to address the complex decision making processes in terms of product movement and information sharing within such supply chains.

The following sections will illustrate some of the features of commonly encountered and commercially available supply chain software.

4.4 COMMONLY ENCOUNTERED APS, ERP AND SCM SYSTEMS INPRACTICE

4.4.1 Introduction

The requirements for and implementation levels of ERP and other supply chain software become apparent when one considers published statistics onthe turnover of software vendors, as well as the users of such software. Statistics published by both Trebilcock (2010:26–28) and Burns (2006:1–7) show that SAP and Oracle dominate the high-end,organisation market place, while the mid-market belonging to smaller ERP vendors is large and fragmented with no definite leader. This market segment includes larger organisations such as Microsoft Business Solutions, Infor and Manhattan Associates. Some of their products will be explained in more detail below.

4.4.2 SAP

According to Cuenca (2004:264), SAP is the leader in the supply of supply chain and e-business solution software. SAP offers different solutions. The standard ERP solution is known as R/3, whereas the mySAP business suite offers open business solutions via the Internet MySAP consists of the following solutions (Cuenca, 2004:265):

- *mySAP ERP*.Provides complete functionality for business analysis, finance, human resources management, operations and cooperative services. In addition, this solution also offers configuration and user management as well as central data administration.

- *mySAP CRM*.Offers a complete solution and all the functions necessary for the planning and management of marketing, campaign management, telemarketing and market and client segmentation.

- *mySAP SCM*.Provides functionality for the coordination and realisation of financial processes, information on materials and exception reporting. Furthermore, mySAP SCM enables planning, execution and collaboration in the supply chain.

One of the most significant attributes of all SAP products is the inherent integration of information and data throughout all the implemented modules. SAP also enables the updating of information by several users simultaneously and in real time. This, in turn, implies that the system is presumed to be always up-to-date, complete and correct. As already indicated, the system consists of several modules (See figure 4.11) which function in a fully integrated manner. In addition, SAP also offers a programming language termed ABAP/4, specific to SAP, which allows the programming of special reports and functionalities.

The different modules perform the following functions (Cuenca, 2004:268–271):

- Module FI (Financial accounting): This component of the application of financial accounting satisfies the necessary international requirements, with which the department of financial management of a company must comply.

- Module CO (Controlling): This module is a complete, integral system for the general control of expenses. It offers the functionality that is necessary to capture the structure of an organisation in the form of cost centres which, in turn, clearly define the organisation in terms of responsibilities.

- Module TR (Treasury management): The objective of this module is the integration of the administration of cash and the provision of liquidity for the logistics activities of the company. The module includes tools for the analysis of the money market, bonds and derivatives and the analysis of exchange risk.

- Module PS (Project system): The project system supports the management of projects throughout all project life cycle phases (concept, construction, cost planning, estimation, realisation, and closure). This module may be applied to all types of projects, including investment, marketing, R&D, construction, and installation, etc.

- Module MM (Materials management): This module encompasses all the activities connected with the logistics function in terms of requisitioning, purchasing and inventory control.

- Module SD (Sales and distribution): The individual components of this module allow for the management of all the activities related to the commercial and sales activities, including, inter alia, orders, promotions, offers, competitions, follow-up of calls, planning, and campaigns. The applications of the SD module have aextensive interrelation with the other modules of SAP R/3, namely, production, materials, costing, quality, projects, human resources, etc.

- Module PP (Production planning): This module has been designed for use in any industrial sector and provides comprehensive processes for each type of manufacturing. The planning of operations, which takes into account all orders or projects on hand, differs from the traditional planning of requirements as determined by MRP. The system offers well-accepted methods for the planning and control of materials to be produced.

- Module PM (Plant maintenance): The plant maintenance module provides planning, control and processing of scheduled maintenance, inspection, damage-related maintenance, and service management to ensure the availability of operational systems, including plant and equipment delivered to customers.

- Module HR (Human resource): The HR module is designed to map all the departments of the organisation, as well as the employment history, payroll, training and qualifications of employees. The HR module also encompasses career management and succession planning, environmental health and safety management, recruitment and resource budget planning.

- Module QM (Quality management): This module monitors, captures and manages all processes relevant to the maintenance of quality in the supply chain. Within this module, it is possible to coordinate inspections of processes as well as arrange for the initiation of corrective actions.

- Module WF (Workflow): This module encompasses functions that may be used in all application components, linking the integrated application modules with cross-application technologies, tools and services. A typical example of a business process that may be actively controlled using SAP Business Workflow is the complete processing of a customer order from its receipt through to delivery of the goods and the issuing of the invoice. These steps may be automated in this business process and they define all the roles of the appropriate employees. It is possible to check a customer's credit line and creditworthiness, query the stock on hand, and automatically place an order. Clerical staff are able to process the individual work items in a working environment familiar to them, request information on the current status of specific workflows at any time, and trace the history of the work process. In addition, all these functions may also be accessed through the Internet.

- Module IS (Industry solutions): This module combines the R/3 application modules and additional industry specific functionality. The following include some of the industries for which modules have been developed:

    i. Aerospace anddefence
    ii. Automotive
    iii. Banking
    iv. Chemicals

v. Consumer products
vi. Engineering andconstruction
vii. Healthcare
viii. High tech andelectronics
ix. Higher education andresearch
x. Insurance
xi. Media
xii. Mill products
xiii. Mining
xiv. Oil andgas
xv. Pharmaceuticals
xvi. Project-oriented manufacturing
xvii. Public sector
xviii. Retail
xix. Service provider
xx. Telecommunications
xxi. Utilities

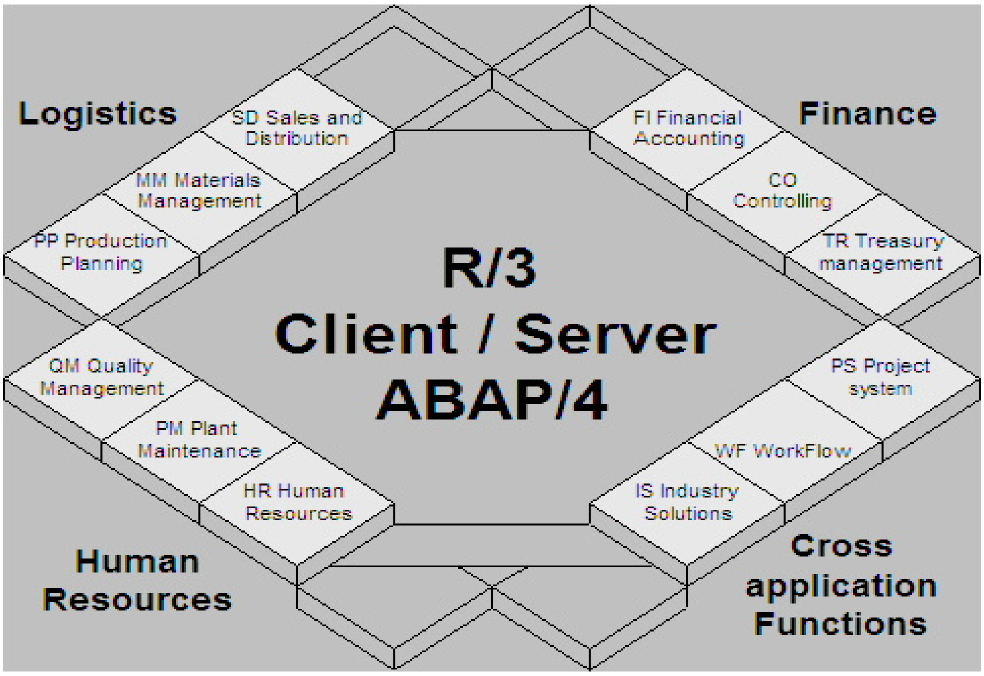

Figure 4.11: The modules of SAP R/3

Source: Adapted from Cuenca (2004:268)

4.4.3 Oracle

Oracle offers a large variety of ERP software, including Oracle based Oracle Fusion Applications and Oracle E-Business Suite, as well as acquired products such as Peoplesoft Enterprise, JD Edwards EnterpriseOne, JD Edwards World, Siebel CRM, Primavera, Agile, AutoVue, as well as several other products that integrate different parts of the software available in order to optimise the software output (http://www.oracle.com/us/corporate/acquisitions/index.html).

Oracle produces software for industries including, but not limited to, the communications industry, higher education and research, engineering and construction, financial services, automotive, aerospace, chemicals, healthcare, insurances, natural resources, media and entertainment, and retail (http://www.oracle.com/us/industries/index.html).

4.4.4 Microsoft

Microsoft offers a variety of ERP solutions, depending on company size.

In particular, these solutions include Microsoft Dynamics AX, Microsoft Dynamics NAV, Microsoft Dynamics GP and Microsoft Dynamics SL (http://www.microsoft.com/en-us/dynamics/erp.aspx).

Microsoft Dynamics NAV is a complete enterprise resource planning (ERP) software solution for medium-sized organisations. This product is an integrated business management solution that meets the wide requirements of the medium market organisations, inclusive of service, retail and manufacturing and distribution organisations. Microsoft Navision constitutes a fully functional ERP solution complete with Internet functionality (http://www.microsoft.com/en-us/dynamics/erp-nav-overview.aspx).

Microsoft Dynamics AX is tailored for the medium to large size company market. As a multifunctional ERP system, Microsoft Dynamics AX encompasses production and distribution, supply chain management (SCM) and project management, financial management and business analysis tools, customer relationship management (CRM) and personnel management. Microsoft Dynamics AX is, thus, a tool with which to create a connected, companywide, information space. In addition, its integrated database ensures the increased managerial efficiency of the enterprise (http://www.microsoft.com/en-us/dynamics/erp-ax-overview.aspx).

Microsoft Dynamics AX-based solution may be easily tailored to suit the company's business specifics as a result of the safe and flexible development environment.

The third product, Microsoft Dynamics GP, is a richly featured, financial accounting and business management solution that allows familiar, powerful software to operate and grow the business. It is possible to choose from the Business Essentials (BE) and Advanced Management (AM) editions of the pre-selected, software modules available for Microsoft Dynamics GP, and add modules to complete the business management solution (http://www.microsoft.com/en-us/dynamics/erp-gp-overview.aspx).

Designed for project-driven organisations, Microsoft Dynamics SL is the fourth product offered by Microsoft.Microsoft Dynamics SL is an enterprise resource planning (ERP) solution that helps streamline business processes, deliver insight, and connect project management and accounting across company divisions and locations (http://www.microsoft.com/en-us/dynamics/erp-sl-overview.aspx).

4.4.5 Infor

The company, Infor, offers a full range of enterprise business software, including enterprise resource planning, global financial management, human capital management, corporate performance management, customer relationship management, product lifecycle management, business intelligence, supply chain management and supplier relationship management.

Infor's solution portfolio of end-to-end core ERP and other solutions (supply chain management, supplier relationship management and product lifecycle management) extend ERP across and beyond an enterprise. Infor CPM helps analyse and measure performance across the entire business while Infor Open Architecture provides a common, modern infrastructure that unifies interfaces and standardises connectivity.

4.4.6 Manhattan Associates ERP

Manhattan Associates (http://www.manh.com/solutions/index.html) provides solutions to manage the entire supply chain more efficiently. Manhattan SCOPE®: Supply Chain Optimisation − Planning through Execution − is the embodiment of Platform Thinking. The Platform Thinking ecompasses the fact that Manhattan Associates believe that supply chains operate on platforms of visibility, holistic intelligence, flexible workflows and shared common elements, which create endured competitive advantage. Manhattan SCOPE enables "whole chain awareness"–thepower to see and act in ways that factor in storage, labour and scheduling constraints; transportation capacity, routing plans and fuel cost parameters; and inventory planning and buying decisions −-whether real-time or ahead of time − so that company performance is optimised at all times.Manhattan SCOPE is designed to deal with a complex supply chain and to increase profitability and service levels. SCOPE provides a complete range of applications − from planning through to execution – and is aimed at optimising every link of a supply chain.

SCOPE applies predictive technologies, a common process platform and key visibility, intelligence and adaptive functionality to leverage the spectrum of people, tasks and events across a supply chain for efficient, accurate performance. In addition, SCOPE's modular, service-oriented architecture facilitates the creation of cross-suite applications to address specific requirements.

Manhattan Associates' Supply Chain Solutions include:

- Planning and forecasting

- Inventory optimisation
- Order lifecycle management
- Transportation lifecycle management
- Distribution management

The above supply chain solutions are used by four distinct platform applications:

- Total cost to serve
- Supply chain intelligence
- Supply chain visibility
- Supply chain event management

Together with cross-application-optimisation, Manhattan Associates' Supply Chain Solutions provide real-time and optimal supply chain solutions.

4.4.7 Conclusion

The ERP and supply chain software discussed above deals with the products of the largest supply chain software vendors only. However, as statistics show, (Burns, 2006:1–7; Trebilcock, 2010:26–28) there numerous software suppliers, especially if one includes MES and APS software. In addition, the statistics indicate that this market is growing, which proves that more and more supply chain software is being purchased and implemented. This growth in supply chain software use clearly points to the fact that organisations are not able to cope with the high customer expectations in a fast-paced world, without employing the assistance of information systems which focus specifically on solving complex supply chain planning and execution issues. The software described above clearly exhibits a high degree of sophistication, considering the number and types of modules implemented. Furthermore, the development and search for better and more advanced tools is ongoing with software vendors continuously upgrading and improving their products in an attempt to make the software more user-friendly, and to provide new tools for the various industry sectors. Advances in computer technology and the desire for a tighter, more integrated supply chain in terms of information flows, material and financial flows are driving this development.

4.5 CONCLUSION

The information systems described included mainly computer-assisted systems, which accept data and information with the aid of numerous input devices, process the data into information, store the data and information and present the result of the processing task on suitable output devices. It was revealed that the individual parts of the system are interrelated and, thus,that the system is an open system. As a result of the high transaction and storage capacity of computers, information systems are utilised in several different areas and for many different purposes. Based on the categorisation of the information systems, it is possible to differentiate between management information systems, decision support systems, expert systems, transaction processing systems and artificial intelligence systems. In order to increase the efficiency of information systems, it is possible to connect such systems to each other to form networks. In this network configuration it becomes possible to transfer information to and to use information from locations close to each other, or as far apart as the circumference of the earth allows.

Information systems play an important role in supply chain management. Firstly, information systems in the supply chain integrate the supply chain tightly insofar as information will become available when and where it is needed and in the correct format. Secondly, information systems in the supply chain or combinations of such systems are able to process transactions and data in real time. Thirdly, the information systems used to manage the supply chain are able to assist in decision making on strategic, operational and tactical levels. The objective in these three cases is to provide information as quickly and efficiently as possible − the topic of this research. This research will specifically investigate the information flow efficiency within members of the supply chain.

In view of the fact that information systems are designed to improve the information flow efficiency it is, therefore, important to provide an in-depth understanding of information systems, especially those used in supply chain management and, hence, the content of this chapter. The following chapter will discuss the basic concepts of business performance measurement in order to lay the foundation for the measurement of information flow efficiency.

CHAPTER 5
BUSINESS AND SUPPLY CHAIN PERFORMANCE MEASUREMENT

5.1 INTRODUCTION

Business organisations encounter manifold and ever-changing challenges within their business environment. In order to remain competitive, it is essential that organisations constantly monitor and, possibly, revise their strategies. These strategies include operational, marketing and supply chain strategies.

Specifically, supply chains are gaining prominence over all other business processes (Kasi, 2005:1). The supply chain spans many organisational functions and multiple organisations (Harrison et al., 2003:63). In an effort to improve both production efficiency and product quality, organisations began to examine the design and members of the entire supply chain more closely (Baiman, Fischer & Rajan, 2001:173).

It is essential that the decisions made with regard to the supply chain should be aligned to the overall corporate strategy of theorganisation concerned (Carter, Monczka, Ragatz & Jennings, 2009:6; Mohamed, Hui, Rahman & Aziz, 2008:153). In determining whether the strategic goals of a business have been realised, Antic andSekulic (2006:71) contend that organisations use a variety of business performance metrics, which are assessed periodically. Beckinsell (2001:5) defines a set of strategically important performance metrics as a performance measurement system.

Historically, business performance measurement systems were mainly, and often solely, financially oriented (Neely, 2003:3). Depending on the chief area of concern, it is possible to calculate various financial ratios, including, inter alia, current ratio, inventory turnover period and debtors to sales ratio. Neely (2003:6–9) maintains that these metrics accentuate different aspects of financial performance.

However, List andMachaczek (2004:1) and Rajamanoharan andCollier (2006:53) argue that financial figures are consequences of the decisions of yesterday and, thus, they do not indicate tomorrow's performance (see also Kaplan& Norton, 1996). In addition, financial metrics remain the preserve of the financial function, although it is well known that financial problems may also occur as a result of deficiencies in other functional areas of anorganisation. Furthermore, increased competitive environments, especially when considered from a global perspective, provide for similar input costs for the different industries. Accordingly, businesses need to consider, not only financial performance, but also performance in non-financial areas, such as customer satisfaction, innovation and internal parameters and process improvements. For this reason, business performance measurements are, increasingly, including non-financial indicators (Paranjape, Rossiter& Pantano, 2006:5). According to Verweire andVan Den Berghe (2003:4), several different frameworks for business performance measurement have been developed, with these frameworks concentrating on strategic alignment. Taticchi, Balachandran andLunghi (2008:1) report the evolution of performance focused on a financial perspective to focus on a non-financial perspective.

List andMachaczek (2004:1) point out that modern organisations use data warehouses and this, in turn, facilitates performance measurement. According to List and Machaczek (2004:1), the main design focus of data warehouses today is on customer-related metrics, such as customer satisfaction, customer relationship management, customer retention, new customer acquisition, customer profitability and market and account share. Thus, together with the traditional financial measurements, a much broader business performance measurement framework is being created. However, depending on the performance measurement model utilised, the set of measurements included in each model varies. However, the key to business performance management remains the integration of financial, operational and strategic information (Winkler, 2004:1; Antić & Sekulić, 2006:74).

Other models that include communication metrics are described by Schuppener (sa:1–20), who prepared a *communications scorecard* (CSC) which measures the added economic gains, within the four perspectives of the balanced scorecard, by using communication instruments. In addition, Zerfass (2004:1–7) proposes the *corporate communications scorecard (CCS)* for the strategic control and measurement of an organisation, in terms of the organisation's communications strategy with its stakeholders, and using the social-political performance of an organisation as an additional perspective with which to measure communication success. These models are of particular interest to this study as they represent measurement frameworks which already include communications metrics. If feasible, a similar concept could be considered for the indicators and metrics of information flow efficiency, given the fact that it is possible to identify a suitable measurement framework.

This research concentrates specifically on the measurement of information flow efficiency as an appraisal of the performance of either the members of the supply chain or the entire supply chain in terms of efficient information flow. However, in order to develop a set of indicators capable of assessing information flow efficiency, it is necessary to gain a deeper insight into the principles of measurement, performance measurement and performance measurement systems, as applicable to businesses and supply chains. The following section will discuss these basic concepts in greater detail.

5.2 BASIC CONCEPTS

5.2.1 Introduction

Business performance measurement comprises two concepts, namely, business performance and measurement. Measurement requires the development of a measurement framework which relates the strategically important key performance areas (KPAs) to individual key performance indicators (KPIs) and the metrics pertaining to each indicator. These metrics provide values for individual performance criteria of each indicator. The metricsmay be measured either directly or indirectly, quantitatively or qualitatively. In addition, the outcome of the assessed metrics for each indicator may be analysed in relation to each other in order to yield the required information about the relevant KPI (Antić & Sekulić, 2006:75).

A multidimensional performance measurement and analysis system is the basis of an effective strategic control system (Antić & Sekulić, 2006:74). According to Antić and Sekulić (2006:74), the multidimensional approach to measurement arises from multidimensional business and management processes and it implies a set of relevant indicators and metrics focused on process performances, as the expression of the contribution of these process performances to the realisation of business goals.

Accordingly, the combination of performance and measurement leads to the following definition that may be applied in general and also to businesses. Performance measurement may be defined as “the process of quantifying the efficiency and effectiveness of past actions and comparing the obtained quantity to a reference” (Bocci, 2004:1; Giannoccaro et al., 2007:91–92). Mahidhar (2005:57) defines business performance measurement as “the process of measuring efficiency, effectiveness and capability, of an action or a process, or a system against given norms or targets”. This definition includes three dimensions, namely, efficiency, effectiveness and capability. Effectiveness is a measure of the performance of the correct activity, whereas efficiency refers to performing the activity correctly, thus referring to the economical utilisation of resources. On the other hand, capability refers to the extent of the ability to applying the correct process (Mahidhar, 2005:58). Business performance measurement is a process in terms of which measurements are taken either continuously or at certain intervals with the results of the measurement being compared to a standard or targetAny deviation from either the standard or the progress towards the target will lead to decisions and actions to align the outcome of a process to the required standard or target In brief, this process describes that of a management process, in this case, the performance management process. The latter will be discussed in more detail in the following section.

5.2.2 The role of business performance measurement systems

According to Kellen (2003:3), business performance measurement systems are formal, information based routines and procedures, which are used by company managers either to alter or to maintain the pattern of organisational activities or business processes, with the aim of achieving strategic goals (Mohamed et al., 2008:154).

Inherently, this definition requires the description of indicators that may be compared to strategic goals. The measurement of business performance metrics enables the managers and employees of an organisation to monitor and control resources in order to achieve set targets with gaps between targets and measured performance pointing to the need for either improvement or intervention.

Performance may be monitored at all levels of anorganisation − from the strategic level through the tactical level to the operational level (Antić & Sekulić, 2006:73). At the strategic level, deviations between the desired strategic performance and achieved performance are identified. The level and direction of performance deviation provides input for tactical decisions. Accordingly, measurement at the tactical level may include monthly reports dealing with the performance of a function or division.

Performance measurements should be analysed in order to facilitate decisions to align actions with strategic objectives and provide feedback on business or supply chain performance and internal capabilities (Mahidhar, 2005:60). Accordingly, Mahidhar (2005:60) asserts that the decision process requires the selection of appropriate performance metrics and targets that will align the behaviour of employees and processes so as to achieve the desired actions and strategies − a prerequisite for a successful business.

5.2.3 The business performance measurement process

Performance measurement refers to an ongoing process of capturing information on the different dimensions of the performance criteria which are important to an organisation for assessing the different dimensions of those aspects of performance that are the most important to the organisation. Performance measurement takes into consideration outcomes from the process (typically achieved results per time period), outputs (deliverables), inputs into the process (resources, staff) and the efficiency of the process. According to CGIAR (2003:9), the set of indicators and metrics comprising the performance measurement system should reflect the ability of an organisation both to achieve and to sustain excellent results on a strategic level. From a strategic point of view, the implementation and maintenance of a performance measurement system or process is clearly illustrated in figure 5.1.

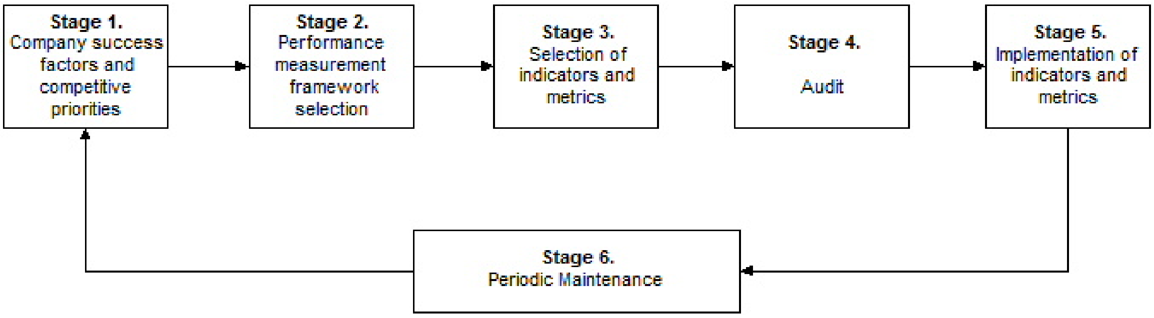

Figure 5.1: Model for the development and maintenance of a performance measurement system

Source: Adapted from Mahidhar (2005:84)

In stage 1, the model requires that strategic company success factors and competitive priorities be defined and also measured. A suitable measurement framework is selected in stage 2, and the requirements are matched against competitive priorities in a performance measurement grid. In stage 3 the important KPI's are then selected from the available list of performance indicators and metrics. The selected key performance indicators are audited in stage 4. Existing key performance indicators that are congruent with strategic goals are retained, while key performance indicators that divert from the new strategic goals are replaced with new key performance indicators. The new key performance indicators are implemented and maintained in steps 5 and 6.

As indicated above, business performance is a continuous process of recording information about the actual performance in thevariousKPAsthat are required to ensure the continued success of a company.

Whilst figure5.1 describes both a high level overview of a performance measurement system and also the way in which performance measurement is implemented, the actual process of measuring, evaluation and feedback is described in the performance measurement process depicted in figure 5.2. This performance measurement process is applicable to either an entire organisation business process or to individual business processes that need to be either monitored or improved. The main emphasis in this performance measurement process is to be found in the fact that the business processes must be congruent with both competitive priorities and business success factors.

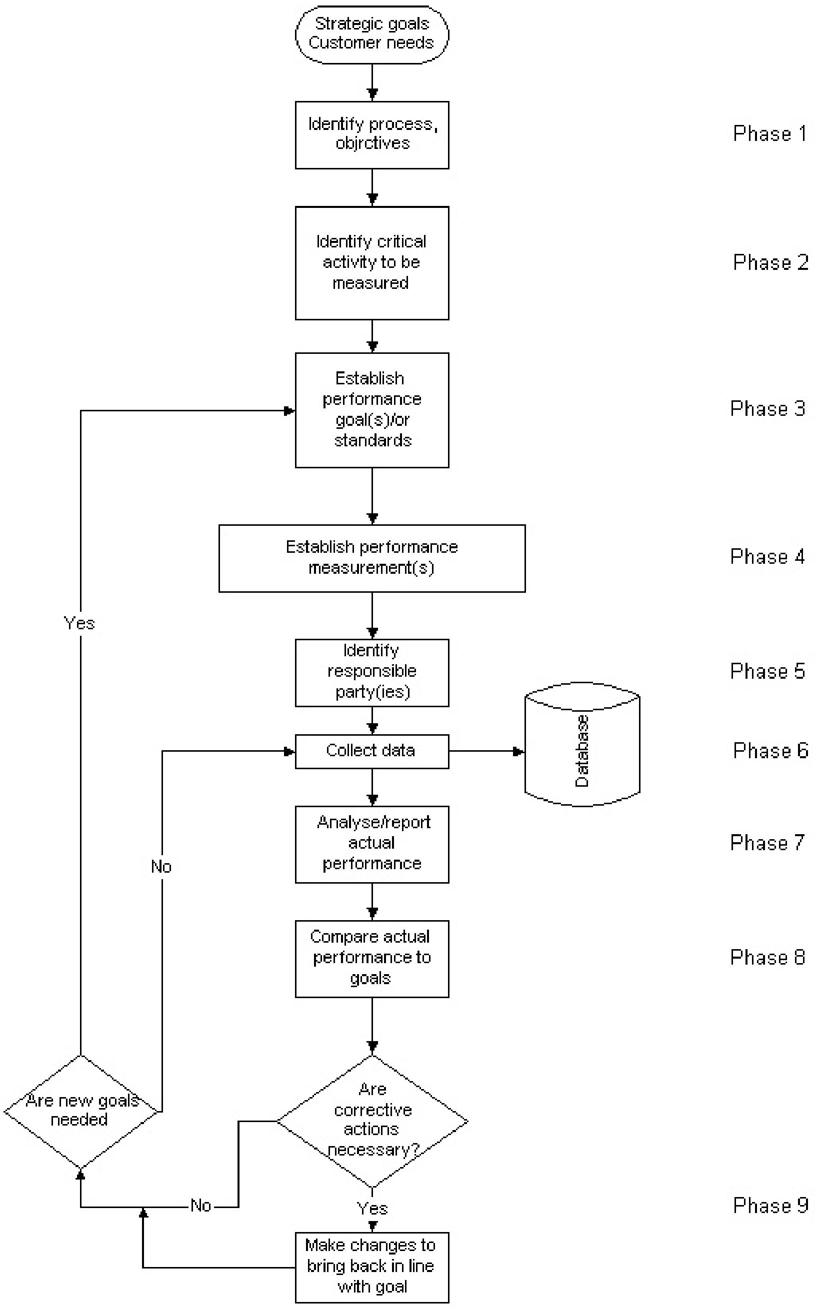

Figure 5.2: The performance measurement process

Source: Adapted from ORAU (2001:i–v)

In phase 1 the strategic priorities and objectives are identified with these priorities and objectives constituting the input into the measurement processes. It is important that everybody in the organisation agree to these objectives and to the subsequent key performance indicators and metrics, otherwise an efficient performance measurement of the business process to be evaluated will not be possible.

In phase 2 the critical activities to be measured are identified. The critical activities are those activities which are most important to the success of the business process. In view of the fact that these activities will be monitored in the future, it is essential that individual performance goals be defined.

The performance goals relating to the business process are established in phase 3. Performance metrics should be tied to a goal. The existence of goals is the only way in which to interpret the results of the measurements in a meaningful way.

Phase 4 establishes performance measurements. In this step different individual indicators and metrics are identified in order to build a complete performance measurements system.

The responsible parties associated with each step of the business process are identified in phase 5. Specific personnel need to be assigned the responsibilities for a specific performance measurement process.

Data is collected in phase 6. Data needs to be captured and pre-analysed in a timely fashion in order to determine early trends and to ensure the adequacy of the data.

In phase 7, the actual performances of the critical activities are analysed and reported. The raw data must be converted into performance metrics and be displayed in an understandable format.

Actual performance is compared to goals in phase 8. This step determines any variation of actual performance to the required standard.

Phase 9 establishes whether corrective or even proactive actions are necessary. Depending on the magnitude of the variations between measurements and goals, corrective actions may have to be instituted to bring the process back into line with the goals set.
It may be necessary to effect changes in order to bring the business process in line with the goals. If corrective actions are required, then the type of intervention needs to be determined. Another important question that is answered in this phase

is whether new goals are needed. Goals and standards need periodic revision in order to keep up with the latest organisational process and any changes which may have been made to them. In general, goals need to be challenging, but also achievable. If it is not possible to attain goals or if great difficulty may be experienced in attaining the goals then it may be reasonable to readjust the expectations. On the other hand, goals that were easily met also need to be adjusted.

The above process is also often referred to as business performance management − see the following definition.

According to CGIAR (2003:8–9), performance management refers to “using information on performance to guide decision making on future goals, plans and institutional actions. It is a continuous process of translating overall institutional” or company “goals into individual actions and outputs, or aligning strategic goals with intermediate outcomes and activities at all levels within the institution or company”. Accordingly, the process of performance measurement should facilitate decision making with regard to strategic objectives and provide feedback to the strategic level on operational performance and internal capabilities.

5.2.4 Conclusion

The above sections discussed the basic concepts underlying business performance measurement and the management process. Business performance measurement was defined as a measurement of efficiency, effectiveness and the capability of processes or past actions and of comparing the quantity measured to a reference or standard.

Business performance systems play an important role in performance measurement. Businesses measure the performance targets of their actions and processes and compare the outputs and outcomes to preset standards/targets in order to determine the alignment of the organisation’s actions with its strategy. However, as the business environment changes, so do strategies often need to be adapted to remain successful. Accordingly, it is essential that the performance measurement systems be reviewed periodically to ensure that the correct indicators are being tracked and that the indicators are still valid in terms of the changed process or environment.

The performance measurement system provides the input for the management of performance. The quantities measured are generally compared with set targets/standards with such a comparison revealing the existence of gaps between the performancemeasured and the standard/target or progress toward these targets/standards. Based on the size of the gap, the decision makers may decide that corrective actions are required to bring the process back to the required level, or they may decide to adjust the standards/targets in line with the strategic requirements of the organisation.

In light of the above, it is clear that both business performance measurement and management play an important role in assessing the success of businesses. In order to carry out effective performance measurement, it is necessary that the performance measurement and management system are carefully designed to suit each level of the operation and also that the management system supports the five important dimensions of monitoring, control, improvement, coordination and motivation.

The following section will review the principles of a measurement framework which, in this study, will be applied to information flow efficiency.

5.3 PRINCIPLES OF PERFORMANCE MEASUREMENT FRAMEWORKS

5.3.1 Introduction

Business performance measurement systems are central to the management of businesses in today's complex business environments, particularly in view of the globalisation of supply sources and customer bases (Webb & Lettice, 2005:3). According to Mahidhar (2005:57), the changing business landscape requires that organisations excel in more than only the financial area with other areas, such as improvements in quality, speed and flexibility gaining in importance. He further argues that, as a result of these changes in the business environment and itsincreased complexities, ways of measuring business performance accurately are becoming increasingly problematic. However, there have new developments in recent years aimed at dealing with the novel complexities of measuring performance (Marr & Schiuma, 2003:680). This section provides a detailed discussion of both the basic concepts of measurement as well as the requirements for performance measurement systems.

5.3.2 The underlying principles of measurement

Lowry (1999-2011:2) illustrates the fundamental forms of measurement.
According to him, all forms of measurement may be expressed as a process of counting, ordering or sorting. For example:

- *Counting*.A desk width may be measured by counting the centimetres from one edge of the desk to the opposite edge of the desk. This also holds true when items are weighed by counting the kilograms that the scale registers when the item is placed on the scale.
- *Ordering*. Ordering items by size, or rating opinions on a 5-point scale, with "1" being the highest score and "5" being the lowest score, effectively means measuring each item in respect of the other.
- *Sorting*. This type of measurement involves the classification of items according to certain characteristics, that is, dividing students into "male" and "female" categories.

These three versions of measurement are, in fact, three different types of measurement that are used under different circumstances and which entail different mathematical and statistical procedures.

When measuring a quantity or quality by means of any of the above three processes, the property measured is generally referred to as *variable*, whereas a specific, measured instance of this property measured is termed a *variate*.

For instance, when measuring the width of a desk, the desk width would constitute the variable, whereas the measured width of a specific desk would be the variate.

The term variable also implies that the result of the measurement may vary from one measurement to another. The opposite of a variable is a constant, for example, the value of $\pi = 3.1415$.

Measurement by counting represents a *standard scalar measurement*as each individual instance of a measurement results in a numerical value that refers to a point on a particular, standard measurement scale, that is, centimetres, degrees Celsius, volts, and ohms and so on. In the case of measuring length in centimetres, temperature in degrees Celsius, or simply counting, the scales used exhibit equal intervals between successive values on that scale. These scales are termed *equal interval scales*. *Unequal interval scales* are found when measuring sound intensity or earthquake intensity. In addition, it is useful to distinguish between *discrete scales* and *continuous scales*. Discrete scales aid in the measurement of discrete variables, whereas continuous variables require continuous scales. Discrete variables may assume certain valuesonly, for example, when counting a number of persons, it is possible to count 10 or 11 persons, but it would be impossible to count 11.1 persons. A measurement in centimetres would, thus,constitute measurement on a continuous scale.

Kellen (2003:3) explained that measuring systems may be either objective or subjective and either quantitative or qualitative. Quantitative metrics may be verified directly from figures, whereas it is not possible to verify qualitative metrics.

An objective measurement may be independently verified, whereas this is not possible as regards subjective measurements. Quantitative metrics may be measured in terms of an absolute value, such as voltage or distance while qualitative metrics must be judged in terms of one or more of their attributes. The latter type of measurement typically falls into the abovementioned category of ordering and sorting.

Measurements may also be either direct or indirect. Direct measurements allow a variable to be measured directly in its proper unit. For instance, when measuring distance with a measuring tape, the actual variable distance may be measured in centimetres or metres, as the scale of the measuring tape contains the unit centimetres or metres. In contrast, indirect measurements relate to the fact that the property of another material must be used to measure the influence of the actual variable on the property of the material used for the measurement. This is typically the case when measuring temperature. It is not possible to measure the actual variable temperature directly, while the volumetric expansion property of another liquid, such as alcohol or mercury, must be used to measure an inherent temperature.

The above measurements discussed represent the basic forms of measurements and scales available with which to express such measurements.

5.3.3 The underlying principles of effective performance measurement

The aim of performance measurement is to appraise the effectiveness of business processes and to assist in the improvement of these processes. It is, thus, necessary that performance measurement systems adhere to certain basic requirements. The Audit Commission (2000:7) has defined the following six key principles:

- *Clarity of purpose*. It is necessary to understand who will use the information, and how and why the information will be used. The interested stakeholders must be identified and metrics devised which assist in better decision making.
- *Focus*. Performance information should be focused on the strategic priorities of the business.
- *Alignment*. The performance information system should align with the strategic objective setting and performance review processes of the business. There should be links between the performance metrics used on an operational level and the metrics used to monitor corporate performance.

- *Balance*. The overall set of metrics should provide a balanced view of the performance of the business and reflect the main aspects. A balance should also be found with regard to the cost of collecting the information and the value of the information.
- *Regular refinement*. The performance metrics must be kept up to date in order to suit changing circumstances.
- *Robustness of performance metrics*. The metrics used should be sufficiently comprehensible as regards their intended use. Independent scrutiny helps to ensure that the system and the information it produces is sound while careful, detailed definition is essential. Where possible, data should be availableon a day-to-day basis.

The above principles correlate well with the principles for developing useful metrics, as published by the National Research Council (2005:3–4). These principles include:

- Good leadership
- A strategic plan
- A good metric should promote strategic analysis
- Metrics should serve to advance scientific progress
- Metrics should be easily understood
- Metrics should promote quality
- Metrics should assess process as well as progress
- There should be a focus on a single metric
- Metrics must evolve
- The development of meaningful metrics will require extensive human, financial and computational resources

When comparing the basic principles as discussed by the Audit Commission (2000:7) and the National Research Council (2005:3–4)above, it appears that the important principles revolve around the fact that good indicators and metrics support strategy, provide a balanced view of the organisation's performance, are easy to understand, and require regular refinement.

5.3.4 The elements of performance metrics

In designing a performance measurement system, Beckinsell (2001:10–11) suggests that the design of such measurements is a process which needs to address the question as to “what constitutes a well-designed measure of performance”. Both Beckinsell (2001:11) and Mahidhar (2005:67) contend that a well-designed performance measurement system should include the following parameters:

- *Title*. Use exact names
- *Purpose*. The relation of the measure with the organisational objectives must be clear
- *Scope*. Business objectives
- *Target*. The actual numerical target to be achieved against the benchmark
- *Formula*. The way in which to calculate the performance achieved
- *Unit of measure*. What units are used?
- *Frequency*. The frequency of recording the measure
- *Responsibility metrics*. The person responsible for collecting data and reporting on it
- *Source of data*. The exact data sources needed to calculate the measure
- *Notes and comments*onoutstanding issues

The above performance measurement elements have been devised to ensure that the minimum data required is collected and that the metrics comply with strategic goals of the organisation.

5.3.5 Dimensions of performance metrics

According to Mahidhar (2005:68), performance indicators and metrics may be broadly classified across three dimensions. These three dimensions include a type of metric, a time indicator and a focus dimension, as shown in figure 5.3.

The type of indicators and metrics concentrates mainly on the financial or non-financial nature of the measure. Financial metrics are directly derived from the profit and loss statements, balance sheets and income statements of a company (Kellen, 2003:3), whereas non-financial metrics are not found in the chart of accounts of an organisation, and include customer satisfaction and production and quality metrics.

The time indicator deals with as to whether an indicator and metric are leading or lagging, depending on the way in which the metric is used. Lagging indicators typically show actual outcomes over a period of time, whilst leading indicators guide decision making, and assess the likelihood of success. For example, revenue and net earnings are lagging indicators as they indicate a position after the fact, whereas customer satisfaction may be considered as a leading indicator for revenue (Basualdo, 2010:1–2).

The focus of a performance metric denotes whether the performance metric stems from a set of internal or external metrics. According to Mahidhar (2005:68), it is essential that a company align its internal indicators and metrics with stakeholder expectations, whereas external indicators and metrics are important for benchmarking performance and assessing an organisation’s competitive position as well as satisfying some of the external stakeholders.

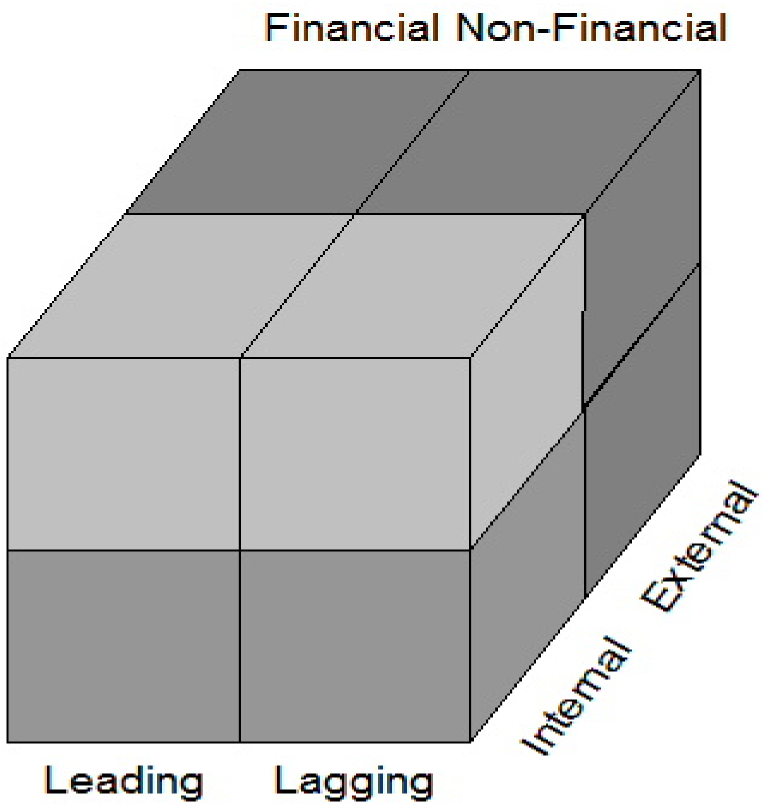

Figure 5.3: Dimensions of performance measurement

Source: Mahidhar (2005:69)

However, Kellen (2003: 4) argues that performance metrics are not fully defined by these three dimensions and adds that performance metrics may also be:

- complete or incomplete
- responsive or non-responsive
- critical or non-critical
- tangibleor intangible.

According to Kellen (2003: 4), metrics may be complete, thus capturing all the relevant characteristics of the specific performance, whilst incomplete metrics do not do this. Metrics may also be responsive and thismay be influenced by individuals, whereas non-responsive metrics are not controlled by individuals. Critical metrics are linked mainly to the strategic goals of a company. Such metrics typically comprise key performance indicators that are critical to the successful execution of an organisation's strategy. Tangible metrics refer to numbers recorded in the organisation's chart of accounts, such as inventory levels and accounts receivable balances, whilst intangible metrics pertain to items such as levels of skill, knowledge, creativity and innovation.

5.3.6 Levels of performance metrics

According to Mahidhar (2005:70), good metrics comprise several levels that span the levels typically found in an organisation. As outlined in section 5.2.2, performance may be measured on three levels. The first level is of a strategic nature, because good business performance metrics support strategy. The second level is of a tactical nature, in order to enable each functional manager to control his/her contribution to the realisation of the desired strategy. The third level comprises operational measurement, which captures transactional data and analyses deviation on a real time basis. The above principles are depicted in figure 5.4.

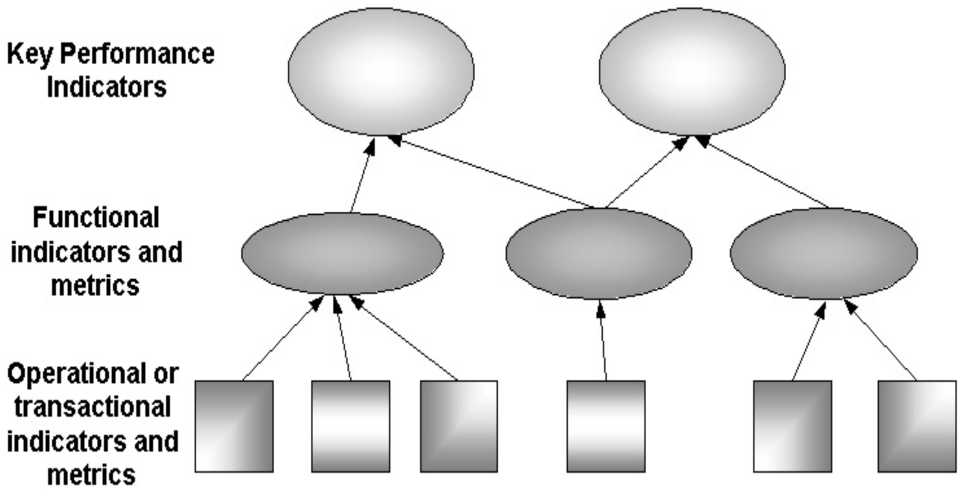

Figure 5.4: Levels of performance metrics
Source: Adapted from Mahidhar (2005:71)

Figure 5.4 identifies strategic measurement as the critical key performance metrics or indicators derived from the strategy of the organisation. The second or functional level provides for metrics that are deriveddirectly from the strategic goals and assigned to the different processes or functions of the organisation. The individual or operational metrics deal with the performance that arises from the real-time transactions and deviations from the standards set.

5.3.7 Conclusion

Section 5.3 presented an overview of both the basic principles of measurement and the principles of performance measurement.

Performance measurement deals with the measurement of specific performance metrics as specified by each organisation. These measurements may consist of continuous, as well as non-continuous, metrics. For example, the measurement of satisfaction levels may consist purely of subjective measurements, such as "*completely satisfied*" or "*not satisfied*", whereas cycle time measurements may be measured in a continuum such as time. Performance metrics must also be clear, focused, robust, easily understood, and serve a definite purpose.

The following dimensions and levels of performance metrics were discussed:

- The dimensions or performance metrics comprise, financial or non-financial aspects, lagging or leading characteristics and internal or external features. In terms of the levels of performance metrics it was emphasised that the metrics should support all levels of decision making, from the strategic to the tactical to the operational. Metrics on the tactical level should align with metrics on the strategic level, while operational metrics should align with tactical level metrics.

- This study focuses on the measurement of information flow efficiency in the supply chain. The measurement of information flow efficiency should follow the basic principles of performance measurement, as discussed above.
- Information flow efficiency metrics should exist at different levels and have the dimensions necessary to enable an as complete as possible evaluation of information flow efficiency – see discussion in the nextsection.

5.4 ELEMENTS, LEVELS AND DIMENSIONS REGARDING THE MEASUREMENT OF INFORMATION FLOW EFFICIENCY

5.4.1 Introduction

It is essential that the indicators and metrics that will assess the performance of the business processes as regards key performance areas become part of either an integrated performance measurement system (Mahidhar, 2005:72) or framework, which unites the information goals of everyone in the organisation in such a way that everyone collaboratesin order to achieve synergistic benefit for the organisation.

The architecture of such a system must take into consideration the elements of indicators and metrics and their dimension and levels, as detailed in sections 5.3.3 to 5.3.6, in order to arrive at a systematic structure.

In general, Mahidhar (2005:73) proposes that frameworks constitute the basic requirements for a successful performance measurement system. These frameworks should incorporate two aspects, namely, structure and procedure. Such performance measurement frameworks would assist in the development of a performance measurement system by (1) clarifying measurement boundaries, (2) specifying measurement dimensions and also (3) providing initial insights into the relationships between performance measurement dimensions.

This research concentrates on the identification of the performance indicators and metrics of information flow efficiency. Accordingly, this research does not aim to develop a new business performance measurement framework (PMF), however it does endeavour to add to an existing framework which will bebest suited to the dimensions and levels of the indicators and metrics to be identified.

The selection of a suitable measurement framework will be discussed in the following sections, beginning with the levels of measurement as discussed in section 5.3.6. The dimensions of measurement of information flow efficiency then will be discussed, with reference to section 5.3.5. Finally, the elements comprising the measurement of information flow efficiency will be developed.

5.4.2 The levels of measurement of information flow efficiency

As shown in figure 2.3 of chapter 2, information forms the basis for all decision making with regard to the four drivers in the supply chain, production, inventory, transportation and location. Without information and the flow of this information between the members of the supply chain, real time decisions about production volumes, inventory positioning, or when to transport goods are not possible. The more information about suppliers, customers, products, and demand and production schedules that is shared, the more responsive the reaction of the supply chain will be to customer requirements.

A study conducted by Kottila, Maijala andRönni (2005:1–5) revealed that a specific supply chaindid not perform well as a result of deficiencies in the information flow between the supply chain members. They concluded that the functioning of the supply chain could be improved by the involvement of outside stakeholders. Such decisions to involve outside stakeholders generally require input from the strategic levels of company management. It may, therefore, be inferred that the optimal functioning of a supply chain and the provision and sharing of information are of strategic importance which, in turn, implies that the first level of measurement will also occur at the strategic or company level, and possibly even include the performance of immediate up and downstream members of the supply chain members.

It is a consequence of that the provision of information as well asthe information flow that they affect all the other functions of the organisation, as indicated above (figures 2.3 and 2.4). In view of the fact that information facilitates collaboration between these functions, it is essential that each of these functions ensure that its procedures in dealing with the other functions are both efficient and effective. It may, therefore,be assumed that the second level measurement will occur at this functional or tactical level. The individual indicators and metrics of a functional information flow efficiency must support the effective organisational performance.

Finally, it is possible to measure the daily transactions variables that affect information flow efficiency as regards each function, thus providing valuable real-time information on the information flow efficiency performance of the individual function that occur at the operational or transactional level.

The measurement levels discussed are equivalent to the performance measurement levels system described in figure 5.3.6 above.

The recognition of these measurement levels leads to the realisation that it is possible to integrate the measurement of information flow efficiency into the SCS and to link the information flow metrics to an objective in each perspective and, thus, to achieve an information flow efficiency KPI within the realm of supply chain optimisation

The following section will discuss the indicators and associated metrics of information flow efficiency.

5.4.3 The dimensions of information flow efficiency measurement

As discussed in section 5.3.5, performance metrics maybe broadly classified across three dimensions, including a type of measure, a time indicator and a focus dimension − see figure 5.3.

In the case of information flow efficiency metrics, the cost incurred in installing an information system which aids the flow of information throughout both the organisation and the supply chain, will be entered in the ledger of accounts of the organisation − as part of operational expenses − as well as in the balance sheet – as part of capital equipment such as servers. However, the information on other metrics dealing with timeliness of information as well as other quality metrics will not be found in the company’s ledger. It may, thus, be deduced that information flow efficiency metrics may include financial, as well as non-financial, metrics (Kellen, 2003:2-4; Mahidhar, 2005:68).

The time indicator deals with whether a measure is leading or lagging, and this depends on the way in which the measure is used. Lagging indicators typically show actual outcome over a period of time, whilst leading indicators guide decision making, and assess the likelihood of success (Kellen, 2003:2-4; Mahidhar, 2005:68). Information flow efficiency metrics will show either an improvement or a decline over time and may, thus, be considered as lagging indicators. As a result of the influence of information flow efficiency on decisions and likely success, it is clear that information flow efficiency indicators become indicators of expected supply chain/organisational performance and may, thus, be considered as leading indicators which may be used for decision making.

The focus of a performance measure indicates whether the performance measure stems from a set of either internal or external metrics. According to Mahidhar (2005:68), a company must align its internal metrics with stakeholder expectations, whereas external metrics are important for benchmarking performance, to assess the organisation’s competitive position as well as to satisfy some of the external stakeholders. The information flow efficiency metrics are, typically, of internal origin in the case of an actual organisation. However, when extending the measurement of information flow efficiency across the entire supply chain, external stakeholder, such as customers, suppliers and intermediaries, become involved.

In conclusion, information flow efficiency metrics may include financial and non-financial metrics, they may be either lagging or leading, and they have either an internal or external origin. The exact composition of the dimensions will become evident after the individual elements to be included in the portfolio of information flow efficiency metrics become known. The development of the elements or metrics of information flow efficiency will be discussed in the following section.

5.4.4 Developing indicators and associated metrics for information flow efficiency

There is no evidence in the literature for of the existence of indicators and the associated metrics of information flow efficiency in terms of supply chain performance measurements. It is, thus, the aim of this study to develop indicators and associated metrics of information flow efficiency in the supply chain and/or organisation. The process of developing the relevant indicators for information flow efficiency and the metrics for each indicator will follow the procedure detailed in figure 5.5. The exact process pertaining tothe development of information flow efficiency indicators and the associated metrics − the topic of chapter 6 − will, however, be briefly discussed in the following sections.

The procedure for the development of indicators and associated metrics will commence with a literature review. The aim of this review is to identify potentially valuable information or information flow measurement models which may be suited for adaptation as regardsthe measurement of information flow efficiency in supply chains and/or organisations. Should such models not exist, this study will then, in step 2, attempt to extract possible elements for information flow efficiency indicators and associated metrics from the characteristics of information quality and information transfer and from the general characteristics applicable to performance measurement systems, which may be measured and which provide an appropriate description of a particular characteristic of information flow efficiency. For example, efficiency refers to a successful performance that may be realisedwithin a specific time period. Accordingly, it is possible to consider*time* as a critical element in assessing information flow efficiency. The timeliness of the information flow may, thus, be utilised in order to measure this critical characteristic of information flow efficiency and, therefore, timeliness may be regarded as an indicator of information flow efficiency.

In remaining with the above example, it would be feasible to consider the time taken to transfer information either between supply chain members or functions in a company as a metric as time may be measured in seconds, minutes, hours, days, etc. Similarly, the cycle time for the transfer of information from customer to manufacturing department may serve as another time related metric as it is possible to measure this cycle time may be measured either directly or *expost* by means of auditing. Characteristics that are capable of providing individual numerical measurements,may also be combined in a defined manner to supply an aggregate performance value for this specific indicator.

Once indicators and suitable metrics have been derived from the characteristics of information and business performance measurement, a questionnaire will be developed and used in order to ascertain the opinions of industry and company leaders about the possible rank of importance of each of the indicators, as well as the rating of importance of the metrics identified for each indicator. Statistical and explorative data analysis will result in a final set of indicators and associated metrics which will be used in the actual case study.

The indicators and associated metrics developed in accordance with the procedure detailed above will be used to measure the performance of information flow efficiency in the supply chain. It would, therefore, be useful to incorporate these indicators and metrics of information flow efficiency into an existing measurement framework. Section 5.5 will discuss the literature sources that incorporate information flow or communication related indicators and metrics in an existing measurement framework.

Communication may be defined as the transfer of information between two or more persons or larger entities such as departments of an organisation or within an organisation. Ion the other hand, information flow may be defined as the flow of raw or processed data across gaps of data or information differences from one entity to another entity. Based on these definitions, communication will, thus, be considered as an element of information flow, that is, information flow includes communication. As mentioned before, communication has been used in organisational performance measurement frameworks (see section 5.5.2), in order both to measure and to manage the socioeconomic communication performance of organisations. This is important as it is essential thatan organisation create goodwill amongst the public; that the company appears socially responsible in the eye of the public; and that important social and economic data are communicated with the public in a timely manner. As regards this type of communication, organisations may choose the sender or who will communicate with the intended recipients, the channel of communication that should be used and the recipient to receive the information.

As outlined in chapter 1, the drivers of information flow or communication will determine how successful and how efficient the flow of information has been. The drivers of information flow include characteristics of information such as timeliness, content and form, all of which have a direct influence on the flow of information. It is, therefore, important to consider the field of information flow in terms of as many aspects as possible, as regards the identifiable drivers of information flow, inclusive of those drivers originating from the field of communication.

5.4.5 Conclusion

This section discussed the levels, dimensions and the development of the elements of a measurement instrument for information flow efficiency. The section also indicated that the dimensions will include financial and non-financial, lagging and leading and internally and externally focused indicators and metrics and as well as discussing the fact that the information flow efficiency metrics should span the transactional, tactical and strategic levels in order to be of optimum value to the measurement objectives.

The following sections will discuss existing communications measurement frameworks in detail.

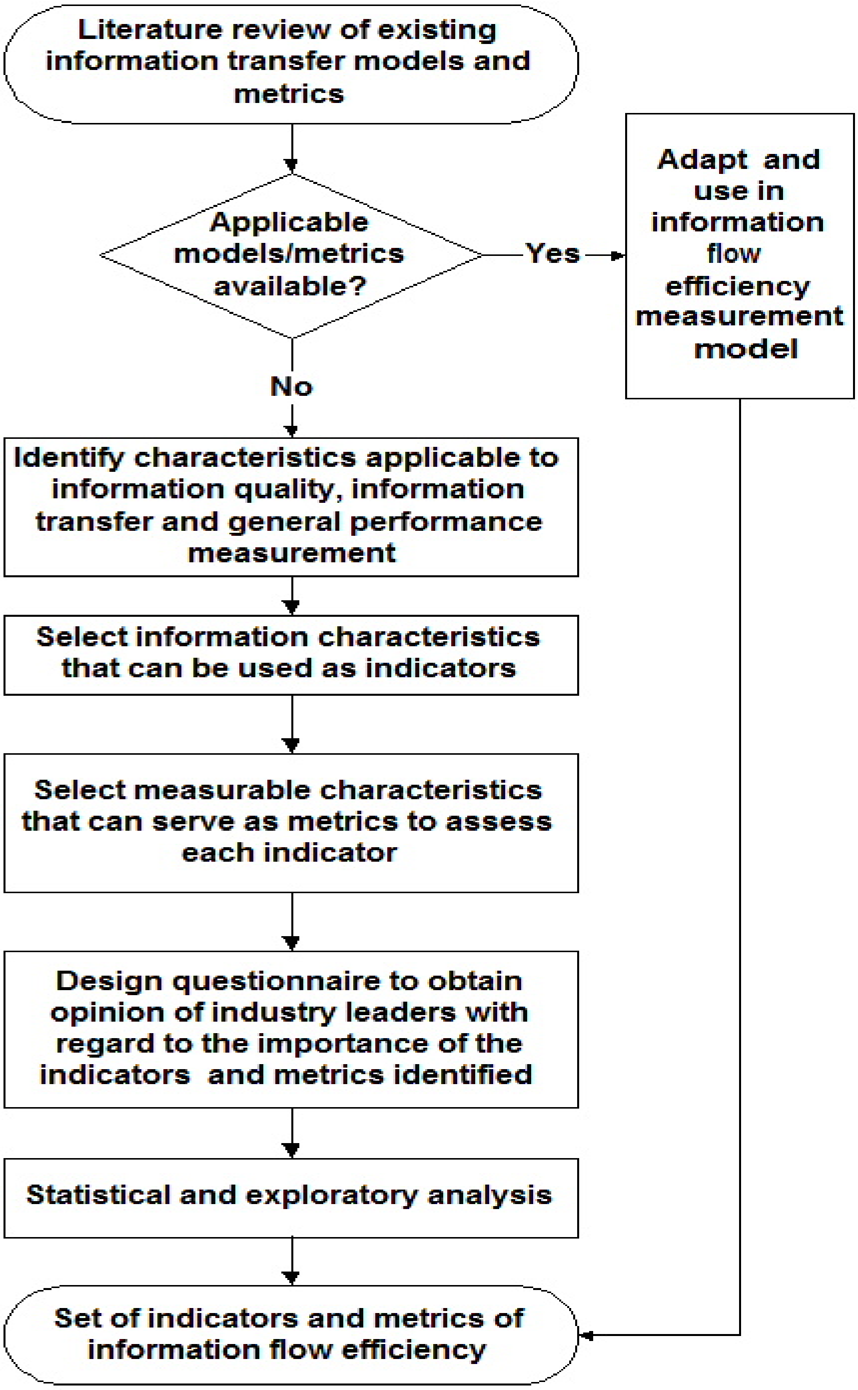

Figure 5.5: Process of identifying indicators and metrics of information flow efficiency

Source: Developed from research process

5.5 EXISTING PERFORMANCE MEASUREMENT SYSTEMS THAT INCLUDE INFORMATION FLOW OR COMMUNICATION METRICS

5.5.1 Introduction

According to Lautenbach andSass (2005:1), communication is a significant contributor to the business success of organisations. However, despite the fact that this is common knowledge, the immediate interdependence of communication and business success is not obvious. However, as a result of the perceived contribution of communication to the value creation within a business, communication has become increasingly important in management sciences. According to Rolke (2006:1), the communication between an organisationand its stakeholders has developed into an individual management function with this management function specifically tasked with creating mutual communications relations, acceptance and cooperation between the organisation and the different public authorities and the general public.

Communication management attempts to achieve transparency in terms of strategy, processes, results and finance and, thus, requires suitable methods and structures for the planning, realisation and control of the necessary communication processes in order to create a link between the communications effects and metrics and the financial results (Rolke, 2006:1–2). It is the economic effect of the envisaged changes in the opinion and behaviour of the public stakeholders as regards the organisation and the measurement of these changes that are of interest. Rolke (2006:4) contends that a number of models are available to assist in evaluating the communications efforts, including:

- Corporate communications scorecard (CCS)
- Communications scorecard (CSC)
- Return on communications
- Communications value systems
- Communicationscontrol cockpit

According to an empirical study conducted by Lopez (2006:5–6), the CCS and the CSC are the models which are the most frequently cited by the organisations listed at the German Stock Exchange (DAX).

Lautenbach andSass (2005:13) are of the opinion that the business scorecard-based models appear to be especially well suited to the evaluation of communications efforts. They base their opinion on the fact that the BSC model represents an established management system, which translates anorganisation's strategies into operative activities. They further contend that the BSC allows for the blending of communications targets with the organisation's strategies. In the following sections the most frequently used practical control and measurement models of communications in organisations will be discussed.

5.5.2 Existing measurement frameworks involving communication and information flow

5.5.2.1 Introduction

As indicated above, two specific models, the CSC and the CCS,are particularly well suited to measuring the contribution of communications to business success. According to Rolke (2006:9), the CCS expanded by a fifth perspective is compatible with already existing balanced scorecards. This is because it is possible to design scorecards for each level of the organisation, throughout the entire organisation, as well as for individual functions, such as the communications function. This is also true of the CSC, which integrates communication requirements into each of the four existing perspectives of the BSC.

However, another communications measurement model, the communications control cockpit, has moved away from the predefined perspectives of the BSC and is oriented mainly towardsan organisation's relations with its stakeholders, especially relations with customers and employees, capital providers and also journalists as the advocates of the public (Rolke, 2006:9).

The above-mentioned frameworks will now be discussed in more detail in the following sections.

5.5.2.2 *The communications scorecard (CSC)*

According to Huber andPfeiffer (2007:8), communications is a value-creating factor that contributes to the efficiency and effectiveness of anorganisation's strategy. The CSC combines tangible and intangible assets, which cannot be separated in the organisation's strategy. Huber and Pfeiffer (2007:8) contend that,in view of the functional, timeous and hierarchical relationshipsbetween all communications instruments and methods, seamless implementation of this scorecard is achieved by the simultaneous planning of all these instruments and methods. The CSC expands each of the existing perspectives of the BSC to take communications into account.

As is the case with the BSC, the CSC begins with an analysis of the strategic goals of the organisation and defines both the key performance indicators and the operative value drivers. It is then possible to deduce, key communications indicators and value drivers from these strategic goals. Thereafter, business economic and communications goals must be synchronised. By quantifying the success parameters, the communications contribution may be both measured and evaluated. It is this way that the contribution of communications to the increase in the value of anorganisationmay be verified (Huber & Pfeiffer, 2007:8–9).

5.5.2.3 *The corporate communications scorecard*

Zerfass (2004:3–6) has suggested an adaptation of the BSC taking into account communications related metrics that were designed specifically to measure the enhancement of business value stemming from public relations communications with the stakeholders of the organisation. He argues that the new strategic concept of communication may be integrated smoothly into the BSC as it enhances the management of the organisation with new indicators and metrics.

Applying this methodology to the generic BSC, Zerfass (2004:3–6) arrived at a corporate communication scorecard (CCS) as depicted in figure 5.6.

The newly adapted BSC, or CCS, now contains a new perspective, which is socio-politically oriented and which contains and records all the indicators and metrics pertaining to this perspective. This new socio-political perspective encompasses objectives and key performance indicators (KPI's) which are linked to the vision and strategy of the organisation. Of special interest is the linkage to all stakeholders, including suppliers, communities, customers, shareholders, local governments and the press.

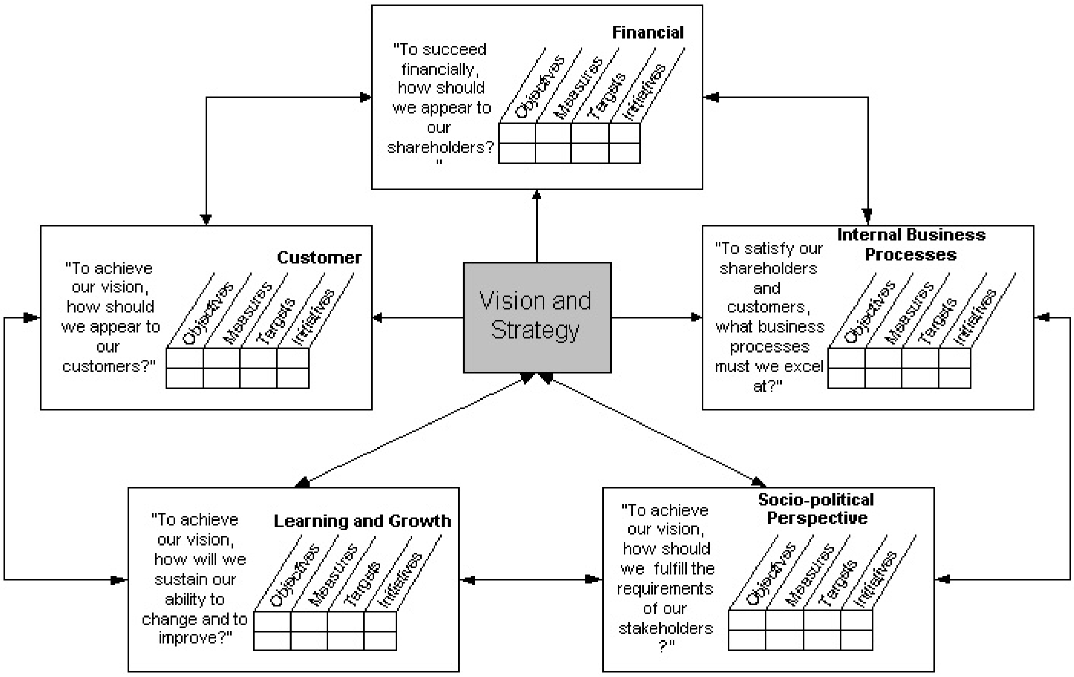

Figure 5.6: BSC expanded to include a socio political perspective.

Source: Zerfass (2004:5)

5.5.2.4 *The communications control cockpit*

According to Zerfass (2005:5), the communications control cockpit, as published by Rolke (2004:49), has its basis in the reputation quotient (RQ) which, however, does not allow for a direct measurement of the communications contributions to theenhanced reputation and, therefore, to an increase in the business success of an organisation. The RQ concept asserts only that a general relation between enterprise value and reputation value exists, based on statistical deliberations.

However, Zerfass (2005:5) argues that the communications cockpit is advantageous in its approach as it proposes to calculate the communications values ImEx (Image- or Reputation Value) and to compare it to the economic value added (EVA) of the enterprise.

The ImEx consists specifically of the reputation values of the stakeholder groups − customers, public, employees and shareholders − and the total of all communication budgets − see figure 5.7.

The model provides three key performance indicators, namely, communications efficiency (KommEf), value-value-relation (2VR) and return on communications (RoCom). The deduction of each of these KPI's is depicted in figure 5.7.

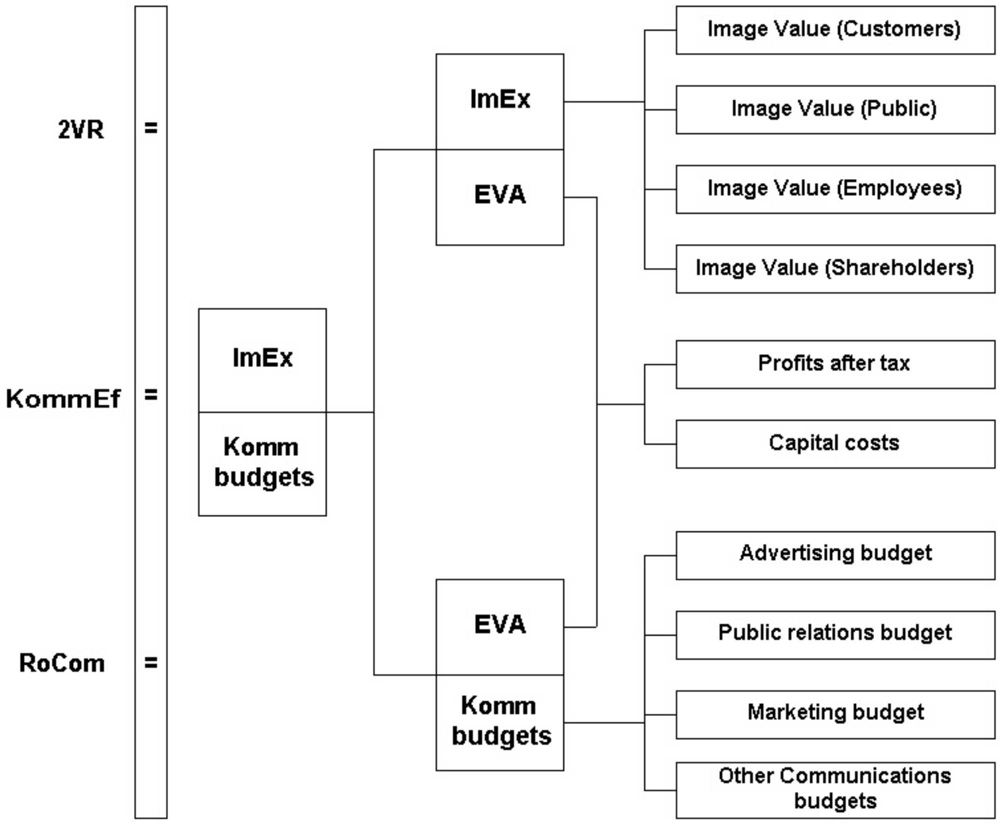

Figure 5.7: The key performance indicators of the communications cockpit
Source: Huber & Pfeiffer (2007:10)

Initially, the concept of the communication cockpit model and its focus on a small number of metrics appear convincing. However, it must be borne in mind that the advantages of the model are to be found in the fact that the model takes into account the relation between enterprise success and communications as a “black-box”. The model is, nevertheless, not able to explain the real operative dependence between the two parameters causally. The key indicator, RoCom, may be considered as an example. RoCom, defined as EVA divided by the communications budgets, should examine whether the investments in communications activities are valuable and meaningful whilst also providing a benchmark to compare to other organisations. However, the model implicitly assumes that any increases in value have been achieved purely by the communications activities, while it is clear that EVA is influenced by several other factors, including product quality, distribution costs, and personnel costs etc, none of which are considered in this model.

Aside from the shortcomings indicated above, the real value of this model may be seen in the fact that communications are not based on either opportunities or blurred quantitative expressions, but may be analysed in terms of a number of quantitative key indicators.

5.5.2.5 A comparison of the communication-oriented performance measurement systems

Huber andPfeiffer (2007:12–13) compare the communications performance measurement systems in terms of advantages and disadvantages as well as their contribution to innovation. The following table 5.1 summarises these facts for each of the systems described.

Table 5.1:Comparison of communications performance measurement systems

Controlling tool	Positive	Negative	Innovation
Balanced Scorecard	Flexible in application	Expensive implementation	First time strategic linking of financial and non-financial key performance indicators
	Large organisations such as Mercedes are using this tool		
Communications Scorecard	Takes into account perspective of communication	Many concepts difficult to comprehend and to implement	Expansion of the BSC to include the communications perspective; communications become controllable and measurable
	Sensible deduction of communications goals and action from the operative area	No detailed execution of individual steps	
Corporate Communications Scorecard	Includes strategic enterprise goals	Time consuming and expensive implementation	Communications are included in general management. Expands the BSC to include a new socioeconomic perspective
	Provides good overview of PR success	Requires extensive experience in order to obtain correct key indicators	
Communications Control Cockpit	Few key indicators,	Single causality for enterprise success	Image a key value for enterprise success; reduction of success factors down to three key indicators
	Follows the enterprise strategy	Theoretically extremely abstract	

Source: Huber andPfeiffer (2007:12)

As depicted in table 5.1, the CSC and the SCS incorporate the perspective of communication into the general tasks of management while the communications control cockpit requires that all improvements as regards enterprise success be based on successful communications activities. However, the communications control cockpit is preferable to the other modelsas a result of the ease of application and the few key performance indicators although the BSC derivatives imply enhanced controllability of key performance indicators and measurability of the contribution of communications to enterprise success.

In view of the fact that this research attempts either to identify or to develop new indicators and metrics of information flow efficiency it appears logical to include these newly developed indicators and metrics into a derivative of the BSC performance measurement framework.

The above discussion of the BSC may be translated into the possibility of including information flow efficiency indicators and metrics into the supply chain scorecard which is in itselfa derivative of the BSC. The following sections will discussthe possible inclusion of information flow efficiency indicators and metrics into the supply chain scorecard.

5.5.3 Conclusion

It has been shown that there are several performance measurement frameworks that take into account the communication between an organisation and its stakeholders. Amongst the BSC frameworks, it was noted that, firstly, the BSC had been expanded to include a new perspective of communication and, secondly, that indicators and metrics of communication had been integrated into the various perspectives of the BSC. However, it must be recognised that the communication indicators, according to Huber andPfeiffer (2007:8) and Zerfass (2004:5), involve all the stakeholders of the organisation, whilst this study specifically considers indicators and metrics of information flow efficiency with the aim of optimising the operation of the supply chain.

The communications control cockpit is, theoretically, an extremely abstract model, which implicitly assumes that any increases in value have been achieved purely as a result of communications activities, while it is clear that EVA is influenced by several other factors, including product quality, distribution costs, personnel costs and others, which are not considered in this model. In addition, the model does not offer any explicit metrics which may be evaluated quantitatively. Accordingly, this model will not be considered as a measurement framework which is suitable for the inclusion of the indicators and metrics of information flow efficiency.

5.6 THE INCLUSION OF INFORMATION FLOW EFFICIENCY MEASUREMENT IN THE SUPPLY CHAIN SCORECARD (SCS)

5.6.1 Introduction

This research deals with the measurement of information flow efficiency. In view of the fact that the measurement of information flow efficiency may assist in improving the operation of the associated supply chains, it is conceivable that information flow efficiency is recorded in the supply chain scorecard.

It is clearly possible to include the indicators and metrics of information flow efficiency in the SCS framework in the same ways in which these indicators and associated metrics of communication were included in the BSC − See discussion above. Firstly, a new perspective may be introduced into the SCS, thus expanding the four basic perspectives and, secondly, the indicators and metrics of information flow efficiency may be integrated into each of the original, basic, four perspectives. The following sections will illustrate these possibilities in detail.

5.6.2 The supply chain scorecard including the perspective of information flow efficiency

The new indicators and metrics of information flow efficiency may be applied across the spectrum of supply chain activities and in support of the supply chain, from the strategic to the operational level. However, apart from the fact that the SCS deals specifically with the optimisation of the supply chain activities, it is conceivable that it may be possible to create a new perspective of, information flow efficiency which will, in turn, lead to a new derivative of the SCS(see figure 5.8).

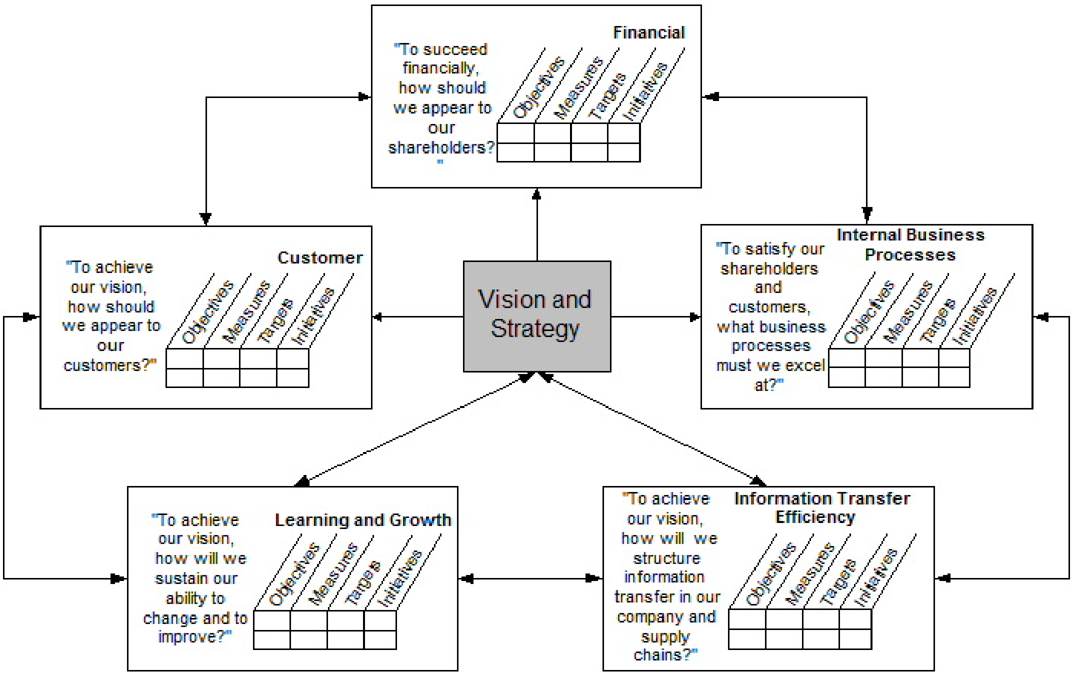

Figure 5.8: The supply chain scorecard with an additional perspective of information flow efficiency

Source: Adapted from Zerfass (2004:5)

5.6.3 The supply chain scorecard expanded to include information flow efficiency indicators and metrics

Another way of dealing with the inclusion of the new perspective would be to expand each existing perspective of the SCS with an information flow perspective. Each perspective would, thus, be extended with information flow efficiency relevant indicators and associated metrics, where applicable. The following figure 5.9 demonstrates this concept, showing examples of new information flow efficiency indicators (in bold and italics).

Customer dimension						
Measure	Input Data	Frequency of measurement	Responsibility	Goal	Current Performance	Resource allocation
Perfect order fulfilment						
Processing accuracy						
Forecasting accuracy						
Budget accuracy						
Delivery performance						
Customer satisfaction						
Product quality						
Adequacy and accuracy of information passed to/received from customer						
Business process dimension (incorporating time and asset utilisation)						
Measure	Input Data	Frequency of measurement	Responsibility	Goal	Current Performance	Resource allocation
Supply chain response time						
End-to-end pipeline time						
Order cycle time						
Production flexibility						
Material labour capacity						
Inventory days						
Net asset turns						
Cash-to-cash cycle time						
Capacity utilisation						
Information cycle time within organisation						
Financial dimension						
Measure	Input Data	Frequency of measurement	Responsibility	Goal	Current Performance	Resource allocation
Total supply chain cost						
Finished goods inventory turns						
Total delivered cost						
Cost of excess capacity						
Cost of capacity shortages						
Cost of information provision/transfer						
Innovation						
Measure	Input Data	Frequency of	Responsibility	Goal	Current	Resource

		measurement			Performance	allocation
New product introductions						
New process technology development						
Partnerships						
Development of information provision/transfer?						

Figure 5.9: The supply chain scorecard with sample indicators of information flow efficiency

Source: Adapted from Hugo et al. (2004:106–107)

The information flow efficiency metrics will be recorded as input data. Accordingly, the information flow efficiency indicators and metrics are fully integrated into the four basic perspectives of the SCS.

5.7 CONCLUSION

This chapter examined the basic requirements and underlying principles for successful business performance measurement and management. Performance measurement was defined as the process of measuring the efficiency, effectiveness and capability of an action or process, or system as compared to standards or targets.

The nature and elements of performance measurement were then discussed with particular attention being paid to the strategic process of developing and maintaining a performance measurement system. This evaluation revealed that performance measurement systems require ongoing reviews in terms of goals becoming redundant and new goals being defined as a result of altered strategies. Based on the abovementioned strategic requirements, a tactical and operational process for the actual performance measurement process was introduced. The performance measurement process starts with strategic priorities, which are then broken down into specific processes and activities. These activities are carried out against the backdrop of set objectives. The results in terms of the objectives are measured, analysed and compared. Further evaluation may expose a need for corrective action which may, in turn, lead to the introduction of new standards/targets. Once the need for corrective action has been identified, the relevant process(es) must be re-engineered.

The basic principles of measurement and the principles, elements, dimension and levels of performance measurement were discussed. The basic measurement review revealed that metrics may be measured either numerically, on a continuous or discrete scale, or as subjective judgements. The principles and elements of performance measurement listed specific characteristics that certainwriters deemed to be necessary in order to produce successful performance measurement outcomes.

The final part of this chapter dealt with the arguments in favour of the development of the elements, dimensions and levels of the indicators and associated metrics for information flow efficiency. The elements are represented by the actual indicators while the metrics of information flow efficiency still have to be developed. The development process was briefly discussed in section 5.4.4 and will be explored in detail in chapter 6. The dimensions discussed include financial and non-financial, lagging and leading and internally and externally focused indicators and metrics.

Finally, based on the expected dimensions, elements and levels of the indicators and associated metrics of information flow efficiency, it emerged from a process of evaluation of the most important measurement frameworks against the requirements of a measurement system for information flow efficiency that the measurement framework of the supply chain scorecard was the most suitable.

Two possible ways of including the indicators and associated metrics of information flow efficiency into these frameworks were discussed, firstly, the adoption of the new perspective of "information flow efficiency" in the supply chain scorecard.According to Paranjape et al. (2006:7), it is possible to include additional perspectives in the BSC as per requirements. For example, where a comprehensive information flow efficiency assessment is required as a result of high strategic importance, it may be useful to agglomerate the indicators and metrics into a new perspective in order to gain an improved overview of the supply chain performance. Secondly,the incorporation of the indicators and metrics into the existing KPIs of the SCS, as a result of the integrative role of information flow efficiency, support the realisation of the existing objectives within the SCS.

This research study deals with the measurement of information flow efficiency as a requirement for supply chain efficiency. Having identified a suitable measurement framework, the next chapter will deal with the actual development of indicators and associated metrics for the measurement of information flow efficiency.

CHAPTER 6
THE MEASUREMENT OF INFORMATION FLOW EFFICIENCY IN THE SUPPLY CHAIN

6.1 INTRODUCTION

The importance of information flow efficiency has been widely acknowledged in contemporary literature on supply chains. Kottila et al. (2005:2) conducted research into the organic food supply chain. They found that the flow of information between the members of the supply chain is essential for the coordination of other flows, such as product flow and the flow of finances. The results of their study revealed that the information flow in the supply chain was ineffective, and that the members' awareness of their individual needs was insufficient. These two factors, in turn, resulted in the inefficient performance of the organic food chain. Jain (2004:4) contends that information is one of the most important assets of an organisation. Consequently, the management of information flow becomes a strategic priority. Managing information and its flow entails both the implementation of an information strategy and the systematic assessment of the information and the associated flows.

Information, however, does not flow freely. Cisco (2005:2) maintains that large computer networks, which enable computer-to-computer communication and proprietary point-to-point installations, may hamper the flow of information in several ways, including a lack of interoperability, limited access to computing and communication resources, and the inability of proprietary networks to adapt and support modernisation.

However, even in purely personal communication, the flow of information may be hindered. Du-Babcock (2003:14–15) asserts that culture and group composition have a decisive influence on the communication behaviour in small groups. Other factors influencing person-to-person communication and the resultant flow of information have been discussed in section 1.2.3.4.

In modern supply chains people operate computers and terminals, supplying information to ERP systems, APS and MES, all of which may work together to constitute fully automated systems. This activity implies that information has to flow between humans and computers, via interfaces. Section 1.2.3.4 indicated the factors that must be taken accountin order to achieve an efficient information flow through these interfaces.

However, information flow is not influenced by external factors only, such as information systems, computers, interfaces and humans, but also by intrinsic factors. According to Cardoso (2006:6), the complexity of the flow of data and information in a process increases with (1) the complexity of the data structures, (2) the number of activities and (3) the mappings between the data pertaining to the activities. It is,therefore, understandable that the measurement of information flow is difficult and that a considerable number of factors have to be taken into account. The absence of meaningful quantitative measurements for information flow in a supply chain in current literature is proof of this.

As a result of the important role played by the efficient transfer of information between the members of the a chain, this research study attempts to develop indicators of information flow efficiency in the supply chain so as to assist in the determination of the organisational and/or supply chain performance. In order to develop such indicators, this chapter contains a literature review on information and information flow measurement between computers, computers and persons and between persons. In addition, this chapter explores the characteristics of information and information flow/transfer as proposed by various writers, for possible use in developing indicators of information flow and its efficiency. A literature review of information and information flow measurement will, thus, be discussed in the following section.

6.2 INFORMATION AND INFORMATION FLOW MEASUREMENT

6.2.1 Introduction

The literature consulted revealed that information flow has been addressed from various perspectives. These perspectives include information flow being considered from a purely physical viewpoint based on information theory, information flowing in computers between units of hardware and between units of software as well as information flow relating to the information exchanged between natural persons.

In the first instance, Shannon’s theory of information (refer to section 3.3.2) forms the basis for the examination and measurement of information pertaining toa random variable contained in another random variable (Dionisio, Menezes & Mendes, 2003:3).

The second perspective deals specifically with the flow of information between the hardware and software components in computers. In terms of the confidentiality of data and information, the efficiency of the exchange of information between the individual hardware components and the efficiency of transfer of information between individual units of software are of particular concern (Amtoft, Bandhakavi & Banerjee, 2005:1).

The third viewpoint of information flow measurement relates to information exchanged between humans and between and within groups of natural persons (Wu et al., 2004:327–335).The fourth case refers to the measurement of information flowing between humans and computer interfaces. Lastly, other measurement methodologies related to information flow will be explored.

The contributions of the individual theories outlined above will be discussed in the following sections.

6.2.2 The information theory based measurement of information

6.2.2.1 Mutual information

According to Dionisio et al. (2003:3–4), the concept of mutual information arises from the theory of communication, as presented by Shannon in 1948. Shannon's information measurement model is based on the logarithmic measure of unexpectedness, or surprise, inherent in a probabilistic event. The total information carried by a set of *n* events is, thus, taken as the weighted sum of their surprise values (Clark, Hunt & Malacaria, 2004:3–4)

$$H(x)=\sum_{i=1}^{n} p_i \log \frac{1}{p_i}$$

The quantity H is known as entropy of the set of events.

Supposing there are two events, *x* and *y*, in question with *m* possibilities for the first event and *n* possibilities for the second. Let p(i,j) be the probability of the joint occurrence of i for the first and j for the second. The entropy of the joint event is:

$$H(x,y)=\sum_{i,j} p(i,j)\log p(i,j)$$

while

$$H(x)=\sum_{i,j} p(i,j)\log \sum_{j} p(i,j)$$

$$H(y)=\sum_{i,j} p(i,j)\log \sum_{i} p(i,j)$$

Through further manipulation of the above quantities the conditional entropy of *y,* $H_x(y,)$ as the average of the entropy of *y* for each value of *x*, is weighted according to the probability of obtaining that particular *x*. (Shannon, 1948:12). In other words:

$$H_x(y) = \sum_{i,j} p(i,j) \log p(i,j) + \sum_{ij} p(i,j) \log \sum_{j} p(i,j)$$

$$H_x(y) = H(x,y) – H(x)$$

or

$$H(x,y) = H(x) – H_x(y)$$

This quantity measures the extent of the uncertainty as regards*y* on average when*x*is known. The uncertainty of the joint event *x,y* is the uncertainty of *x* plus the uncertainty of *,y* when *x* is known.

Clark et al. (2005:5) contend that information theory provides a more general way of measuring the extent to which information may be shared between two sets of observation. Given two random variables,*x* and *y*, the mutual information between *x* and *y*, written *I(x;y)* is defined as follows:

$$I(x;y) = H(x) + H(y) – H(x,y)$$

This quantity is a direct measure of the amount of information carried by X which may be learnt by observing y (or vice versa), or the information transferred from *x* or *y* during the observation of the other variable. However, mutual information does not provide an answer as regardsthe direction and speed of the information flow, nor does it provide any measure of the efficiency with which information has, in fact, flowed between the variables X and Y.

6.2.2.2 Transfer entropy

According to Schreiber (2000:461),several writers have made use of mutual information to quantify the information overlap of the information content of two systems. However, he maintains that mutual information does not contain any dynamic or directional information. Schreiber (2000:461), thus, derives a different metric, namely, transfer entropy, to describe and quantify the exchange of information between two systems, separately,in both directions, and, if required, conditional to common input signals.

Schreiber (2000:461) uses the Kullback entropy or mutual information formula for the derivation of the transfer entropy:

$$M_{IJ} = \sum p(i, j) \log \frac{p(i, j)}{p(i)\, p(j)} .$$

To examine the direction of the information transfer, a time-lag is introduced into the above formula in order to arrive at the following expression:

$$M_{IJ}(\tau) = \sum p(i_n, j_{n-\tau}) \log \frac{p(i_n, j_{n-\tau})}{p(i)\, p(j)} .$$

To incorporate dynamic structure it is necessary to study transitional, rather than static, probabilities. This is achieved by applying the entropy rate, rather than the stationary Shannon entropy, to more than one system, since the dynamics of the processes is contained in the transitional properties. The method of constructing a mutual information rate by generalising the entropy rate to two processes (I, J) is the measurement of the deviation from independence of the processes. This leads to the formulation of the corresponding Kullback entropy which, in this case, is defined as the *transfer entropy*:

$$T_{J \to I} = \sum p(i_{n+1}, i_n^{(k)}, j_n^{(l)}) \log \frac{p(i_{n+1} | i_n^{(k)}, j_n^{l})}{p(i_{n+1} | i_n^{(k)})} .$$

Schreiber (2000:462) recommends that the most natural choices for l are l=k or l=1 although the latter is usually the preferred choice.

Baek, Jung, Kwon andMoon (2005:1–7) used this model to investigate the information flow relevant to the analysis of the stock market They were able to identify the effects that certain economic events in a specific industry sector have on other industry sectors, thus clearly outlining the direction of the information flow. However, despite the fact that this model is more advanced than the mutual information model above, it does not indicate the efficiency with which information has been transferred between two data series.

6.2.3 Information flow measurement in computer hardware

6.2.3.1 Information flow as an improvement in accuracy

Clarkson, Myers andSchneider (2005:37) investigated the information flow as regards computer security from a high security level to a lower level, specifically between a computer and an attacker (a person not authorised to access a specified computer program) seeking access to a password-secured program located on a computer. These authors propose that the information flow relevant to a password-checking program corresponds with an improvement in the accuracy of an attacker's belief about the state and the certainty of the password. This theory is based on the fact that an attacker's certainty increases after each incorrect attempt to guess the correct password with which to gain access to restricted software. Clearly, the traditional definition of information leakage in terms of the reduction of uncertainty about secret data is insufficient.

Clarkson et al. (2005:37) define the quantity of information flow,*Q*, caused by an experiment (ε, b'$_H$), as the difference between the outcomes of the attacker's pre-beliefs and the attacker's post-beliefs:

$$Q\left(\left\langle \varepsilon, b'_H \right\rangle\right) \cong D(b_H \to \dot{\sigma}_H) - D(b'_H \to \dot{\sigma}_H)$$

where

$$D(b_H \to \dot{\sigma}_H)\ is\,the\,accuracy\ of\ the\,attacker's\ pre-belief$$

$$D(b'_{Hi} \to \dot{\sigma}_H) is\,the\,accuracy\ of\ the\,attacker's\ post-belief$$

ε = experiment

b'_H = belief after the outcome of the experiment

of the experiment (ε, b'_H)., which corresponds to the information flow according to an improvement in the belief of the attacker.

This model examines the increasing certainty of an attacker in his attempt to find a correct password. However, it does not provide any information about the efficiency with which information flow occurs.

6.2.3.2 Information flow measurement in memory management

According to Buck (2004:1),the information flow from and to memory is becoming more and more important as a result of the fact that increases in processor speed are outpacing the increases in speed of access to the main memory.

In light of this development, it is becoming ever more important that applications make effective use of memory caches. Information about an application's interaction with the cache is, therefore, crucial to enhancingthe application'sperformance. Such information may be obtained either by means of hardware or software tools.

Hardware tools incorporate performance monitor chips (PMC) for each processor-memory element (PME), which receives event signals from the other PME elements (with the emphasis on memory events). The data collected may be read by the PME itself or by the I/O subsystem. Other hardware tools include monitoring hardware with on-board memory to hold time-stamped events, which are triggered by software. The time-stamps provide a view of the information flow to the memory caches, which may be evaluated for the purpose of enhancing performance.

Software tools use software, that is, program codes, to control hardware performance monitors and to gather results. Such a program code may be inserted during the programming of the actual software or even after compilation of the programme code. The program code inserted collects the necessary information in order to visualise the memory cache performances.

This performance measurement of the information flow in memory caches is suitable only for the measurement of information flow performance in computers but not in interpersonal information transfers.

6.2.4 Information flow between humans

6.2.4.1 Analysis of individual communication/information flow in small groups

Du-Babcock (2003:3) measured interpersonal communication in small groups, using the effective decision-making theory (EDMT). The EDMT model uses individualism-collectivism and self-construal to predict communication behaviour. Specifically, the theory proposes that conflicts and conflict styles initiated by the differences in turn-taking in speech between the individual speakers are largely influenced by the cultural individualism-collectivism, self-construal and cultural group composition.

According to Du-Babcock (2003:3), a decision-making group may be perceived as a system with inputs, processes and outcomes, with the inputs influencing the processes, and the process parameters influencing the outcomes. The input variables are provided by cultural member characteristics (individualism-collectivism), group characteristics (heterogeneous-homogeneous) and group composition. The process variables on which the EDMT focuses are turn taking in speech and conflict behaviour.

The outcomes obtained from experiments are recorded as the number of times individuals from different cultural background take turns in speaking, as well as their speaking time.

Du-Babcock's results show that cultural characteristics and group composition both have a profound effect on the communication behaviour in small groups.

The above findings emphasise the effects that cultural influences have on communication or information flow between humans in groups. However, the findings do not quantify the effects of these cultural influences on the information transfer. Du-Babcock's technique is also not applicable to computers.

6.2.4.2 A power law model for the representation of information flow in social groups

Wu et al. (2004:327) argue that the information flow in social organisations is relevant to the issues of productivity, innovation and the extracting of useful ideas from the general pool of information. According to Wu etal. (2004:327), the speed with which individuals are able to act and plan their future activities is determined by the way in which information spreads.

Today, e-mail has become a preferred means of communication or information flow and it pervades business, social and scientific information exchange. As a result of the abundance of data available, e-mails are a good topicfor research. Wu et al. (2004:327) investigated a company's e-mail comprising a total of 40 individuals (30 individuals from within the company, and 10 individuals from outside of the company) in order to study the information flow based on the observation that an item of information relevant to one person is more likely to be of interest to individuals within the same social circle, than to those outside of it. According to the researchers this phenomenon is as a result of the fact that the similarity of the characteristics of the nodes in social networks decreases as a function of the distance from the nodes. This power-law network model is connected to the spread of business information, specifically as regards person-to-person information flow, because it is individuals who initiate the flow of information most likely to be of interest to the other party or parties.

Wu et al. (2004:327) used an epidemic model on a scale–free network. Such a model shows a particular threshold, indicating that the spread of information in a person-to-person(s) communication in organisations is limited.
In order to study the information flows physically in a power-law network, Wu etal. (2004:327–335) used the degree distribution of this specific network, given by:

$$p_k = Ck^{-\alpha} e^{-k/\kappa}$$

as a starting point. In the equation α=1, with an exponential cut-off at κ and C being determined by the normalisation condition. Through further mathematical manipulation the probability is that first person who has received a piece of information will transmit it to a number *l* of his/her neighbours, thus infecting the neighbours. Using a binomial distribution, Wuet al. (2004:327) found that it was possible to express this probability as follows:

$$p_i^{(1)} = \sum_{k=l}^{\infty} p_k \binom{k}{l} T^l (1-T)^{k-l}$$

where the superscript "(1)" refers to the first neighbours − those who received the information directly from the initial source. The *transmissibility T* is the average total probability that an infective individual will transmit an item to a susceptible neighbour and is derived as a function of r_{ij}, the rate of contacts between two individuals while τ_{ij}, is the time for which an individual remains infective. If both rate and time are randomly distributed, the *transmissibility T* becomes a constant and may be expressed as follows:

$$T = (T_{ij}) = 1 - \int_0^{\infty} dr d\tau P(r) P(\tau) e^{-r\tau} \ .$$

The generating function for $p_i^{(1)}$ is given by:

$$G^{(1)}(x) = \sum_{l=0}^{\infty} \sum_{k=l}^{\infty} p_k \binom{k}{l} T^l (1-T)^{k-l} x^l$$
$$= G_0(1+(x-1)T = G_0(x;T)$$

Supposing that the transmissibility decays as a power of the distance from the initial source and, choosing the weakest form of decay, then the probability that the *m*-th neighbour will transmit the information to a person with whom he/she has contact is given by:

$$T^{(m)} = (m+1)^{-\beta} T$$

whereβ> 0 is the decay constant. Using this relation to extrapolate to the m-th neighbour, the following equation is obtained:

$$G^{(m+1)}(x) = G^{(m)} G_1 (1 + (x-1)(m+1)^{-\beta} T$$

with the condition that the average number of affected individuals remains finite:

$$(m+1)^{-\beta} T G'_1(1) < 1.$$

The following conclusion may be drawn from the above derivations, namely, that the transmissibility of information decays with time. Wuet al. (2004:327–335) tested this theory on the transmissibility of e-mail information. The results show that the number of individuals whom a given e-mail message reaches is extremely limited, in contrast to what one would expect on the basis of a virus epidemic. In the context of this study, the above research shows that the information flow, specifically in a person-to-person(s) scenario in organisations, is restricted and, therefore, not as efficient as may have been expected.

6.2.4.3 Measuring information flow in human networks using wearable sensors

Pentland (2004:62) studied the use of wearable sensors in the interpretation and understanding of the information flow in human networks. The aim of his study wasboth to find answers as to the way in which individuals are influenced in their daily decision making and who influences them, as well as to propose new tools with which to improve the information flow within groups and organisations. In order to achieve this, Pentland (2004:62) attempted to develop models that were able to detect the dynamics of the interactions between individuals in a human network.

The sensors used in the study consisted of headset microphones, in conjunction with a PDA or mobile telephone. The function of these sensors was, to collect both direct and ambient audio information. It is possible to transmit such information to wireless networks and computers, via Bluetooth or other modern transceivers. By means of using a two- layer, hidden Markov model and mutual information between two voice streams, it is possible to detect voiced/unvoiced and speaking/non-speaking regions as well as the synchronisation of conversation, that is, two persons speaking to each other, respectively.

Once face-to-face conversation has been identified, through the use of wearable sensors, a computational model is required that is able to predict the dynamics of the individuals communicating and their interactions.

Pentland (2004:64) proposed the *influence model* as an approach in terms of which to describe the connections between the various Markov chains, as represented by the human network.

In the initial human experiments, applying this model, the writers only focused on the speaking pattern of individuals and, in particular, on the turn-taking dynamics of conversations − see discussion in section 6.2.4.1.

In his experiments, Pentland (2004:68) found that persons, who elicit new information in a conversation, exhibit a larger influence on the conversational dynamics with these conversation dynamics being able to provide quantitative estimates of the direction and magnitude of the flow of information. Quantifying face-to-face interaction within an office environment is of specific interest, because such interaction is the usual method of communicating complex and important information. However, even informal information flow between colleagues, that is, in the hallway, may be extremely important to an organisation. Furthermore, influence parameters, such as turn-taking and centrality[5], and their magnitude are

[5]Centrality is a standard social science measure of how important an individual is to information flow within a social network.

decisive factors in measuring the direction and the effectiveness of the information flow or communication.

6.2.5 Information flow measurements in human-computer interfaces

6.2.5.1 The measurement of pointing device efficiency using Fitts's law

In ergonomics, Fitts's law (Grosjean, Shiffrar & Knoblich, 2007:95–98) describes human movement in a mathematical form, which predicts the time required to move rapidly to a target area, as a function of the distance to the target and the size of the target (Grosjean, et al., 2007:95–98). This is particularly relevant to human-computer-interfaces (HCI), which make use of pointing devices, such as a mouse, joysticks, and others.

Fitts's law is used to model the act of pointing, both in the real world (i.e. with a hand or finger) and on computers (i.e. with a mouse).

Fitt's law is a mathematical expression of the form:

$$T = a + b\log_2\left(\frac{D}{W} + 1\right)$$

where

T is the average time taken to complete the movement. (Traditionally, researchers have used the symbol MT for this to denote movement time.)
a represents the start/stop time of the device while b stands for the inherent speed of the device. These constants may be determined experimentally by fitting a straight line to measured data.
D is the distance from the starting point to the centre of the target
(Traditionally, researchers have used the symbol A for this to denote the amplitude of the movement.)

W is the width of the target measured along the axis of motion. W may also be regarded as the allowed error tolerance in the final position, since the final point of the motion must fall within ± W/2 of the target's centre.
ID commonly replaces the log expression in the form of:

$$ID = \log_2\left(\frac{D}{W} + 1\right)$$

where ID is the index of difficulty, as originally defined by Fitts.

Zhai (2004:791–809) contends that an index of performance *IP* (also termed throughput *TP*), in bits/time, may be defined in such a way so as to indicate how quickly pointing may be done, independent of the particular targets involved. There are three conventions for defining *IP*, namely:

The first convention is $IP = 1/b$ (which has the disadvantage of ignoring the effect of *a*),

The second convention is $IP = ID_{average}/MT_{average}$ (which has the disadvantage of depending on an arbitrarily chosen "average" *ID*),

The third convention is $IP = IP_{average} = \frac{1}{N}\sum_{i=1}^{N} ID_i / MT_i$.

However, despite the definition used, measuring the *IP* of different input or interface devices allows the devices to be compared with respect to their pointing capability.

However, Zhai (2004:791–809) concludes that Fitt’s law and its parameters, a and b, as shown in the formula below, are suited specifically to characterising input performance in HCI, which suggests the use of Fitts’s law in its complete form, that is,

$$MT = a + b\ ID,$$

when carrying out the necessary data regression.

6.2.5.2 Process, outcome and affect in human computer interactions, according to Dillon

Dillon (2001:1) contends that the evaluation of human–computer interaction has, traditionally, been defined in terms of usability. Historically, usability was concerned with the features of an application, whilst more advanced considerations addressed the aspect of the interaction in terms of human action.

Dillon (2001:1) refers specifically to the ISO 9241 standard in order to decide on an acceptable definition of usability as regards all the definitions available. According to him, the ISO standard defines usability as the "effectiveness, efficiency and satisfaction with which specified users can achieve specified goals in particular environments".

However, when taking into account tasks such as the following, effectiveness may prove difficult to measure (Dillon, 2001:2):

- Creative production (writing, design)
- Information retrieval
- Reading
- Data analysis
- Management
- Making a purchase

The particular difficulties may be encountered in determining the metrics used in typical test scenarios and their relationship to meaningful task outcomes for users in the individual contexts.

Efficiency metrics, typically, involve metrics of the resources used to perform certain tasks, for example, time, effort and cost. In assessing efficiency and in taking into account the interaction of a user with a web page, such indices may include (Dillon, 2001:3):

- Time taken to complete the task
- Number of steps taken
- Number of deviations from ideal path

User satisfaction is clearly determined by factors such as personal experience with other technologies, preferred working style, manner of introduction to the product and the aesthetics of the product.

However, according to Dillon (2001:4), invoking such metrics may place undue emphasis on speed and accuracy. Furthermore, the types of user response that need to be measured are not necessarily task-based, that is, the process underlying creative thinking, where the cause and effect relationship is not clearly demarcated.

In view of the problems indicated above, Dillon (2001:4) proposes alternatives with which to measure overall user experience. Accordingly, he suggests that user experience may be regarded as existing on three levels:

- Process
- Outcome
- Affect

The process refers to the actions and responses of the user involved in interacting with the interface. The outcome encompasses the variables and measurements of what the user attains from his/her interaction with the interface.Affect includes all attitudinal, emotional and mood-related elements of the user’s experience.

In essence, the process-outcome-affect approach emphasises the following three key issues:

- What the user does
- What the user attains
- How the user feels

Or, in other words:

User experience = actions + results + emotions

Amongst other possible measures, Dillon (2001:6) proposes the following new measures with which to evaluate human–computer interaction:

- Aesthetics
- Perceived usability
- Learning over time
- Cognitive effort
- Perception of information shapes
- Intention to use
- Self-efficacy

This new approach is necessary in order to capture all aspects of the user's interaction with the interface as well asthe user's experience. In addition, user experience is dynamic, and the current measurements, based on efficiency, effectiveness and satisfaction, generally fail to address this fact. Furthermore, the current theories about the interaction of humans with computer devices are limited in terms of their applicability to design.

However, in order to arrive at a complete representation of the quality of the interaction, it is essential that interaction measurements include user-centred criteria that deal with the process, the results of the interaction process and the user's emotions.

6.2.6 Other information flow measures

6.2.6.1 Tobin's q

Tobin's '*q*', according to Villalonga (2004:210), represents the ratio of the market value of an organisation's existing shares (share capital) to the replacement cost of the organisation's physical assets (thus, replacement cost of the share capital). Tobin's '*q*' states that, if *q* (representing equilibrium) is greater than one ($q > 1$), then additional investment in the organisation would make sense because the profits generated would exceed the cost of the organisation's assets. However, if *q*is less than one ($q < 1$), then the organisation would be better advised to sell off its assets instead of trying to put them to use. The ideal state is where *q* is approximately equal to one, thus denoting that the organisation is in equilibrium.

Villalonga (2004:210) uses Tobin's *q* as a measure of an organisation's resource intangibility. He argues that tangible assets are capitalised, whereas intangible assets are expensed, that is, written off in the income statement. Accordingly, the book value of assets does not represent the real value of the organisation, whereas the market value of assets does reflect the additional value arising from the intangible assets.

Tobin's *q* is, thus, not a direct measure of information flow, but must rather be seen as a value denoting the accumulation of unique information, which has been converted into knowledge − an intangible asset −and which provides the organisation with sustainable earnings above those of similar organisations.

Villalonga (2004:216) measures the resource intangibility as a predicted value obtained from the regression of Tobin's *q* on three accounting measures of intangible assets, namely, Research &Development stock, advertising stock and intangibles-in-book. In particular, the following two econometric models are estimated: the hedonic regression of Tobin's q, and a dynamic panel data model of the relationship between q and the persistence of organisation-specific profits. The hedonic equation is expressed as follows:

$$\ln(q_{it}) = \alpha_j + \beta^*_{1j} RDSTOCK_{it} + \beta^*_{2j} ADSTOCK_{it} + \beta^*_{3j} OTHERINTANG_{it} + \varepsilon_{it}$$

where q = Tobin's q, RDSTOCK is the R&D stock divided by assets, ADSTOCK is the advertising stock divided by assets, and OTHERINTANG is intangibles-in-book divided by assets. The subscript *j* in all coefficients indicates that the values *ln(q)* are calculated separately for different organisations. The β represent the regression coefficients.

The values obtained for *q* from the above calculation are related to the organisation-specific profits based on the following fixed-effect model:

$$FSP_{it} = \alpha_i + \beta_0^* FSP_{it-1} + \beta_1^* q_{it} + \sum_{j=1}^{J} \beta_{2j}^* FSP_{it-1}^* q_{it}^* D_j + \varepsilon_{it}$$

where FSP_{it} are organisation-specific profits, q is Tobin's q, and D_j are sector-specific constants. In this model, Villalonga (2004:218) contends that β_0 is the persistence of the organisation-specific profits coefficient after controlling for other regressors, β_1 captures the effect of resource intangibility on the level of FSP, and β_{2j} is the effect of resource intangibility on the persistence of FSP in each sector.

Using actual data from different industry sectors, Villalonga (2004:219) found that there are substantial variances across the different sectors as regards the value-relevance of intangible assets. His results also indicate that Research and Development stock is a valuable intangible asset in the mining, construction, food, textiles, manufacturing and chemical, transportation and services industries, but not in other industries. Advertising stock was found to be valuable in most industries while the book value of intangibles is generally irrelevant.

6.2.6.2 Similarity measures

Metzler, Bernstein, Croft, Moffat andZobel (2005:1) explored the information flow between texts in a text collection, for example, newspaper archives or a web crawl, which contains a significant amount of repeated text information. They were particularly interested in on the possibility of identifying alternative versions of the same information.

It is believed that similarity comprises a similarity spectrum with exact identity at the one end, and topical similarity at the other. Metzler etal. (2005:1) used a specific information flow analysis tool to develop methods to track the flow of facts and concepts through a text corpus.

In order to generalise similarity, Metzler et al. (2005:3) propose the use of similarity measures at sentence level as well as combined sentence similarity at document level.In order to measure similarity levels at sentence level, they successfully applied techniques such as word overlap measures, inverse document frequency, relative frequency measures and probabilistic models.For document similarity, a bottom-up approach was followed to create a similarity score based on an exhaustive cross-alignment between all the sentences in two documents.

However, this method of tracking information flow relates to document and sentence similarity in an archive of text information only.

6.2.6.3 Information latency as a measure of information flow efficiency

Hoitash, Kogan, Srivastava and Vasarhelyi (2006:1–24) propose a latency measure that facilitates the measurement of both information flow and process latency. They define latency as "the delay that information flow experiences from the source to its destination". According to them, digitalised, seamless information flow and processes are highly desirable because they may, potentially, be associated with a higher level of productivity within an organisation. However, Hoitash et al. (2006:1–24), argue that the use of non-digitised data and processes contributes to a number of deficiencies, which may result in additional direct or indirect costs to the company. Accordingly, Hoitash et al. (2006:1–24) propose to measure the digitisation level of a company's processes and information transfer. They regard a company as digitised as long as there are no discontinuities in the real-time flow of information throughout all the processes, including data capture, data processing, data and information storage and information communication.

In order to measure the latency of information flow and processes, Hoitash et al. (2006:1–24) modelled information flows using data flow diagrams (DFDs). Essentially data flow diagrams (DFDs)model information flows in a system by breaking the system down into a data source, dataflow, data processing, data storage and data users − See figure 6.2 below. As depicted in figure 6.1 and described by data flow diagrams (DFDs), processes may be subdivided into as many lower level processes necessary to describe both the main process and the associated information flows fully with each process being evaluated in terms of the time it takes to complete the process. All the times which areapplicable to a specific, main process are aggregated into a single time or latency measurement applicable to this mainprocess.

Figure 6.1 depicts an entirevideo rental process as outlined by Hoitash et al. (2006:1–24) while figure 6.2 represents a more detailed DFD of the total video rental system process illustrated in figure 6.1. The DFD in figure 6.2 shows the main elements referred to above, namely:

- *Processes* − denoted as boxes containing numbers such as "Rental Video Item" with number "1",
- *Dataflows* − represented by lines with arrows, such as "Return Receipt", originating in process 1 and pointing to the "Customer" external entity,
- *Data stores*− symbolised by rectangles open on the right hand side, and marked by characters such as "D1 – Customer",
- *External entities* − characterised by square boxes, such as the "Customer" box in figure 6.2

The completion times will be computed for each dataflow shown in Figure 6.2, and then aggregated into latency measures for the entire process.

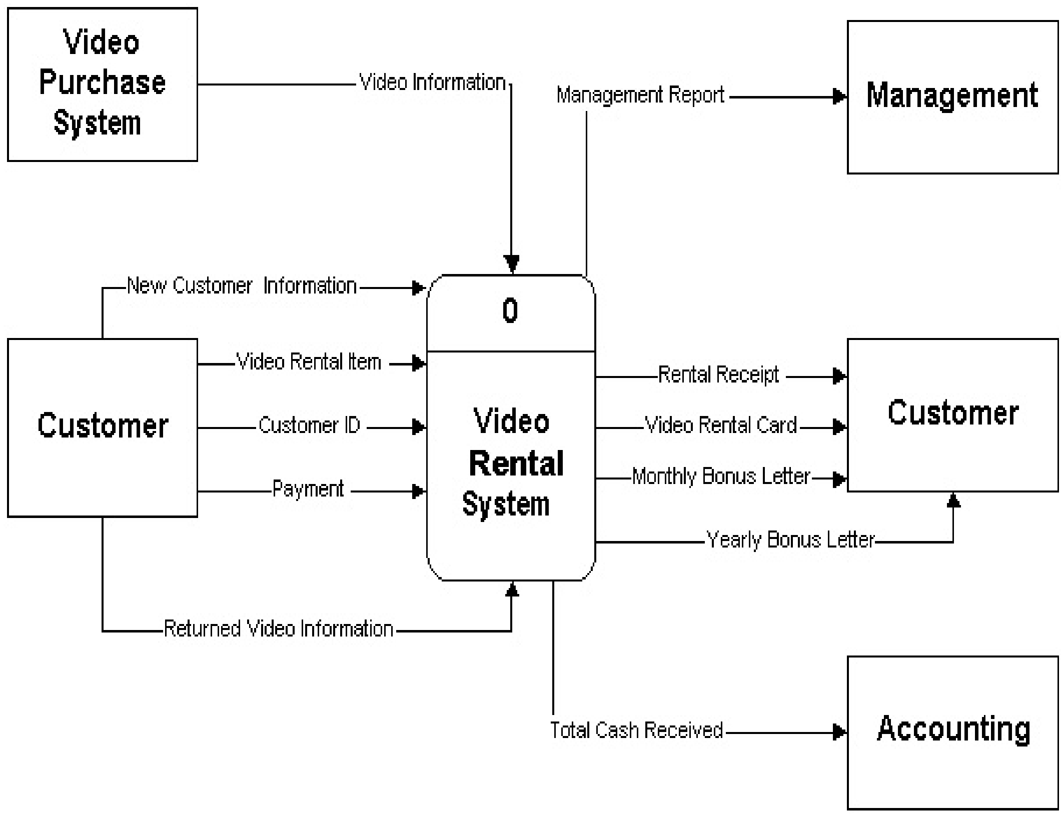

Figure 6.1: Example process of a video rental system

Source: Hoitash et al. (2006:1–24)

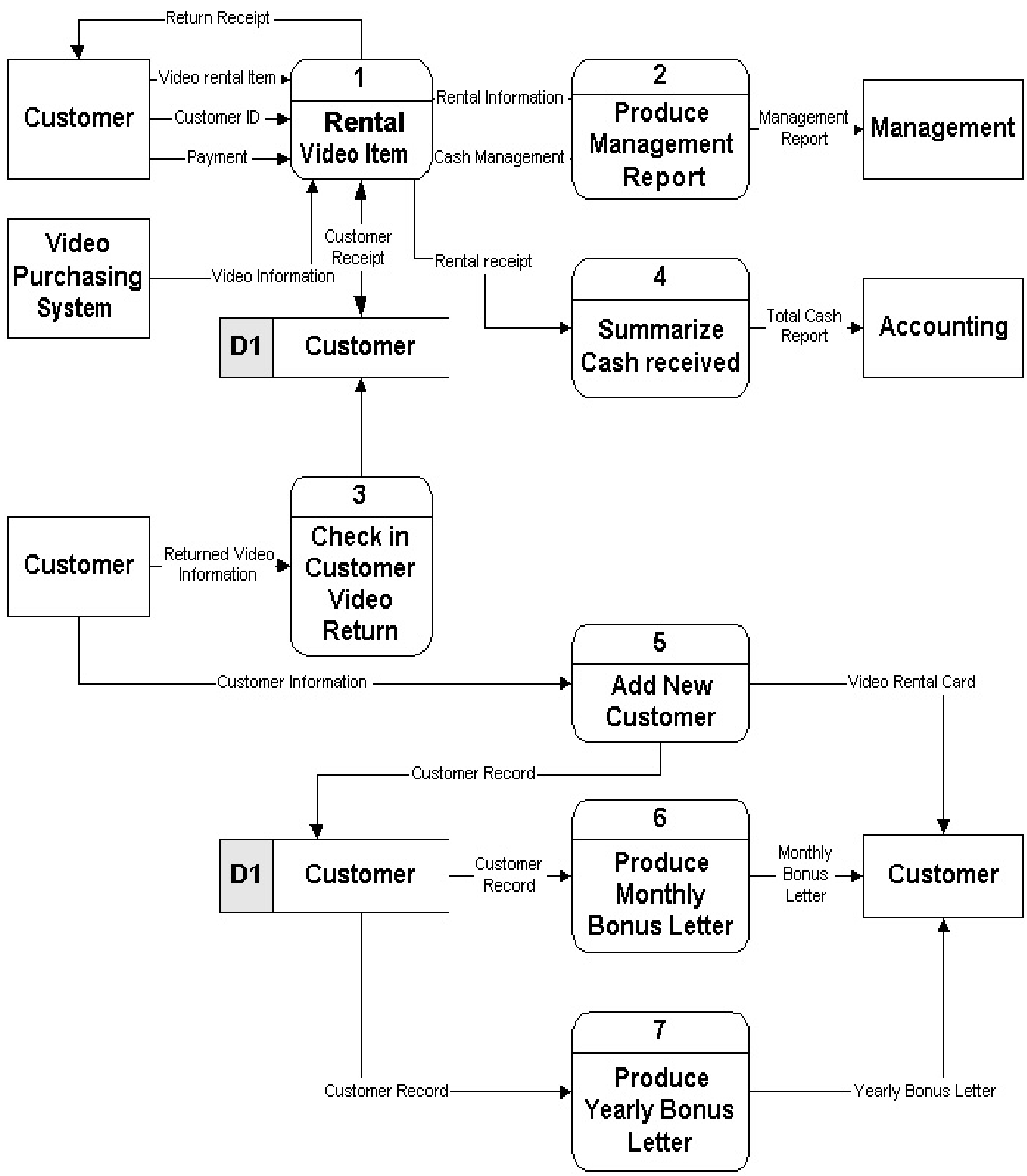

Figure 6.2: Data flow diagram of the video rental system process

Source: Hoitash et al. (2006:1–24)

The method of calculating latency times is similar to the calculation of path times in networks. However, although this method is extremely attractive as regards small networks, it may, however, consume large amounts of resources when calculating latency times for very large networks, such as large organisations or entire supply chains.

6.2.6.4 *Communication audit*

According to GuideStar Research (2006:2), organisational communication does not mean information delivery only, but it is considered as a prerequisite to drive strategic business performance and accountability. It is, thus, essential that communication be well planned, well designed and focused on realising strategic goals. In order to ensure the effectiveness and efficiency of the communication process, a periodic assessment of the communication process is required. Both GuideStar Research (2006:2) and Coffman (2004:1) propose the audit method for the assessment of the communication process.

Coffman (2004:1) defines a communication audit as "the systematic assessment, either formal or informal, of an organisation's capacity for, or the performance of, essential communication practices".

The communications audit has both evaluative and formative value. From an evaluative point of view, the communications audit provides an indication of where the organisation stands in terms of its communication capacity or performance while the formative quality of the audit points to areas in which the organisation could strengthen its performance.

According to Coffman (2004:5), the audit itself involves gathering data about the communication and communication practices and the assessment of the performance of each of the communication elements as measured against set targets.

Schade (2007:1–4) asserts that a typical communications assessment or audit involves a series of steps that begin by broadly identifying the major areas of the communications within the company.

GuideStar Research (2006:3) contends that the results of a carefully planned communication audit will reveal the following:

- Whether the organisation’s communications activity is efficient
- Gaps in information supply versus information demand (of particular importance to this study)
- If the communications are on target or in tune with the requisite company strategy
- The degree of universal understanding of company vision
- Attitudes and strategic behaviours that are incorporated into job performance
- Productivity levels of the organisation’s most important collaborative business relationships
- Where attention is required for continuous communications improvement.

However, the communication audit assesses the performance of the organisation’s communication after the fact, that is, it does not rely on real-time data, but appraises the effectiveness and efficiency of the communication from the following:

- The information created by the communication process, that is, date and time stamps of paper and electronic documents
- The experience of personnel, that is, senders and receivers of the communicated information and, thus, involved in the communication process
- The performance of the processes depending on the communication

The audit approach entails the following five steps for a successful implementation (Schade, 2007:1–4), namely:

- Analyse the existing communications models
- Conduct executive interviews
- Facilitate management and employee focus groups or interviews
- Coordinate a communications survey
- Develop a needs based communications plan

ISO19011, 2002 contains a further general definition of an audit as a systematic, independent and documented process for obtaining verifiable records, statements of fact or other informationand evaluating this information objectively in order to determine the extent to which the requirements contained in a set of policies, procedures or requirementsare fulfilled. Audits are performed to ascertain the validity and reliability of information, and also to provide an assessment of a system's internal control. The goal of an audit is to express an opinion on the person/organisation/system and so forth under evaluation, based on work done on a test basis. However, as a result of practical constraints, an audit seeks to provide *reasonable assurance*only that the statements made regarding the person/organisation/system are free from material error. Hence, statistical sampling is often adopted in audits. Audits are a commonly used management tool to assess an organisation's capabilities and performances, as outlined above.

6.2.6.5 Information audit

An information audit is a process that will effectively determine the current information environment (Henczel, 2001:1). Essentially, the information audit is similar to the communication audit in that it utilises the audit methodology to evaluate the information environment in organisations. The information audit specifically identifies the information currently supplied to the users and compares the result to the information required by the users so as to enable them to perform their necessary work duties effectively and efficiently. The information audit also attempts to identify the information that is needed to achieve organisational objectives, who needs the information, how it will be used and how it flows both through the organisation and between the organisation and its external environment.

Henczel (2001:4) recommends that a seven-stage model be used to introduce the information audit into an organisation. These seven elements include:

- Planning
- Data collection
- Data analysis

- Data evaluation
- Communicating recommendations
- Implementing recommendations
- The information audit as a continuum

The above model is not a highly structured and controlled process that operates in a tightly defined manner but rather it is a structured framework that is flexible and able to 'bend' to meet the varying conditions and constraints of an organisation. In other words, the components may be “tailored” to suit the objectives of the organisation and the resources available.

The initial information audit constitutes the first generation audit. It provides a snapshot of the organisation’s performance and capability of distributing, storing and providing information effectively and efficiently. Once an initial audit has been performed, decisions must be made about the way in which to improve the information environment where necessary. Each subsequent audit conducted will add to the information environment development, and ensure that the resources used for the improvement initiatives are being utilised correctly.

While it would appear that the information audit is extremely similar to the communication audit, the information audit does not,however, prioritise the efficiency of the information provision − a vital factor in the communication audit − but concentrates on the gaps between information availability and information requirements.The efficiency of the information provision seems to be a secondary concern.

Conducting an information audit will enhance the understanding of how an organisation works with regard to information and, consequently, with regard to knowledge.

6.2.7 Applicability of the information flow measurements to information flow efficiency in supply chains

6.2.7.1 Introduction

Various information flow and flow efficiency related measurement models were described above. The measurement models described differ as regards both nature and application. Whilst some are theory-derived, others stem from the practical application of existing appraisal methods. The applicability of these measurement models to the assessment of supply chain information flow efficiency must still be assessed. The following sections explore the nature of each model in detail, and describe its applicability to the measurement of supply chain information flow efficiency.

6.2.7.2 Applicability of information flow measurement models based on information theory

Firstly, measurement processes were discussed based on information theory. These measurements rely on the existence of two performance time series of data emanating from related processes, for example, the returns achieved by individual stocks and the underlying stock market as discussed in section 6.2.2.2. In this case, the information flow analysis yields common information content between the two time series, that is, attempting to quantify the amount of information carried in one of the time series but emanating from the other.

This type of comparison is purely mathematical and is based on Shannon's information theory. However, the calculations involved in the comparison of the time series are sophisticated and require a clear understanding of the mathematical background of the information theory. Although attempts have been made to incorporate the direction of information flow into these models, there has been no attempt made to quantify the efficiency with which the information was carried over from one time series to the other.

In addition, the time series mentioned above represent performance values, in this case, the return yields of individual stocks, an index portfolio, or a market portfolio. However, such performance values are not commonly available for the different processes found in the supply chain. Nevertheless, for those time series available, it is possible to detect interdependence between the informational items making up the time series but, as explained above, it is not possible to deduce the efficiency with which the information has flowed from one item to the other (Baek et al., 2005:1–7). Generally, in stock markets, the information available about specific organisations, as well as the environments in which they operate, influences the value of the stocks and, therefore, their return, directly.

Based on the above facts, it is clear that the measurement processes based on the information theory are not suitable to measure the information flow efficiency in supply chains.

6.2.7.3 Applicability of measurement models dealing withinformation flow amongst computer hardware

The information flow within computer hardware occurs in small, short parts of a second, making it impossible either to observe or to follow. Accordingly, special programs or software are required to track the flow of information within computer hardware. Such programs are capable of assessing how information flows into specific areas of the hardware and monitor the speed with which this occurs. This, in turn, provides certain information about the efficiency of the hardware use.

However, although it is possible to make assumptions about the efficiency with which information flows in computers, between different hardware and between hardware and software, programs of this nature are not able to cater for the measurement of the information flow between computers and humans or between humans, as is so often the case in supply chain processes. Accordingly, the measurement of the information flow within computers addresses one element only of information flow measurement in the supply chain.

6.2.7.4 *Applicability of measurement models dealing with information flow amongst humans*

The information flow between humans, especially within small groups, which tend to occur frequently in supply chain organisations, has been discussed in section 6.2.4.

The specific models discussed focus particularly on the representation of the information flow in small human groups and with the modelling of the occurrence and distribution of information flow within groups and amongst humans, as well as the influences of other factors, including cultural differences and group composition, on the information flows. However, these models of information flow prediction provide a measurement of the way in which the information spreads amongst humans rather than measuring the efficiency with which information is transferred between humans.

Accordingly, the proposed analyses of the information flows amongst humans and within small groups does not provide the necessary efficiency measurements required to offer any meaningful statement about the information flow in supply chains.

6.2.7.5 *Applicability of measurements dealing with information flow between humans and electronic interfaces*

Section 6.2.5 dealt with the information flow and efficiency measurements in human–computer interactions. Specifically, Fitts's law was cited to address the efficiency in the application of pointing devices as an interactive medium between humans and computers.

However, although, Fitts's law is capable of measuringthe efficiency pertaining to different pointing devices, it does not take into consideration the complete interaction between humans and computers. For example, the human interaction with computers also encompasses the effectiveness of the interactive screens that the interface provides, as well as the layout of the information on the screen. These parameters were discussed in the second part of section 6.2.5, which considered the overall user experience of the human computer interaction. It was emphasised that the pure efficiency measured, that is, the time taken to complete a task, is insufficient in measuring the overall efficiency with which a task could be completed using interactive tools. Accordingly, new, more human-centred assessment criteria were introduced in order to evaluate human–computer interaction. These criteria also influence the efficiency of the information flow through the interface, as information flow also depends on significant parameters, as depicted in the communication model in figure 3.4. Furthermore, information flow efficiency is also impacted upon by factors that influence the interpretation, location and decipherability of the information on the interface.

Thus, for the reasons cited above, it is clear the methods of measuring human–computerinteraction, asdescribed, represent incomplete media for the measurement of supply chain information flow efficiency, as these methods measure some of the factors that affect information flow efficiency only.

6.2.7.6 Applicability of non-classified information flow measurements

The discussion of the non-classified information flow metrics commenced with the illustration of the first metric*Tobin's q*, a metric of the ratio of the market value of an organisation's existing share capital to the replacement cost of the organisation's physical assets. This metric has been used to include intangible resources in the assets of an organisation. Intangible assets comprise mainly the accumulated knowledge which an organisation uses to gain an aggressive advantage over its competitors. Accordingly, *Tobin's q* does not represent a metric of information flow efficiency, although it is a metric of accumulated knowledge and accumulated knowledge has its foundation in the information flow which has occurred during a certain period of time. Therefore, although this metric does not assess information flow efficiency directly, it has been discussed here in order to provide a more comprehensive overview of the metrics dealing with information and its flow.

The second metric is based on similarity of information and it attempts to identify the closeness of word structures, sentences or complete texts, in terms of their similarity to each other. Statistical evaluation methods are employed to produce similarity indices so as to rank the similarity of different texts to a given original.

However, in view of the fact that this measurement model deals with similarity issues only, it does not add to the efficiency measurement of the information flow in supply chains. In fact, given its nature, it is more closely related to the similarity measures of time series as described in section 6.2.6.2.

A more useful metric was demonstrated in section 6.2.6.3, namely, the metric which illustrates the use of *latency time measurements* to express information flow efficiency. In terms of this method, which is based on a detailed process chart and data flow diagram of an organisation, the individual time delays between the start and end nodes of the data and information activities that span a specific sub-process, are measured. The time values so derived are accumulated into a total time delay metric for each sub-process, while also taking into account serial and parallel activities. The sub-process latency times are accumulated into total process latencies.

This method appears to be extremely effective in describing the flow of data and information in small networks. However, in view of the complexity of the processes in larger corporations and supply chains, this method may become very tedious in these larger corporations and in supply chains.

The *communication audit* concentrates especially on the assessment of the communication within an organisation, with the focus on the transfer of strategic goals and information throughout the organisation. The systematic assessment of an organisation's communication capacity will reveal the information created by the communication process, the experiences of the personnel involved in the communication process, and the performance of the processes which are dependent on the communication.

The *information audit*focuses on the type of information supplied versus the information required by strategic decision makers. Both the information audit as well as the communication audit utilise the audit methodology to appraise the communication and information provision capacity of an organisation.

As a result of the fact that the audit methodology is able to provide facts such as the content, user experience and process performance values, it may be regarded as a suitable tool with which to assess the efficiency of the information flow in supply chains.

However, the audit methodology does not provide sets of indicators and metrics, which are readily applicable to information flow efficiency measurement and these indicators must be developed for and tailored to each case, as required.

6.2.7.7 Conclusion

This section provided a more in depth discussion of the inherent advantages and disadvantages of each measurement and thesuitability of each method in terms of supply chain related information flow efficiency measurements.

As discussed in sections 6.2.7.2 to 6.2.7.6, most of the measurement models described are able to measure certain elements of information flow and/or information flow efficiency. However, the information theory based models are either extremely limited in their application or they are difficult to apply in practice, despite the fact that they have being scientifically proven. Techniques involving the information flow measurement within computers require very specific software, which may not be commercially available, to measure small time differences within applications. On the other hand, human-to-human information flow measurement also does not provide any clear insights into the efficiency with which the information flow occurs. Finally, as described above, the knowledge-related models measure only the variations in knowledge, where knowledge represents a specific amount of information flowing either from or to the body of knowledge, and these models do not provide any indication of the efficiency of this information flow.

This research is concerned with providing indicators and metrics of information flow efficiency which may be used in practice and in every organisation.

From the above discussion, it is apparent that two theories/methodologies/techniques/measurements only are capable of dealing with the assessment of the efficiency of the complete information flow process as found in supply chains. These methods include:

- the information latency method
- the audit methodology.

However, although the information latency method produces useable efficiency values in terms of time values, it was emphasised above that this method could become extremely tedious, as it is necessary to draw up and evaluate a dataflow diagram for each supply chain participant. This, in turn, implies that each data activity must be measured in terms of its latency. In addition, there is a special accumulation protocol for latencies, addressing serial and parallel activities, which must also be adhered to. This method also does not consider any measurements other than those based on time.

The audit methodology appears to be more efficient in assessing supply chain processes than the information latency method, as it concentrates on the evaluation of entire sub-processes, as compared to having to break such processes down into individual data activities. It is also possible actually to check the performance of the metrics in an audit as it may be checked physically, for example,the length of time it takes a person to complete a task. Reports may be checked against actual performance and it may, for example, be ascertained whether passwords exist or not. Furthermore, deviations from required standards may be observed. This methodology may be applied to all processes, organisations and supply chains alike and, thus, this methodology may be regarded asan universal instrument for the possible measurement of the information flow efficiency in supply chains and organisations. However, as pointed out above, the only drawback to this method is the unavailability of indicators and metrics that are applicable to information flow and its efficiency.

The sources of the indicators of information flow efficiency will be discussed and explored in the following section.

6.2.8 Conclusion

In order to measure information flow efficiency it was important to review the existing literature as regards the availability of possible measurements relating to information flow efficiency.

The first sections of this section discussed the measurements available for the evaluation of information flow and information flow efficiency.

The measurements discussed were divided into information flow measures based on information theory, information flow between computer hardware and software, between humans, between humans and electronic interfaces, and other non-classified information flow measurement models. Whilst explaining each model in detail, inherent application fields were provided for each of the measurements, as detailed by the relevant writers sited.

The last part of the chapter provided a detailed discussion of the inherent advantages and disadvantages of each measurement as well as the appropriateness of each method to supply chain related information flow efficiency measurements. It was found that two theories/methodologies/ techniques/measurements only are capable of assessing the efficiency of the complete information flow process, as found in supply chains. These methods are

- the information latency method and
- the audit methodology.

The inherent disadvantages of the information latency model are that it may become extremely tediousand it also does not consider other measurements except those based on time. The audit methodology appears to be a more efficient method for assessing the information flow efficiency in supply chains, although assessment metrics for information flow efficiency are not readily available. However, this research is concerned with providing indicators and metrics of information flow efficiency, which may be used in practice and in every organisation. The following section discusses the sources of the indicators and metrics of information flow.

6.3 SOURCES OF INDICATORS OF INFORMATION FLOW EFFICIENCY

6.3.1 Introduction

It is clear from the communication model, as depicted in figure 3.4that the information transferred between two humans is subject to certain conditions. The sender requires a channel through which to feed the information to the receiver, while the receiver must be in the same frame of mind as the sender to receive and understand the information. In addition, the receiver needs to have certain knowledge about the topic of the information in order to be able to interpret the information sent. Noise may also influence the transmission process to such a degree that the information becomes either irretrievable or unusable.

It is, thus, clear that the efficiency of the information transfer does not depend only on the speed of the transfer itself, but also on factors such as format, comprehensibility, content, completeness, relevance, validity, cost-effectiveness, consistency and accuracy. The above understanding of information transfer may be derived from the basic definition of efficiency in terms of which efficiency is described as “the accomplishment of, or ability to accomplish a job with a minimum expenditure of time and effort”, where the term *time* refers to the physical time expended whilst the term *effort* refers to non-time based aspects such as mental and physical exertion. Accordingly, parameters other than solely time-based indicators and metrics must be considered.

In order to provide a comprehensive list of possible indicators and metrics for the measurement of information flow efficiency, the characteristics applicable to information (also referred as qualities of information) and information flow were reviewed. Software very often plays a role in processing information and, therefore,the characteristics of software quality were discussed. In addition, qualitative characteristics were defined for financial or accounting information as this type of information is useful for financial and economic decision making and, hence,reference was also made to these characteristics.

The underlying principle of the association betweenthe characteristics of information and information quality and the indicators of information flow efficiency has its origin in the relation between the information quality and information transfer. For example, user-friendlier and error free presentation of information improves the speed with which the information may be both understood and interpreted and, thus, reduces any delays in passing on the information or making decisions based on this information. It is, therefore, evident that the time taken to pass on information is not the only factor which is critical to information flow, but also that other factors, for example, understandability, security and accuracy, may impact on the information flow. These principles are also set out clearly with reference to accounting and financial information. It is essential that financial information be useful for the decisionmakers who use this information to make far reaching decisions, for example, decisions regarding the economic wellbeing of small and large corporations. Accordingly, financial accounting standards organisations around the world have defined those characteristics that make financial and accounting information useful and to which such information should display.

The above mentioned characteristics of information flow, business process performance evaluation and financial information actually represent the drivers of information flow efficiency. Each of the drivers that were identified impact directly on information flow efficiencyeven if such efficiency is not measured in direct terms. For example, the understandability of information impacts directly on the efficiency with which information may be interpreted and, therefore, with the efficiency with which such information flows to the next supply chain participant. It is, therefore, of the utmost importance to be able to measure the performance of the drivers of information flow efficiency in order to be able to obtain an overall view of the information flow efficiency in supply chains. The following sections will explore those characteristics which are specific to information quality as well as those characteristics which are applicable to general business performance measurements.

6.3.2 Characteristics of information and information quality

Lin(4) (2006:8) and Stair andReynolds (2011:7) list characteristics that are applicable to information systems and information quality. These include the following:

- Information accuracy, that is, error-free information
- Complete information − contains all the important facts
- Flexible information may be used for a variety of purposes
- Reliable information is important to the decision makers
- Relevant information may be depended upon
- Timely information is delivered when it is needed
- Information is verifiable
- Information is accessible

The following section will outline the characteristics generally applicable to a business performance measurement framework.

6.3.3 Characteristics of measures applicable to business performance measurement

According to Kellen (2003:22), there are not many sources that report on the key characteristics of those indicators that are desirable in a business performance system. The importance of such key characteristics dependslargely on specific writers and the studies which have been conducted.

The following key characteristics of performance measurement system criteria were identified by De Haas andKleingeld (1999:233–261) (referred to by Kellen, 2003:22–23):

- Controllability
- Validity

- Completeness
- Cost-effectiveness measurability
- Specificity
- Relevance
- Comprehensibility
- Coherence

According to Kellen (2003:22–23), Jensen andSage (2000:33–61) enumerate the following metric design characteristics (goals) of performance measurement systems:

- Cost effectiveness
- Strategic alignment
- Acceptability
- Usefulness
- Acquirability and implementability
- Consistency
- Accuracy
- Reliability
- Repeatability
- Believability
- Timeliness
- Responsiveness
- Known responsibility
- Security

Kellen (2003:23) contends that the abovementioned key characteristics constitute a minimum number of the possible characteristics only that may be applied to indicators in a business performance system. Such systems need to be tailored to the needs of each organisation, where necessary. Other writers enumerate similar characteristics – See below.

Eckerson's (2004:1–5) research confirmsthe following key characteristics of Kellen:

- Validity
- Comprehensibility
- Timeliness
- Relevance
- Acceptability

Rosella Software (2008:1), which is specifically involved with predictive knowledge and data mining, defines the following qualities of good KPIs:

- Validity
- Specificity andmeasurability
- Reliability
- Relevance
- Comprehensibility
- Timeliness

According to Breyfogle (2008:1–3), effective and reliable metrics require the following characteristics:

- Strategic alignment
- Consistency
- Repeatability and reproducability
- Timeliness
- Actionability or acquirability
- Predictability

Sullivan, McDaniel, Siegel, R&B Consulting and McDaniel Lambert Inc. (2004:2–4) enumerate the following list of characteristics of good metrics:

- Measurability
- Comprehensibility
- Timeliness
- Repeatability
- Controllability

- Insightfulness

Abbadi (2007:1–19) refers to good metrics as being:

- Quantitative
- Objective
- Timely
- Universally acceptable
- Inexpensive
- Obtainable
- Repeatable
- True from ground level

Ying, Hong andZhengchuan (2004:4–6) summarise the basic factors required for evaluating modelling techniques as follows:

- Validity
- Comprehensibility
- Flexibility
- Multi-perspectiveness
- Suitability
- Expressiveness
- Coherence
- Completeness
- Efficiency
- Effectiveness
- Formality
- Arbitrariness

Serrat (2010:1–8) names the following five dimensions of performance:

- Relevance
- Efficiency
- Effectiveness

- Sustainability
- Impact

The following section will discuss the characteristics applicable to software.

6.3.4 Qualitative characteristics of financial accounting information

Carmichael et al. (2007:67), Epstein et al. (2009:33), and Porter andNorton (2010:60) contend that the primary objective of financial reporting is to provide information which is useful for making investment and credit decisions. According to them, the qualities that make information useful have been designated its *qualitative characteristics*. Nikolai et al. (2010:46) indicate that the United States Financial Accounting Standards Board has specified the characteristics of information as depicted in figure 6.3 as those necessary if the information is to be at its most useful. Carmichael et al. (2007:68) argue that, without usefulness, there would be no benefits from information to set against the costs.

Nikolai et al. (2010:46) are of the opinion that it is essential that useful accounting information possess each of the qualitative characteristics to a minimum degree. However, different situations may require tradeoffs in terms of which the level of one quality is sacrificed for an increase in that of another quality.

Carmichael et al. (2007:68), contend that the two primary components of usefulness are relevance and reliability. Despite the fact that relevance and reliability are easier to determine than usefulness, they point out that the concepts of predictive value, feedback value, timeliness, verifiability, representational faithfulness, neutrality and comparability together serve as criteria for determining the usefulness of information.

Porter andNorton (2010:60) explain that the standard-setting body of the United Kingdom distinguishes between qualitative characteristics that relate to the content of the information presented and those that relate to presentation. Relevance and reliability are considered as the primary criteria of content, whilst comparability and understandability are considered to be the primary qualities relating to the presentation of information.

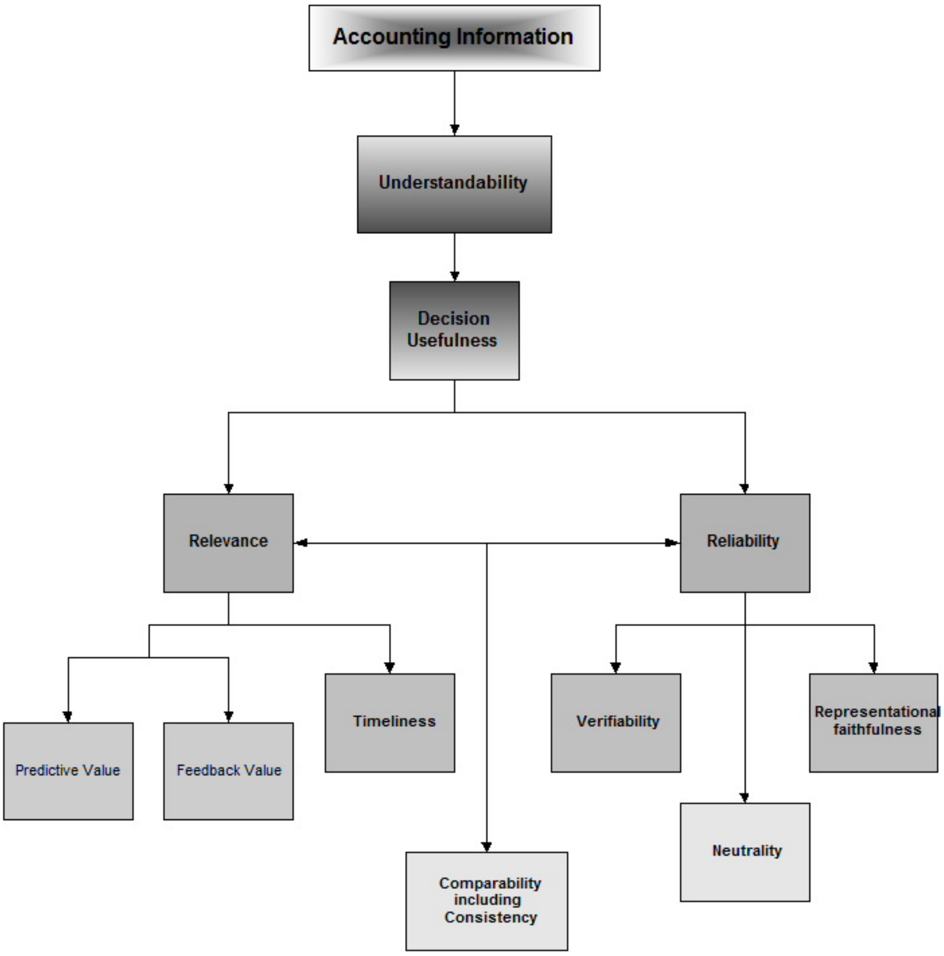

Figure 6.3: Characteristics of accounting information

Source: Adapted from Nikolai et al. (2010:47)

Each of these qualities will be discussed in detail in the following sections.

Understandability. According to Porter andNorton (2010:57), the understandability of financial information varies considerably, depending on the background of the user, that is, should the information be understandable to everyone or to those persons possessing the necessary accounting background only. Porter andNorton (2010:57) argue that financial information should be understandable to those who are willing to spend time understanding it while Nikolai et al. (2010:46) are of the opinion that accounting information should be understandable to those users who have a reasonable knowledge of business and economic activities and who are willing to study the information carefully. Understandability is the critical link between the user or decisionmaker and the accounting information.

Decision usefulness. Nikolai et al. (2010:46) explain that decision usefulness refers to the overall qualitative characteristic to be used to judge the quality of accounting information. Whether or not information is useful depends on the decision to be made, the way in which the decision will be made, the information already available and the ability of the decisionmaker to process the information. Carmichael et al. (2007:68) argue that usefulness of information may not be interpreted to mean whatever a particular individual interprets it to mean. In other words, the holistic evaluation only of the concepts of relevance and reliability and their components of predictive value, feedback value, timeliness, representational faithfulness, verifiability, neutrality and comparability together serve as criteria for determining the usefulness of information.

Relevance. Relevance refers to the information's capability of making a difference in a decision (Walton, Haller & Raffournier, 2003:74; Porter & Norton, 2010:57). Nikolai et al. (2010:46) contend that a different decision is the result of the information's capability of assisting the user to predict the outcomes of past present and future events, and to confirm or correct prior expectations.

Reliability. Reliability assures decisionmakers that they may depend on the accounting information to be effective in doing what it is expected to do (Walton et al., 2003:74). If it is tobe reliable, it is essential that financial information portray the important financial relationships of an organisation (Epstein et al., 2009:34). Accordingly, information is deemed to be reliable if it is both verifiable and neutral and if the users may depend on it to represent that which it is intended to represent.

Verifiability. Information is considered verifiable if it is free from error (Porter & Norton, 2010:58). In other words, several independent metrics will obtain the same accounting result (Epstein et al., 2009:34).

Neutrality. The characteristic of neutrality implies that accounting information should serve to communicate without attempting to influence behaviour in a particular direction (Epstein et al., 2009:34, Walton et al., 2003:74).

Representational faithfulness. According to Carmichael et al. (2007:71), representational faithfulness refers to the correspondence or agreement between a metric and the phenomenon it purports to represent. In other words, information must be without bias (Epstein et al., 2009:34). Walton et al.(2003:74)also describe representational faithfulness as validity as the accounting information must represent what really happened or existed.

Timeliness. Walton et al. (2003:74), Carmichael et al. (2007:71) and Nikolai et al. (2010:46) agree that information is timely when it is available to the decisionmaker before it loses its ability to influence the decision.

Predictive value and feedback value. Accounting information has predictive value when it helps decisionmakers to forecast more accurately the outcome of past or present events while information has feedback value when it enables the decisionmaker either to confirm or to correct prior expectations (Nikolai et al., 2010:46).

Comparability. In terms of its basic accounting definition, comparability is a quality of information that enables users to identify similarities in and differences between two sets of economic phenomena (Carmichael et al., 2007:77; Porter & Norton, 2010:57). Walton et al. (2003:74) contend that accounting information is comparable if it is measured and reported similarly for different organisations.

Consistency. Consistency implies conformity from period to period without changes in policies and procedures (Carmichael et al., 2007:78; Porter & Norton, 2010:57).

The individual quality characteristics of financial and accounting information were discussed above. According to the writers cited, understandability and usefulness are the most important qualities that financial and accounting information should exhibit. Understandability, which precedes usefulness in the accounting information hierarchy, has been broken down into two main characteristics, namely, “Relevance” and “Reliability”. These main characteristics were broken down further into individual characteristics, as depicted in figure 6.3.

However, despite the hierarchical structure of the characteristics of financial and accounting information, which distinguishes between user-specific and decision-specific qualities (Carmichael et al., 2007:69), Nikolai et al. (2010:46) argue that the hierarchy is not designed to assign priorities to the qualitative characteristics, but that financial and accounting information must possess each of the qualitative characteristics to a minimum degree.

As regards the development of indicators and associated metrics, all of the above mentioned qualities will be considered.

6.3.5 Characteristics of software quality

McGarry, Card, Jones, Layman, Clark, Dean and Hall (2002:8–9) illustrate software measurement by adopting a measurement information model. This model is based on a project management approach to software development. In a typical project it is important that fixed goals are met in terms of budget, schedule, quality and functionality.

Accordingly, the model addresses measurement based on the following common software information categories:

- Schedule and progress towards milestones
- Resources and cost, thus measuring the balance between work performed and resources assigned
- Product size and stability, thus addressing the capability and functionality of the software
- Product quality in terms of measuring the product’s capability of meeting the user’s needs

- Process and performance, thus evaluating the efficiency of the product
- Technology effectiveness, thus addressing the viability of the proposed technical approach
- Customer satisfaction, thus quantifying the degree to which the product meets the customer’s expectations.

The above main categories of measurement may be broken down into the metrics, including, inter alia, size, effort, and number of defects for each category.

6.3.6 Conclusion

From the discussion above, it is evident that, although the importance of individual characteristics and categories of measurements varies according to specific writers, several of the sets of characteristics and categories selected overlap and are duplicated. In order to compile a duplicate-free list of characteristics or a master set of characteristics, it was necessary to scrutinise and reduce the above mentioned characteristics.

Once the number of characteristics had been reduced, a set of possible indicators, in-line with the framework as set out in table 1.2, was created. The following section will discuss the master set of indicators and expand on each indicator with metrics, which metricswill be assessed utilising a Likert response format type question.

6.4 DEVELOPING INDICATORS AND ASSOCIATED METRICS

6.4.1 Introduction

With reference to section 1.2.6.1, the following structure for the information flow efficiency measurement framework is now introduced.

Table 6.1: Information flow efficiency measurement framework

Measurement framework	**Example**
OBJECTIVE	Information flow efficiency
INDICATOR	Information integration %
METRIC	1. Average information transmission time (sec) 2. Information cycle time (hours)

The above table depicts a new objective,*Information flow efficiency*, which may be measured as a result of the identification of *indicators* and associated *metrics.* In order to identify the*indicators* and *metrics* for information flow efficiency, it was necessary to evaluate characteristics relevant to the fields of business performance measurement, information technology and software quality for their suitability as regards measuring information flow efficiency. Once all potentially applicable characteristics had been identified, a duplicate-free master set of characteristics had been compiled. The following sectioncatalogues the reduced set of characteristics.

6.4.2 A master set of characteristics

The following list of characteristics isrelevant to the fields of business performance measurement, information technology and software quality and financial information. Their relevance to information flow efficiency may be derived from the effect that the absence of any of the characteristics would have on information flow efficiency. Using the example of "relevance", the first characteristic below, it becomes clear it would not be possible for information to flow efficiently if non-relevant information were transferred, as this would necessitate a process of clarification of that information which had been sent until such time that the information sent became relevant to the topic in the mind of the receiver. However, such a process would violate the definition of efficiency, as contained in section 6.3.1, in terms of which a minimum of time and effort are required for efficiency.

Similar cases may be made for all other characteristics which, essentially, represent the drivers of information flow efficiency. From the perspective of financial information, it was pointed out in section 6.3.4 that this type of information must possess each of the qualitative characteristics to a minimum degree.

Upon examination of the total number of characteristics available, the following duplicate-free list was retrieved (refer to sections 6.3.2, 6.3.3, 6.3.4 and 6.3.5):

Table 6.2: Master list of characteristics

- Relevance
- Usefulness
- Repeatability
- Believability
- Timeliness
- Responsiveness
- Consistency
- Interpretability
- Accessibility
- Accuracy
- Acceptability
- Security
- Comprehensiveness

Despite the fact that it is not possible to measure the above characteristics directly, these characteristics may, however, function as *indicators,* as defined in table 6.1 above. In order to assess performance in respect of each indicator, it is necessary to associate those particular activities that may be observed physically with that indicator. For example, it is not possible either to observe or to measure timeliness, which may, however, serve as an efficiency measurement. Timeliness must, therefore, be linked to an activity (metric), for example, the time required to respond to the receipt of an order, or the time required to process incoming e-mails. In both these cases, the timestamps on either a faxed document or on the electronic document may be examined to yield a measurement of the delay between the incoming and the outgoing message. The following section discusses the extraction of suitable indicators and associated metrics

6.4.3 Indicators and associated metrics developed from the master set of characteristics

In order to expand the master set of characteristics, as described above, it was necessary to investigate the main information and data transfer processes required to ensure a smooth functioning of the supply chain. It is, thus, necessary to consider these processes (discussed in section 2.2.2) as well as the generally applicable supply chain metrics, as found in the balanced supply chain scorecard.

The following indicators and associated metrics were arrived at:

6.4.3.1 Relevance

Relevance is a term used to describe how significant, connected, or applicable something is to a given matter at hand (Merriam-Webster(6) 2010). From the financial perspective, “relevance” refers to the capability of the information to make a difference to a specific decision. In terms of information flow, relevance may be construed as involving the applicability of the information presented to the actual situation under review, while the information is also capable of making a difference to a specific decision. Accordingly, the following questions,the responses to which can be assessed, may be asked:

- Does the information/data presentation meet the needs (too much or too little)?
- Willthe information/data presentation and content adjust to future needs?
- Are the information/data needs regularly reviewed (Iis feedback programme in place)?
- Are the information/data priorities considered?

6.4.3.2 *Usefulness*

Usefulness refers to the quality of having utility and, especially, practical worth or applicability (Merriam-Webster(1) 2009). From a financial perspective usefulness refers to the overall, qualitative characteristic of the quality of the information. In its individual sense and in terms of its applicability to information flow efficiency, usefulness may be interpreted as how well used the particular information is, in terms of the frequency with, and the level at which, the information/data presented is consulted when ascertaining the status of a particular project or situation. The following possible measurable questions were, thus, formulated:

- Is all the information/datacontained in the presentation useful to the user?
- Does the use of specific information/data dissipate over time?
- Is the information/data produced useful to all the users, from the strategic to the operational level?

6.4.3.3 *Repeatability.*[6]

Based on a statistical concept, repeatability is the concept that survey procedures should be repeatable from survey to survey and from location to location. In other words, the same data, processed twice, should yield the same results (OECD – Glossary of statistical terms(1) 2002). However, repeatability was not defined in financial terms Although it may, however, be linked to the concept of comparability, which refers to a quality of information that enables users to identify similarities in, and differences between, two sets of economic phenomena. As regards information flow efficiency, repeatability deals with the fact that it is possible to obtain the information/data for a second time by providing the same input parameters. However, repeatability may be inhibited when long time periods are required to produce the information/data, whilst the actual information/data may change far more quickly. This may be the case in real-time transaction systems, where data input may change unannounced and, thus, influence the results

[6]Repeatability is also called reproducibility - OECD – Glossary of statistical terms(1), 2002

of a report or query. Although this phenomenon may be desirable in certain performance areas of the organisation this would, however, have to be clearly stipulated. Based on this reasoning, the following possible, measurable questions were identified:

- Is it possible to reproduce this information/data within days?
- For which period is the information/datavalid compared to the time required to produce it?
- Would it be possible to repeat the information/data if it were reproduced from different report tools?

6.4.3.4 Believability

Believability may be defined as the capability of being believed, with believed being accepted as true (Merriam-Webster(2) 2009). In relation to information flow, believability clearly concerns the correctness of the data/information contained in a report or query, as well as the continued correctness of the specific data/information. Incorrect data may occur as a result ofeither incorrect query design or multiple versions of this data/information being kept at different data locations, without consistent version control. This relates closely to the financial definition of verifiable information which is considered to be information which is free from error. It also implies that the information is reliable. Reliability, as regards the financial perspective, assures decisionmakers that they may depend on the information to be effective in terms of doing what it is expected to do. Representational faithfulness, which refers to the correspondence or agreement between a metric and the phenomenon which it purports to represent, is included in the concept of*reliability*. The following possible measurable questions were identified for this measure:

- Is the information/data perceived to be always correct?
- How often has incorrect information/data surfaced in reports/presentation?
- Do multiple versions of information/dataexist on PCs, and networks, and in the paper archives?

- Are older versions of the information/datamixed with newer versions?

6.4.3.5 *Timeliness*

Timeliness refers to the speed of dissemination of the data,that is,, the lapse of time between the end of a reference period (or a reference date) and the dissemination of the relevant data (OECD – Glossary of statistical terms(3) 2006). Financial information ischaracterised as timely when it is available to the decisionmaker before it loses its ability to influence the relevant decision. Accordingly, timeliness, in the sense of information flow, is related to the efficiency of the information provision and it clearly refers to pertinent questions regarding the time it takes to provide the information and whether it is possible to produce the information on time. However,of equal importance is the response time to certain information received. This may be considered as one of the most important factors influencing information flow efficiency. The following possible, measurable questions were identified:

- How long does it take to retrieve information/data?
- Is the information/data always produced on time?
- What is the time difference between the receipt and reading of e-mails/faxes?
- What is the time difference between the receipt and responding to e-mails/faxes?
- Is late or missing information/data communicated?

6.4.3.6 *Responsiveness*

Responsiveness may be defined as quick to respond or to react appropriately (Merriam-Webster(3) 2009). However, responsiveness was not defined in financial terms. Responsiveness in terms of information flow is, thus, deemed to deal with the actual availability of data/information after the fact. In other words, responsiveness probes the time delay between the actual data/information becoming available and the actual possibility of being able to retrieve it from, for example, an enterprise resource planning system. The following measurable questions could possibly be asked:

- What is the time difference between the occurrence of activities and reporting of those activities?
- Are reports/information updated as soon as the data/information changes?
- Is transactional data updated real-time?

6.4.3.7 Consistency

Consistency refers to the steadfast adherence to the same principles, course, and form and the agreement, harmony, compatibility, correspondence or uniformity among the parts of a complex phenomenon (Dictionary.com(1) 2008). In terms of financial information, "consistency" implies conformity from period to period without any changes in policies and procedures. in the sense of information flow consistency concerns the uniformity and stability of the data/information which is being either transferred or retrieved. The main issue is, thus,whether uniform and correct data/information is possible, even if it retrieved from or transferred to different sources. Possible, measurable questions to be assessed include:

- Is it possible to compare information/data of the same nature between different sources?
- Are changes to the presentation of information/data communicated globally?
- Is the process of information/data provision/derivation clearly defined?

6.4.3.8 Interpretability

Interpretability relates to the verb, "to interpret", which means to bring out a meaning of something, or "to explain" (Dictionary.com(2) 2008). Although interpretability was not defined from a financial perspective, it does, however, relate closely to the concept of "understandability". In other words.financialinformation should be understandable to those users who have a reasonable knowledge of business and economic activities and who are willing to study the information carefully. As regards information flow interpretability could, therefore, be linkedboth to the ability to read the content of the data/information, as well as to the ambiguity of the content retrieved from the data/information by different persons. A set of possible measurable questions included:

- Are the variables in the presentation of the information/data clearly defined?
- Is the classification/division of the information/data understandable?
- Are help functions available to explain how the data/information is derived?
- Is multilingualism taken into account?

6.4.3.9 Accessibility

In statistical terms accessibility is used to describe the ease with which and the conditions under which statistical information may be obtained (OECD – Glosssary of statistical terms(2) 2006).However, this characteristic was not defined in terms of financial information. Nevertheless, in terms of information flow, accessibilitytakes into account the ease of obtaining information and the user-friendliness of interfaces aiding the access of data/information. Possible measurable questions to be asked in assessing this measure included:

- Are there obstacles to accessing information?
- Are the access screens for information retrieval user friendly?
- Is information access personalised?
- Is the user able to choose his/her own information content?
- What is the relative cost of accessing information/data?

6.4.3.10 Accuracy

Accuracy refers to the degree of conformity of a measure to a standard or true value (Merriam-Webster(7) 2010). This characteristic of "accuracy" relates closely to the financial definition of verifiable information which is information which is considered to be free from error. Conformity to a standard also implies the characteristic of neutrality which, in terms of financial information, indicates that the information concerned should serve to communicate, without attempting to influence behaviour in a particular direction. Based on the above definitions, “accuracy”,as regards information flow, deals with the correctness of the data/information which is used to make decisions. Possible measurable questions include:

- Is the data/information always correct?
- The number of corrections required to amend the information/data produced?
- Does a quality standard for information/data collection/presentation exist?
- How is both internal and external data accuracy checked?
- How is faulty/erroneous data treated?
- Are accuracy levels for the data/information specified?

6.4.3.11 Acceptability

Acceptability refers to being capable or worthy of being generally approved (Merriam-Webster(4) 2009). However, the financial hierarchy of characteristics of information did not include “acceptability”. Nevertheless, acceptability,as related to information flow, is concerned with the acceptance of the general format and the personalisation of the layout of the data/information. Possible measurable questions include:

- Do all the users of the data/information agree with the presentation/layout/content?
- Is it possible to customise/personalise the data/information layout easily?
- Do specific users of the data/information use the data/information presentation?

6.4.3.12 *Security*

Security as regards information systems and data/information is defined as the protection of information systems against both the unauthorised access or modification of information, whether in storage, processing or transit, and the denial of service to authorised users or the provision of service to unauthorised users. Security, thus, includes those measures necessary to detect, document, and counter such threats (University of Nevada 2010). No financial interpretation was provided for this characteristic. Possible measurable questions included the following:

- Is detailed information/data protected against unauthorised access?
- Is detailed information/dataprotected against unauthorised change?
- Is detailed information/data backed up regularly?

6.4.3.13 *Comprehensiveness*

Comprehensiveness involves covering a topic completely or broadly (Merriam-Webster(5) 2009). However, this characteristic was not defined in the financial perspective. In terms of information flow comprehensiveness covers the overall completeness of the data/information required in order to arrive at meaningful decisions based on the data/information. The following possible measurable questions were identified:

- Does the information/data produced cover all required aspects/variables?
- Do reports/information cover all requirements at all organisational levels?
- Is the information/data cascaded upwards into the next level indicators?

6.4.4 Conclusion

The above sectiondetailed a master set of the key characteristics that are desirable in terms of appraising the performance of information quality, the quality and understandability of financial information and the general efficiency and effectiveness of business processes. As discussed in sections 6.3.1 and 6.4.2, these characteristics impact on the efficient flow of information and may, therefore, serve as indicators of information flow efficiency. However, indicators do not provide a measurable entity. Accordingly, it was necessary to develop suitable metrics associated with each indicator− metrics which could be assessed against a scale to provide a numerical score defining the performance of a specific information flow efficiency indicator.

In view of the fact that it was the objective of this study to measure the efficiency of information flow, this section provided the basic set of indicators and associated metrics required to assess the level of information flow efficiency.

No importance or weight had, as yet,been assigned to the indicators and associated metrics. However, the importance of each indicator and metric was determined by means of a survey in terms of which the opinion of company leaders was sought. A statistical evaluation enabled the identification of the most important indicators and metrics, as indicated by the respondents, while the unimportant indicators and metrics were eliminated. The remaining indicators and metrics formed the basis for the measurement of information flow efficiency by means of an audit.

6.5 CONCLUSION

This chapter reviewed the existing measurements relating to the transfer or flow of information. The review was structured to deal with solely theoretical measures based on information theory, the information flow indicators in computers, the information transferred between computers and humans, the information flow among individuals and within groups of humans,as well as other information and information-flow related measurement methods.

An analysis of the individual measurement methods revealed that two methods only, namely, the information latency measurement model and the audit methodology, were suitable to be used as a basis for the measurement of the information flow efficiency in supply chains − the aim of this study. However, the measurement of information latency, which has a sound foundation in the analysis of networks, requires the breakdown of an organisation’s activities into data/information flow processes, which may prove difficult in an entire supply chain. In addition, the information latency, as a measurement of the time delay of information transfer, reflects only one of the possible parameters influencing the transfer of information. Accordingly, this method did not present a complete view of the information transfer/flow efficiency of an organisation.

The audit methodology is able, inherently, to take into account multiple parameters of information transfer. However, the single,most significant drawback of this method is the fact that it does not provide specified parameters or measurements to be assessed. Nevertheless, this drawback was also considered to be one of the method’s greatest advantages, as it allows for a task oriented and topic relevant configuration of the required indicators and metrics.

Relevant indicators and metrics were drawn from the characteristics applicable to information, software and financial information quality. The rationale for this conclusion may be found in the fact that information which conforms to good quality standards, will aid in both the correct understanding and the quicker transfer of information. Accordingly, these characteristics were considered as the drivers of information flow efficiency.

In order to apply the audit methodology to the measurement of information transfer efficiency, it was necessary to provide indicators and metrics to assess the level of information flow efficiency. A master set of information characteristics was presented, which will serve, in turn, as a selection of indicators to be ranked according to importance.

The literature did not provide a clear view of the importance of information and information quality characteristics, nor does it offer any recommendations, specifically in the context of information flow efficiency

As explained in the next chapters, a ranking of indicators was carried out by organisation managers by means of a questionnaire. The questionnaire was developed as follows: For each indicator, a set of questions was developed, which could be evaluated using a Likert-type response format.

A statistical evaluation of the responses of the managers will provide a final set of indicators and metrics, which could be used to measure the actual level of information flow efficiency in both organisations and supply chains. The topic of the measurement of performance levels will be discussed in chapter 7.

CHAPTER 7
RESEARCH METHODOLOGY

7.1 INTRODUCTION

Information and its flow has been the cornerstone of numeroussupply chain models (refer to chapter 2). Whilst literature studies (refer to sections 2.2.2 to 2.2.7 and 2.3.1.5) have identified that a relationship exists between shortcomings in the performance of a particular supply chain and the flow of information, no study has, as yet, provided metrics with which to assess the flow of information in organisations and /or supply chains. In addition, no meaningful method has, as yet, been proposed to measure the efficiency of information flow, especially in view of the complexity of information, as detailed in chapter 3.

The primary objective of this research, as indicated in chapter 1, is to develop indicators and associated metrics of information flow efficiency within supply chains.

7.2 PROBLEM STATEMENT

According to numerous writers of supply chain related literature (refer to sections 2.2.2 to 2.2.7), information flow and the efficiency of information flow play an important role in the efficient functioning of supply chains.

As regards the flows of materials, funds and information, as detailed in chapters 2 and 3, the measurement of the efficiency of these flows of material and funds has received the bulk of attention in the literature. However, in order to be able to control supply chain performance, it is essential that managers also pay attention to the efficiency of information flow and, thus, they require an instrument for measuring the efficiency of the information flow. However, as discussed in chapters 4, 5 and 6, there is a dearth of measurements for information flow efficiency. However, the measurement of information flow efficiency will aid the assessment of supply chain performance and assist in providing realistic expectations of possible improvements which may result from increasing the efficiency of the flow of information.

Hence, the following question is being investigated in this study:

What indicators and associated metrics may be used to evaluate information flow efficiency in the entire supply chain?

7.3 RESEARCH OBJECTIVES

7.3.1 Introduction

In order to answer the above question and to realise the primary objective of this study, it is necessary both to develop a research design and to employ research methods appropriate to this study.

The development of an instrument for the measurement of information flow efficiency by identifying possible indicators and associated metrics, and the explorative testing of this instrument of information flow efficiency measurement, constitute the main objective of this study.

The scope of the research problem is clearly reflected in the primary and secondary objectives of this study, as detailed in the following sections

7.3.2 Primary objective

It is clear from chapters 2 and 3 that the information flow in the supply chain is a complex issue, whilst the concept of information itself is multifaceted. The primary objective of this research is, therefore,

- **to develop and to conduct an exploratory test of an instrument for the measurement of information flow efficiency in the supply chain.**

The following secondary objectives were formulated in an effort to realise the primary objective of the study

7.3.3 Secondary objectives

In order to develop an instrument for the measurement of information flow efficiency, the following secondary objectives were formulated:

(1) to identify possible indicators of information flow efficiency

(2) to identify or develop possible associated metrics for the measurement of each indicator

(3) to determine the most important indicators and associated metrics for information flow efficiency in a sample case study of a specific telecommunications cable manufacturing supply chain in South Africa

(4) to develop scales for each metric against which the performance of each metric may be assessed

(5) touse these indicators, metrics and scales developed to conduct an exploratory test of the information flow efficiency measurement instrument in the sample case of a telecommunications cable manufacturing supply chain.

7.4 RESEARCH DESIGN

7.4.1 Introduction

There are two main types of research, namely, exploratory and conclusive research. Conclusive research may, in turn, be subdivided into descriptive and causal research (Shukla, 2008:30). Both, conclusive and exploratory research, rely on one or two data collection techniques. Of these data collection techniques, observation or direct communication constitutes primary research while a literature review comprises secondary research (Crosby, DiClemente & Salazar, 2006:77–78).

Research methods may be classified as qualitative or quantitative research methods (Myers, 2004:2). These methods are explained in detail in the section below.

7.4.2 Research designs and methods

7.4.2.1 Conclusive research design

The“conclusive research method” is a type of research which is intended to provide information that may be used either to draw conclusions, to make decisions or to choose different courses of actions (Chernyak & Nebukin, 2009:2–3).*Conclusive research* may also be quantitative. In other words, it takes the form of numbers that may be quantified and summarised (Crosby et al., 2006:78–79).

Descriptive research or statistical research provides data on the *population or universe* being studied. However, it is capable only of describing the “who”, “what”, “when”, “where” and “how” of a situation (QuickMBA:Marketing, 1999–2010:3). Hence, descriptive research is used when the objective of the research is to provide a systematic description that is as factual and accurate as possible. Such research details the number of times something occurs and it lends itself to statistical calculations such as determining the average number of occurrences or central tendencies. The two most common types of descriptive research designs are *observation* and s*urveys* (Mitchell & Jolley, 2010:204–205).

If the objective of a research study is to determine which variable may be causing certain behaviour – that is, whether there is a cause-and-effect relationship between *variables* –then causal research is recommended. In order to determine causality, it is necessary to hold constant the variable that is assumed to cause the change in the other variable(s), and then to measure the changes in the other variable(s). This type of research is extremely complex and it is not possible for the researcher ever to be completely certain that there are not other factors influencing the causal relationship, especially when dealing with people’s attitudes and motivations. There are two research methods which may be used to explore the cause-and-effect relationship between variables, namely,*experimentation* and *simulation.*

7.4.2.2 Exploratory research design

According to Crosby et al. (2006: 78–79), *exploratory research* is often conducted when a problem has not yet been clearly defined, or the real scope of the problem is, as yet, unclear. Exploratory research helps determine the best research design, data collection method and selection of subjects, and it may sometimes even conclude that the problem does not exist.

Exploratory research may be fairly informal, relying on secondary research such as a review of available literature and/or data, approaches such as informal discussions with consumers, employees, management or competitors, or more formal approaches through in-depth interviews, focus groups, projective methods, case studies or pilot studies (QuickMBA:Marketing, 1999–2010:2–3).

Generally, despite the fact that although exploratory research may develop new hypotheses, it does not seek to test these hypotheses, although it may provide significant insight into a given situation (QuickMBA:Marketing, 1999–2010:2–3).The results of qualitative research may provide some indication of the “why”, “how” and “when” of something occurring.

7.4.2.3 Qualitative research method

Qualitative research methods were developed in the social sciences to enable researchers to study social and cultural phenomena. Examples of qualitative methods include action research, case study research and ethnography. Qualitative data sources include observation and participant observation (fieldwork), interviews and questionnaires, documents and the researcher’s own impressions and reactions.

7.4.2.4 Quantitative research method

Quantitative research methods collect numerical data in order to explain, predict and/or control phenomena of interest. The results of this type of research are arrived at mainly through statistical data analysis and may be presented as a series of numbers displayed in graphs, tables or other statistical forms (Abawi, 2008:1–14).

7.4.2.5 *Case study research method*

The term “case study” has many meanings. It may be used to describe a unit of analysis (e.g. a case study of a particular organisation) or a research method. Myers (2004:6) defines the case study method as an empirical inquiry that investigates a contemporary phenomenon in its real-life context, especially when the boundaries between the phenomenon and context are not clearly defined.

7.4.3 Research design chosen for this study

The aim of the research work presented in this study was to provide indicators and associated metrics, which could be used to measure information flow efficiency. The research design required for this study may be deduced from the research process that was followed − see figure 7.1 − in order to realise both the primary and the secondary objectives.

In step 1 of the research process, a literature study was performed. This literature study explored the current body of knowledge in terms of the measurement of information flow and information flow efficiency in the SC. As regards available measurement frameworks and characteristics of information, quality of information and business performance measurement,the literature was reviewed with a view to incorporating certain elements in a survey.

The survey was designed in step 2 of the research process in such a manner that it might yield (1) an insight into the information integration in organisations/supply chains, using the specific telecommunication cable manufacturing supply chain as a case study, as well as (2) the importance ranking and rating of indicators and associated metrics of information flow efficiency in the SC.

Once the most important key indicators and associated metrics of information flow efficiency had been determined, statistical analysis and explorative data analysiswere used in step 3 of the research process to develop scales for the actual measurement process.

A case study was carried out in step 4 of the research process in order to explore the use of the new indicators and associated metrics of information flow efficiency in certain organisations of the telecommunication cable manufacturing supply chain.

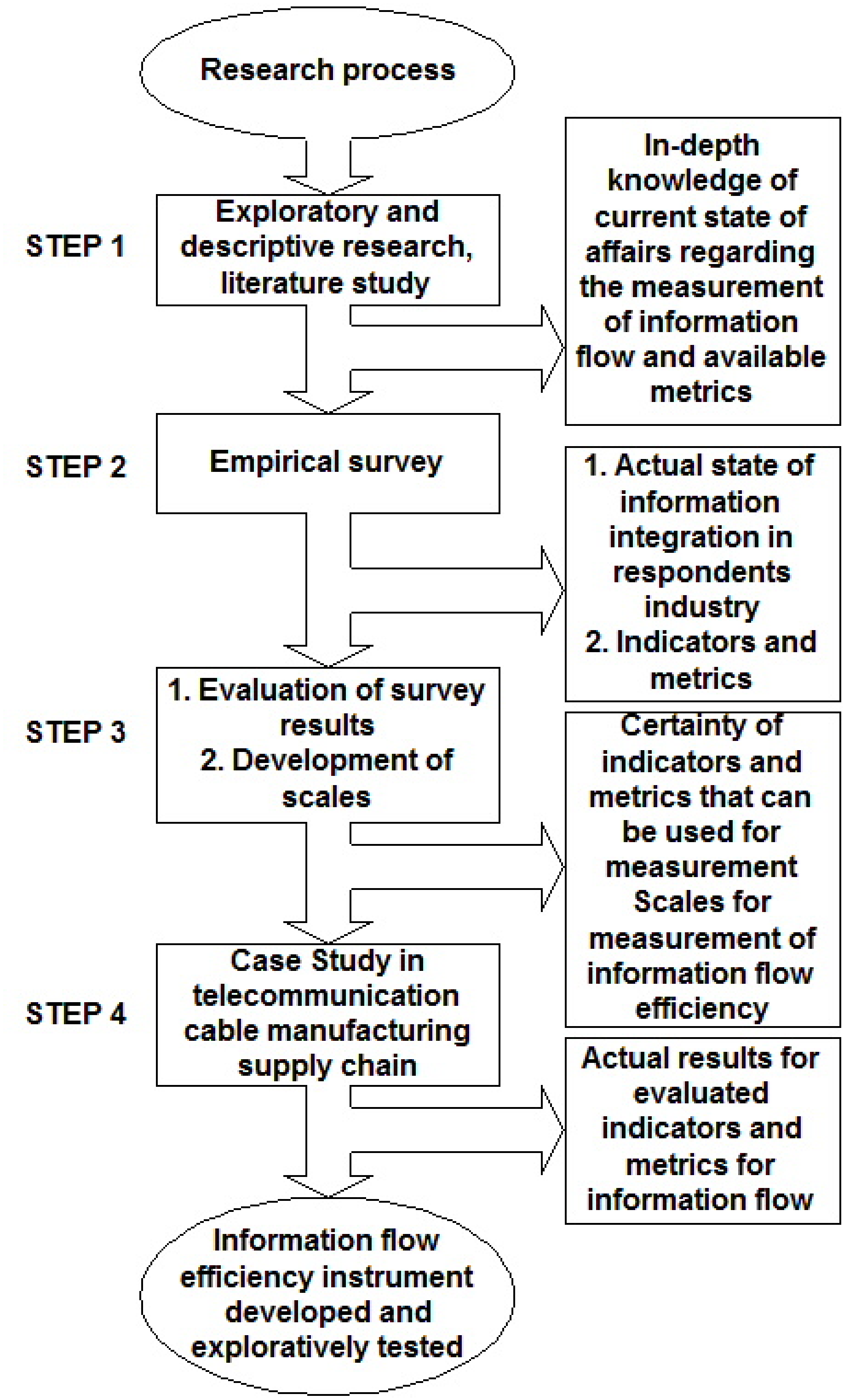

Figure 7.1: Research process for this study

It emerged from the above explanation of the research process that an exploratory study would be suited to ascertain the existing body of knowledge regarding the information flow in supply chains, the efficiency of this information flow (including the information systems aiding the flow), the informational integration of supply chains, the underlying complexity of the concept of information, existing measurement systems of information flow, performance measurement frameworks, thecharacteristics of information quality and business performance measurements.

After this exploratory study had been conducted, a descriptive study was carried out. This descriptive study involved designing a survey questionnaire, which explored the informational integration of a telecommunication cable manufacturing supply chain in South Africa and determined the most important indicators and associated metrics of information flow efficiency pertaining to the supply chain. The target population of a particular telecommunications cable manufacturing supply chain was researched by using a convenience sample (refer to section 7.5.2. for further discussion).

Statistical analysis was used to identify the key indicators and the associated metrics of information flow efficiency according to the views of the managers of the organisations within the above supply chain.

As part of the validation of the indicators and the associated metrics derived,it was deemed necessary to conduct an exploratory test of the information flow efficiency instrument. The evaluation of the instrument is explanatory in nature and answers the question as to “how” information flow efficiency may be measured. In addition, since the overall problem of the measurement of information flow efficiency had, as yet, not been solved, this problemrepresents a contemporary phenomenon within a real-life context, with the researcher having no influence over either the outcomes or the interaction between the variables.

The domain in this research study is clearly restricted to that of a specific telecommunications cable manufacturing supply chain and was, thus, clearly specified. A case study method was adopted in the second part of the empirical study.

The information flow efficiency indicators and the associated metrics developed in this study will be deduced from the results of the questionnaire − see next section.

7.4.4 Research techniques

7.4.4.1 Introduction

Each of the research methods discussed above makes use of one or more techniques for collecting primary data. These techniques range from interviews, observational techniques such as participant observation, experiment observation, surveys through to archival research. In addition, the techniques may also comprise case studies and mathematical models such as simulations and sampling methods. Survey research was identified as the most suitable primary research technique for this study

7.4.4.2 Survey design

7.4.4.2.1 Introduction

One of the main objectives of this study was to develop indicators and associated metrics that may be used to evaluate the efficiency of the information flow in an organisation and in supply chains. It emerged from an extensive literature search that little attention had been paid to these issues and that there was little indication that indicators for measuring information flow efficiency even existed. The characteristics of information flow and information quality as well as the general characteristics of business performance measurement and financial information quality were used to develop indicators and associated metrics.

A questionnaire (see Appendix I) was designed. This questionnaire was used to survey the opinions of respondents regarding the importance of indicators for the measurement of information flow efficiency in their organisation. The statistical evaluation of the responses enabled the researcher to assign an importance rating to each indicator and associated metric.

It had been indicated in the literature that integrating information technology in an organisation and supply chain facilitates the efficient the flow ofinformation through both the organisation and the supply chain (Stadler & Kilger, 2008:285).

This is as a result of fact that decisions may be made more speedily as the flow of information about certain supply chain events approaches real-time. For this reason, the questionnaire contained questions regarding the use of information technology in pertinent areas of the supply chain management and this, in turn, allowed for an evaluation of the informational integration of the supply chain in question, while taking into account all the supply chain partners. The survey also posed questions regarding the information integration level between organisations, thus enabling an assessment of this information integration level.

7.4.4.2.2 Development of the survey and survey questions

In order to investigate the efficiency of the information flow with the aim of arriving at indicators and associated metrics for the measurement of information flow efficiency, the characteristics of information quality, as suggested by Lin(4) (2006:8) and Stair andReynolds (2011:7), as well as the general characteristics applicable to business performance measurement as detailed by Kellen (2003:22), Abbadi (2007:1–19), Breyfogle (2008:1–3), Serrat (2010:1–8), Carmichael et al. (2007:67), Epstein et al. (2009:33), Porter andNorton (2010:60), Nikolai et al. (2010:46) and Walton et al. (2003:74), were used to produce indicators and associated metrics for a possible assessment of information flow efficiency. A master list of applicable characteristics had been compiled and is presented in section 6.4.2.

As regards the design of the survey instrument guidelines were followed, as contained in *Collecting data: surveys*, published by Taylor-Powell andHermann (2000:1–24) and also in the Form Design Standards Manual of the National Statistical Service (2009).

In compiling questions relating to the use and benefits of information technology for use in the questionnaire utilised in this study, the proposed model questionnaire of the Voorburg Group on Services Statistics as described by Roberts (2001:1–15) was used and adapted. The article by Fawcett, Magnan and McCarter (2005:1–19) entitled "Benchmarking information integration in supply chain management" provided further assistance in terms of the elements of information integrating systems to be included in the questionnaire.

The survey questions were structured in such a way so as to extract information about the size of the respondents' company, the use of EDI and Internet, the importance of information flow efficiency indicators and associated metrics and the use of information flow enhancing systems. The questions in the questionnaire (see Appendix 1) are presented in table 7.1 below.

Table 7.1: Overview of survey questions

Section / Question	Content of question/section and reason for inclusion into survey questionnaire
1	This section was for information to the respondents only
2	This question asked for the number of people working in the company. The aim of this question was to assess the company in terms of its size. This information could then be used to assess trends in terms of information technology use by company size.
3	This question inquired about the size of the company in terms of turnover. This would assist in extracting any trends relating to the use of information technology depending on size.
4	The respondents were asked to comment on the use of EDI and/or Internet for company purposes. EDI is often used to integrate information technology systems, whilst the Internet may offer websites with online ordering, payment and other facilities, thus assisting in providing fast electronic services.
5	The respondents were asked to comment on reasons why they are not using either EDI or the Internet (if this were, indeed, the case), thus providing information about the primary concerns associated with the use of information

	technology.
6	The respondents were asked to provide information on how often they use their EDI system or the Internet for business purposes, thus offering clues as to the trust and efficiency of the systems used.
7	The respondents were asked to indicate for which broad purposes EDI and/or the Internet were used, thus providing information about the use of transaction enhancing technologies.
8	The respondents were required to specify the exact activities for which the businesses used EDI and/orInternet, thus providing more, in depth knowledge about timesaving electronic activities.
9	This question inquired about purchases and sales being conducted via EDI and/or the Internet, thus providing some indication as to the volume of transactions through electronic channels and some indication of the trust placed in this means of conducting transactions.
10	This question enquired as to the way in which the businesses receive and place orders, thus indicating the use of traditional and/or more advanced online and integrated technologies.
11	The respondents were asked to indicate the location of both their customers and suppliers, indicating the global diversification of the businesses and their communication requirements.
12	The respondents were asked to provide some indication of their perceived benefits of using EDI and/or the Internet, from both a purchasing and a sales perspective.
13	This question enquired about the use of company websites.
14	This question requested information about the contents of the websites.

15	This question asked the respondents to indicate how many orders are placed and/or received via EDI and/or the Internet.
16	This question requested the opinions of the respondents with regard to the importance of efficient information flow in the success of supply chain management. High importance would indicate the need for high levels of electronic integration of business activities, thus supporting the aim of this research study.
17	This question enquired about the respondents' opinionsas to whether the measurement of information flow efficiency would assist in enhancing the transparency of supply chain processes. A positive response would support the intentions of this research.
18	This question enquired about the respondents' opinionsas to whether the measurement of information flow efficiency should form part of the balanced scorecard. A positive response would support the intentions of this research.
19	This question probed the importance of the characteristics of information and information flow. This question is important in the context of this research, as it is designed to provide the indicators and metrics of information flow efficiency required in the second part of the empirical study which will attempt to measure the actual information flow efficiency in organisations and supply chains.
20–32	These questions explored the importance of the distinct metrics belonging to each individual indicator of information flow efficiency − see section 19 above.
33	This question enquired about the use of integration-enhancing information technology systems, such as enterprise resource planning (ERP) systems and others.

34	This question asked for specific vendors in order to indicate any trends.
35	ERP and other systems comprise several modules integrating the different functions of an enterprise. This question enquired about which modules of the respective systems are in use.
36	The respondents were asked to indicate whether they were employing electronically integrating and real-time transaction recording systems, such as bar-coding and RFID.
37	Respondents were asked to indicate whether their ERP and other systems were able to connect seamlessly with their customers' and/or suppliers' systems. The answers to this question will provide clues about the electronic integration of supply chains.
38	This question enquired about any benefits the integrative systems provide.
39	The respondents were asked to indicate the degree to which the electronic systems meet their needs. The answers will point to the actual degree of integration achieved having implemented the relevant information technology.
40	Respondents were asked to judge the degree to which the information transfer between, firstly, different modules of ERP and other systems and, secondly, between humans and the modules of ERP and other systems, is hindered, thus provingevidence of lower than anticipated integration.
41	The respondents were requested to indicate the time taken to complete the questionnaire for future survey design considerations.
42	The respondents were asked for their comments for future survey design considerations.

7.4.4.2.3 Sample design and sample realised

(i) Sampling

Sampling refers to that aspect of statistical practice which is concerned with the act, process, or technique of selecting a representative part of a population for the purpose of determining parameters or characteristics of the whole population (Merriam-Webster(8), 2010). Each observation measures one or more properties of an observable entity. In business, sampling is widely used for gathering information about a population. According to Trochim (2006:1), sampling is the process of selecting units (e.g. people, organisations) from a population of interest so that by studying the sample, results may be generalised back to the population from which they were chosen. A distinction is made between *probability* or *random* and *non-probability* or *non-random* sampling (Kelley, Clark, Brown & Sitzia, 2003:261–266). Trochim (2006:1) points out that probability sampling involves the*random* selection of units, while non-probability sampling does not involve random selection of units.

Non-probability sampling may be divided into two broad types, namely,*accidental* or *purposive* (Trochim 2006:1). Non-probabilitysampling is commonly applied when qualitative methods (i.e. focus groups and interviews) are used to collect data (Kelley et al., 2003:261–266). Accidental or convenience sampling involves the selection of volunteers with the sample usually being made up of those individuals who are the easiest to recruit. On the other hand, purposive sampling involves the selection of a specific population and the members of this population only are included in the survey (Kelley et al., 2003:261–266).

According to Kelley et al. (2003:261–266), random sampling is employed when quantitative methods are used to collect the data (i.e. questionnaires). In addition, random sampling allows the results to be generalised to a larger population and statistical analysis to be performed, if appropriate. The use of this technique implies that each individual within the chosen population is selected by chance and is as likely to be picked as anyone else. Systematic sampling and stratified sampling are special sampling techniques within random sampling.

(ii) Sample design

An appropriate sample design would have been to consider the entire manufacturing industry or industries as the target population, for example, the South African steel industry and plastics industry. Together, the population size of the steel and plastic industry would have been 3 628 units. This means that, if the correct sample size calculation had been applied, a random sample of 348 units would have been required.

Initially, the researcher followed this approach and contacted the respondents with the aim to send out questionnaires in batches of ten to twenty at a time, with varying response due dates. However, after an initial approach to 70 prospective respondents, two responses only were received. Communicating personally with the prospective respondents and outlining the importance of the project did not, in any way, succeed in changing the response rate. This exercise took up approximately five months. Accordingly, given the time restrictions of this research as well as the reasons provided for not participating in this study − ranging between "not being interested", "having too many questionnaires to fill in already", "not having time" to "being unimportant", "cannot partake due to being in the same industry as the researcher's company" and "confidentiality issues"− the researcher was forced to apply convenience sampling, by approaching senior and executive managers in the supply chain where the researcher was employed−a telecommunications cable manufacturing supply chain.

The final sample comprised a convenience sample of 32 supplier and serviceproviders of a specific telecommunications cable manufacturing supply chain. According to Castillo (2009:1–2), convenience sampling is a non-probability sampling technique in terms of which subjects are selected as a result of their convenient accessibility and proximity to the researcher. The most obvious criticism about convenience sampling is both sampling bias and the fact that the sample is not representative of the entire population. Bias refers to the constant difference between the results from the sample and the theoretical results from the entire population. In addition, the fact that the convenience sample may not be representative of the entire population also places restriction on the generalisation and inference making as regards the entire population.

The convenience sampling method used produced a list of organisations that included supply, manufacturing and intermediary organisations and agencies. The specific organisations were selected on the basis of the researcher's personal relationships with the prospective respondents in question and this enabled the researcher to persuade these potential respondents to participate in the survey and ensured guaranteed returns of the questionnaires

As regards the actual testing of the measurement instrument of information flow efficiency, a convenience sample was again taken from the group of organisations belonging to the same supply chain. The realised sample comprised 25 organisations. The convenience sample was structured in such a way that the sample selection constituted an almost complete representation of the entirety of those organisationsactively participating in the abovementioned supply chain.

7.4.4.2.4 Data and data collection

The potential respondents, as identified by the convenience sample, were approached either by means of direct contact, or by e-mail. As many as possible respondents from the specific telecommunications cable manufacturing supply chain, which includes the regular raw material and intermediary service suppliers, were approached in order to maximise the sample size. All the survey forms were returned either by e-mail or by hand. During the evaluation of the survey forms collected, any queries relating either to obviously incorrect answers or any questions not answered were solved telephonically or personally. The evaluation was conducted using Excel spreadsheets.

7.5 EMPIRICAL TESTING OF THE PROPOSED MEASUREMENT INSTRUMENT OF INFORMATION FLOW EFFICIENCY

7.5.1 Introduction

This research study aimed at identifying indicators and associated metrics for information flow efficiency. These indicators and associated metrics were identified by selecting suitable performance measures applicable to information flow and information quality and general business performance measures, as described in section 6.3, sources of indicators of information flow efficiency. A survey in the form of a questionnaire was designed and issued in order to obtain the respondents' opinionsregarding the importance of each of the indicators and associated metrics that were to be assessed. Statistical cluster analysis was used to group together the indicators based on similar characteristics.

Cluster analysis was conducted to explore the possible groupings of indicators for the refinement of the instrument with the aim of ultimately supporting the validity and reliability of the instrument.

Cluster analysis is a statistical technique which seeks to identify homogenous subgroups of cases in a population. In other words, cluster analysis seeks to identify a set of groups which both minimise within-group variations and maximise between-group variations (Tan, Steinbach & Kumar,2006:490).

The resultant indicators and associated metrics that were ranked and rated as important and subsequently selected, based on the explorative analysis (as discussed in chapter 8), were exploratively tested in 25 organisations− seesection 7.5.2 below. These information flow efficiency indicators and associated metrics were tested by conducting personal interviews with the participants, using an interview question guide (see Appendix 3 and discussions insections 7.5.4 and 7.5.5 below).

It is important to emphasise that the overall sample size used in this study was extremely small. This, in turn, raises the issue of validity. As a result of the small sample size and the fact that a convenience sample was used, the results of this research are exploratory. Accordingly, the validity of the instrument itself must still be determined using a much larger and more representative sample in further research.

7.5.2 Sampling for the exploratory testing of the instrument

The exploratory testing of the instrument for measuring information flow efficiency was conducted in a subset of 25 organisations of the original organisations that participated in the study survey. Certain types of businesses, such as agencies, which do not produce any material,do not own any inventory nor carry out any financial transactions, as well as foreign organisations, located mostly in the Far East, were not considered for the actual testing of information flow efficiency. This exclusion was based on the fact that the agency organisationsscarcely contribute to the supply chains in question, while the foreign organisations may have experienced language difficulties which may have caused problems as regards their understanding the questions. When choosing the 25 organisations, it was also important to include only organisations which contributed to the performance of the specific telecommunications cable manufacturing supply chain on an ongoing basis.

As a result of the fact that different personnel within one company may have had inconsistent views about the same metric, it was necessary to consult with more than one expert per company. The use of expert opinion will be described below in sections 7.5.3 and 7.5.4. However, this was possible in eight of the 25 organisationsonly that were approached. As regards these eightorganisations it was possible to obtain a more accurate view of information flow efficiency. Within the remaining organisations, the lack of availability of other senior staff involved in carrying out supply chain activities in the company meant that it was possible to interview one person only.

7.5.3 Expert opinions in research

According to Daneshkhah (2004:8–9),whether or not expert judgement may be considered as an informed assessment or an estimate, is based on the expert's training and experience as regards an uncertain quantity or quality of interest.

An expert is a person with special knowledge or skills in a particular domain. Daneshkhah (2004:9) infers, thus, that certain criteria for selecting expert(s) include: experience in passing judgements and making decisions, based on evidence of expertise, that is, degrees, research, publications, positions and experience, awards as well as willingness to participate, impartiality and inherent qualities such as self-confidence and adaptability.

Judgement refers to inferences made in forming opinions (Daneshkhah, 2004:9). Accordingly, an expert judgement should be the inferential opinion of a domain specialist regarding an issue within his/her area of expertise. The judgement is obtained through a formal elicitation process that seeks to minimise biases and to help the expert arrive at a subjective assessment of the issue at hand.

However, although expert opinions may be particularly useful in certain situations, there are also disadvantages which may originate from these expert opinions. The advantages and disadvantages of expert opinions or judgements will be discussed in the following section.

Daneshkhah (2004:11) asserts that expert judgments are, typically, appropriate when:

1. Data is sparse or difficult to obtain. It may happen that information is not available from historical records, prediction methods or literature. (This was particularly true for the measurement of information flow efficiency in supply chains, as no such measurements have, as yet, taken place.)

2. Data is too costly to obtain.

3. Data is open to different interpretations, and the results are uncertain. This criterion may also apply in the case of information flow efficiency, as it is possible that the questions asked, although clear and unambiguous, may be interpreted in various ways in different situations or environments.

4. There is a need to perform an initial screening of problems.

Despite the fact that the above criteria outline circumstances in which expert judgements are desirable, reports that experts are subject to similar biases as ordinary lay people, although they may not be influenced in either the same manner or the same context. Daneshkhah (2004:11) mentions other objections, including the fact that expert opinions may be superficial and imprecise as a result of the experts not being able to express their uncertainty in terms of the subject to be judged. This, in turn, may lead to a non-credible basis for the decision-making process

7.5.4 The actual use of expert opinions in the exploratory testing of the instrument

In accordance with what is recommended in the literature, it would seem that the measurement of information flow efficiency constitutes an example where the use of expert opinion appears to be justified, particularly as regards the requirement that an expert must have the necessary experience in making decisions based on experience, position and knowledge. In this study, this requirement was met by interviewing personnel who had been involvedwith the management of the respective company supply chain. In each case, the personnel interviewed possessed the requisite knowledge and experience to have a clear opinion of the level of performance in terms of each of the metrics and they complied with the criteria as outlined in section 7.5.3 above.

In this research, expert opinions were used to obtain assessments of the subjective metrics included in those metrics discussed in section 6.4.3. Such metrics, for example, deal with the perceptions of the degree to which the users' needs are met and the relevance of certain data and reports to the user.

The experts were asked to rate the metrics as per section 6.4.3, whilst being confronted with a situation with a 100% rating as well as a situation that would attract a 0% rating. Specifically as regards the time-based metrics, intermediate ratings and associated situations were supplied. This method provides for a calibration effect, which ensures that situations and circumstances within the desired range only are considered, that is, situations and circumstances falling outside the given extreme situations attracting 0% and 100% ratings will not be considered.

Although it was possible to derive a reasonably accurate performance for each metric in each company, it was not possible to assume a generalisation of performance across all organisations. This latter statement is based on the uncertainty that an expert of one company would evaluate the specific situation in a second company in the same manner as the expert of the second company. This uncertainty has not been assessed in this research and will need to be addressed in further research work.

7.5.5 The explorative testing process

The actual testing of information flow efficiency was carried out using the audit method, as described in sections 6.2.6.4 and 6.2.6.5.

Specifically, members who carry out the supply chain activities, for example, logistics managers, purchasing managers, sales managers, production managers, as well as directors, were interviewed and, where possible, samples were taken to prove that it was possible to carry out the activities in the time and manner proposed and with the degree of efficiency proposed. The number of interviewees varied from one to four, depending on the size of the company, the willingness of company members to participate in completing the questionnaire, and the management functions available in the company's supply chain. For example, a small company may employ a sales executive only, in addition to the owner or managing director. In some instances the only senior person available was the owner. However, as many supply chain personnel as possible were interviewed. Table 7.2 below indicates the personnel questioned in the variousorganisations and the position of the company in the telecommunication cable manufacturer's supply chain.

Table 7.2: Personnel interviewed in variousorganisations and position of companies in the telecommunications cable manufacturer' supply chain

Company Number	Persons interviewed	Position in supply chain
Company 1	Director and Sales Manager	Supplier
	Planning Manager	
	Logistics Manager	
Company 2	Commercial Director	Supplier
	Sales Manager	
Company 3	Operations Director	Intermediary
	Account Manager	
Company 4	International Sales Manager	Supplier
Company 5	Director	Intermediary
Company 6	Managing Director	Supplier
	Sales Manager	
Company 7	Technical Sales Director	Supplier
Company 8	Director	Supplier
Company 9	Director	Supplier
Company 10	International Sales Manager	Supplier
Company 11	Managing Director	Supplier
Company 12	National Sales Manager	Supplier
	Orders Clerk	
	Logistics Clerk	
Company 13	National Sales Manager	Supplier
	Orders Clerk	
	IT Manager	
Company 14	Managing Director	Supplier
Company 15	Managing Director	Supplier
Company 16	Managing Director	Intermediary

Company 17	International Sales Manager	Supplier
Company 18	Managing Director	Supplier
Company 19	Managing Director	Supplier
	National Sales Manager	
Company 20	Managing Director	Supplier
Company 21	National Sales Director	Supplier
Company 22	International Sales Manager	Supplier
Company 23	Managing Director	Supplier
Company 24	Technical and Sales Director	Supplier
Company 25	Managing Director	Manufacturer
	Sales Administration Manager	
	Planning Manager	
	Purchasing Manager	

As indicated above, different personnel were interviewed using the indicators and associated metrics of information flow depicted in chapter 8 in the form of a questionnaire. All the metrics (questions) were evaluated as a percentage, with values ranging from 0 to 100%.

The questions were aimed at both electronic as well as paper systems in order to obtain an overall, company-wide, information flow efficiency score for each measure and for each variable.

7.5.6 The types of information considered

For the purpose of the measurement of information flow efficiency, specifically supply chain related types of information were considered, for example, operational or production information, logistics and order specific information (purchasing and sales), and financial information. In some cases, in questions relating to particular metrics, it was necessary to split the information with which the company had to deal into the above mentioned categories as the different types of information, as detailed above, would react differently within the metric assessed. The need to split information into the different types was dependent on the complexity of the information transfer systems and procedures installed and used in the specific company. It may be argued that information, which is resident in a computer system, may be virtually up-to-date until another transaction occurs. However, production information may not always be up-to-date, as the production progress may not be measured continuously for the following reasons: technology not allowing for continuous updating, the cost of implementing new technology which would enable continuous measurement, and so on. Accordingly, the situation of the individual company and its ability to transfer the different types of information efficiently, as detailed above, would determine whether it was necessary to split the company information into the types of information mentioned above, whether to combine the information types may be combined or whether the information required further splitting.

Where information needed to be split, the interviewees were required to judge the percentage each type of information constituted in terms of the entirety of information available. The sum of the weights of the individual types of information multiplied with the relevant percentage score provided an overall score for the particular metric under consideration. By splitting the information into different types, a more accurate result was obtained as compared to assessing the entire company information as one entity.

7.6 CONCLUSION

It was decided that the most appropriate research strategy for this research was a combination of a literature study, an empirical survey and a case study, using quantitative measuring instruments such as questionnaires, as well as the necessary methods of statistical analysis.

During the literature study, the existing body of knowledge in terms of the measurement of information flow and information flow efficiency was explored as well as themeasurement frameworks available and the characteristics of information, the quality of information and business performance measurement for incorporation into a survey.

Following the literature study, a survey was designed in such a manner that the survey yielded an insight into the information integration in organisations/supply chains as well as the perceived importance of the indicators and associated metrics of information flow efficiency. The survey was carried out in a specific telecommunication cable manufacturing supply chain, which was willing to participate in the survey, as detailed above. The individuals who participated in the survey were considered as experts within their own organisations.

Statistical cluster analysis and box plots were used to extract the most important information flow efficiency indicators, for each of which a set of associated metrics was developed.

In order to ensure more accurate results from the case study and to avoid bias in the individual opinions of the experts, as many experts as possible in each company were interviewed. Certain of the organisations, however, did not have more than one expert available to be interviewed. In total, 17 organisations had one person only available, fourorganisations had twopersons available, threeorganisations hadthreepersons available and onecompany had fourpersons available for interviewing.

The following chapter, chapter 8, will discuss the results of the empirical study and recommend further research work to be conducted.

CHAPTER 8
RESEARCH RESULTS AND CONCLUSIONS

8.1 INTRODUCTION

This research attempted to identify indicators and associated metrics of information flow efficiency.

The aim of the first part of the empirical study was to identify and select indicators and associated metrics that may be applied to measure information flow efficiency. The second part of the empirical study involved testing the indicators and associated metrics in a case study in selected organisations in a particular supply chain, in an attempt to measure information flow efficiency.

Sections 8.2.2 to 8.2.6 present the results of the survey, which was designed to evaluate the general characteristics of information and information flow. The evaluation was carried out by ascertaining the opinions of company leaders in a specific telecommunications cable manufacturing supply chain in South Africa, in this regard. The survey was aimed at determining both the ranking in importance of a selected list of indicators and metrics for information flow efficiency, as well as the informational integration of organisations and the general use of integration-promoting information technology.

Section 8.3 presents the results of the actual testing of the indicators and metrics.

8.2 SURVEY RESULTS

8.2.1 Introduction to survey results discussion

The survey instrument was structured in the form of a questionnaire which aimed both at providing evidence of the information integration both within organisations and within supply chains, and at ascertaining opinions regarding the importance of information and information flow characteristics. The findings enabled the researcher to establish indicators and metrics for the measurement of information flow efficiency with important characteristics being converted into indicators and metrics for information flow measurement.

The first part of the survey instrument was aimed at collecting general data regarding the size of the business concerned in terms of turnover and number of employees. The second part of the survey dealt with the use of electronic data interfaces (EDI) and the Internet. The third part of the questionnaire comprised possible indicators of information flow efficiency, based on the master set of characteristics (as listed in section 6.4.2, and the metrics proposed in section 6.4.3) with the respondents of the survey being asked to rank the importance of the information characteristics. Each of the metrics was subjectedto an importance level valuation, thus allowing for equal valuation ratings. The last part of the survey attempted to collect data regarding the use of enterprise resource planning systems (ERP), advanced planning systems (APS) and manufacturing execution systems (MES), all of which generally provide better real-time information across parts of or the entire business processes, thus leading to enhanced information flow efficiency.

As discussed in section7.4.4.2.3, the researcher was able,based on convenience sampling, to find 32 respondents who werewilling to participate in the survey of a total number of 104 active suppliers of raw materials and intermediary services to the specific telecommunications cable manufacturing company with which the researcher is associated.

8.2.2 Profiles of respondents

This section describes the profiles of the respondents. In terms of turnover, 3.1% of the responding businesses had a turnover of less than R5 million, 43.8% had a turnover of between R5million and R100 million, 28.1% had a turnover between R100 million and R1000 million, whilst 25% of the responding businesses had a turnover greater than R1000 million.

The results of section 1 of the survey are presented in figure 8.1 below.

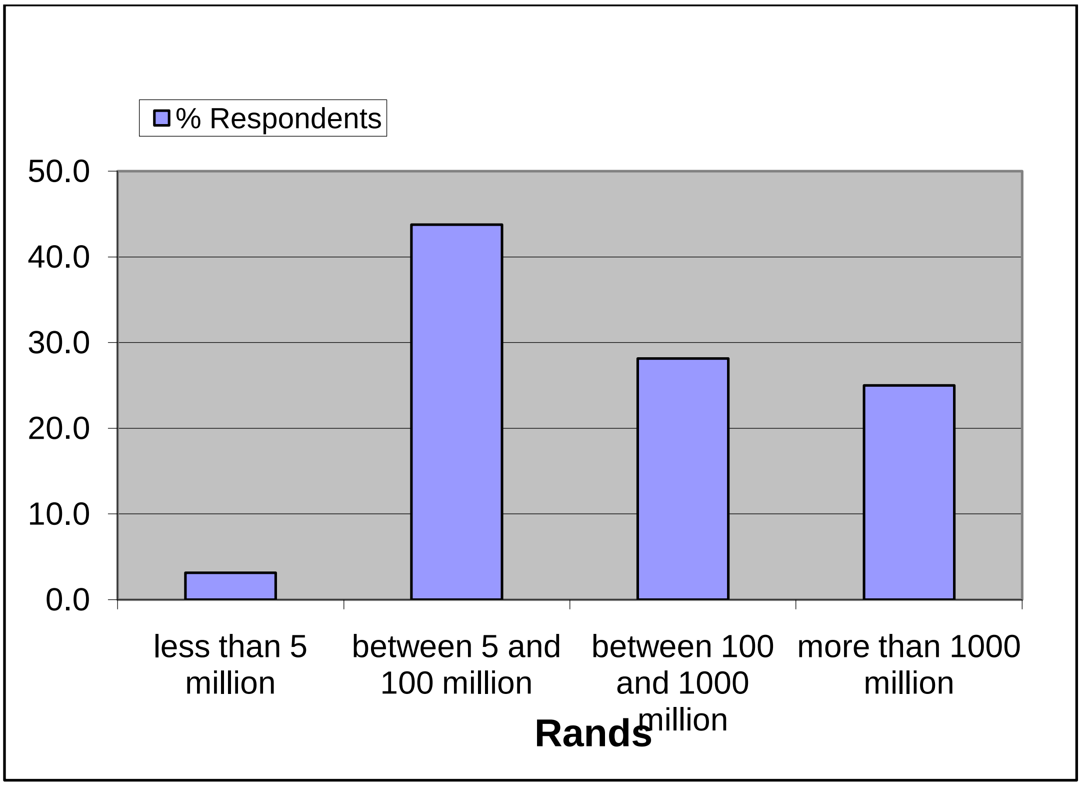

Figure 8.1: Size of respondent businesses according to turnover

8.2.3 Information system use

The aim of this section was to gain an insight into the use of relatively uncomplicated information technologies for the purpose of making it easier both to carry out transactions and to integrate businesses internally and externally.

The respondents were asked to provide an overview of the way in which, the extent to which and for which purposes EDI and Internet technology are used and to provide reasons, if applicable, for not using such technology. Typically, EDI and the Internet may be used to connect businesses and their systems in order to transfer information more quickly between these businesses, as well as to access and to capture information more easily.

This section of the survey will, thus, provide an indication of the extent of the use of this information technology.

In question 4, the respondents were asked whether or not they made use of EDI and/or Internet. The results showed that 84.4% of all the respondents indicated that they did, indeed, make use of these technologies whilst the remaining 15.6% indicated that they did not make use of this technology (see figure 8.2).

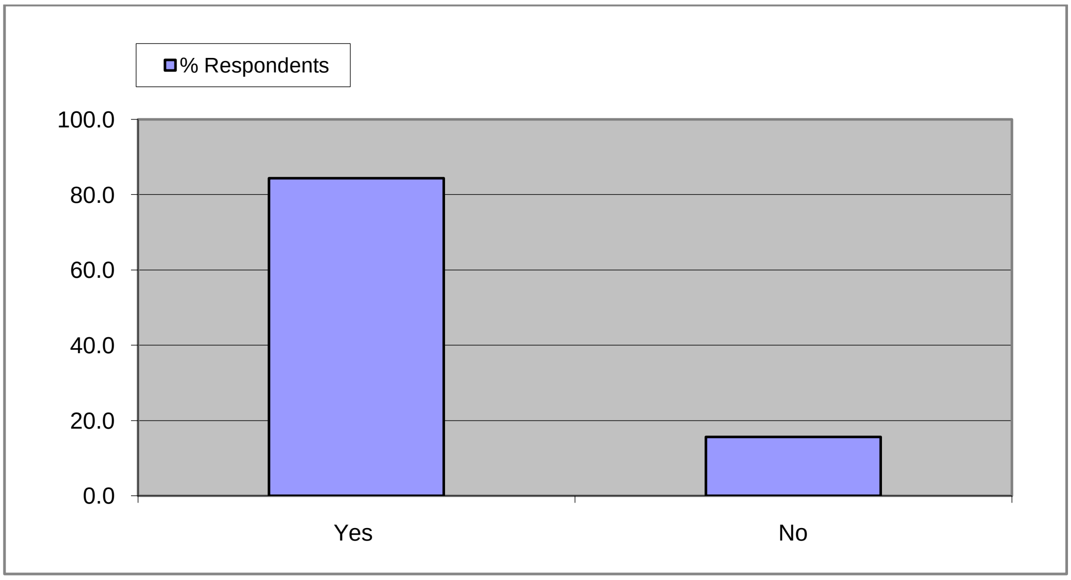

Figure 8.2: Percentage of respondents using and not using EDI and/or Internet

The use of EDI and/or Internet in terms of company turnover categories, as per figure 8.1, is depicted in figure 8.3 with thisillustrating the use of EDI and/or Internet by company size based on turnover. The results indicate that 100% of those organisations with a turnover of less than R5m (one respondent), 85.7% of organisations with a turnover of between R5m and R100m (12 respondents), 88.9% of organisations with a turnover of between R100m and R1000m (eight respondents) and 75% of organisations with a turnover of more than R1000m (six respondents), use EDI and/or Internet technology. The fact that 100% of those organisations with a turnover of less than R5m use EDI and/or Internetstems from the fact that one organisationonly qualified in this turnover category and this company uses EDI and/or the Internet

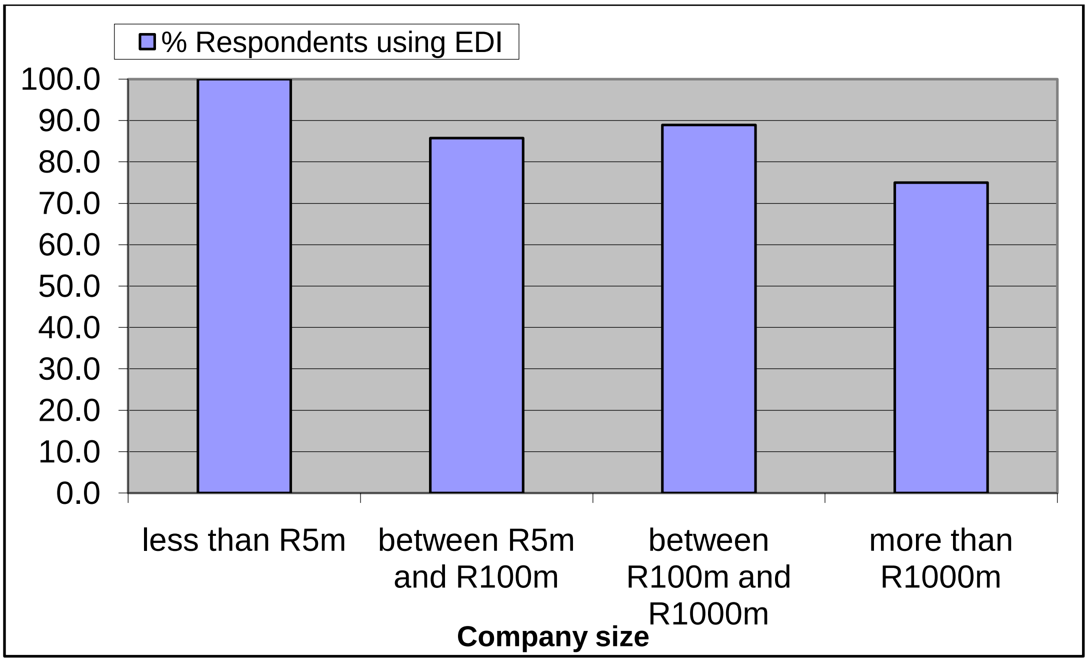

Figure 8.3: Use of EDI and/or the Internet according to company size (turnover)

In answer to question 5, in terms of which the respondents were requested to provide reasons as to why they were not using EDI and/or Internet, 66.7% cited privacy and security concerns as their main reason, 33.3% indicated that the costs were too high, 16.7% citedeither a lack of interest or no use of the technologies, 16.7% specified concerns over malware and viruses,while 16.7% cited other reasons which included the fact that the overall effort of implementing EDI may be too onerous, since the supplying company's system, as well as the client's system, required adjustment (see figure. 8.4). (The respondents were free to choose more than one option, thus the total will not equal100%.)

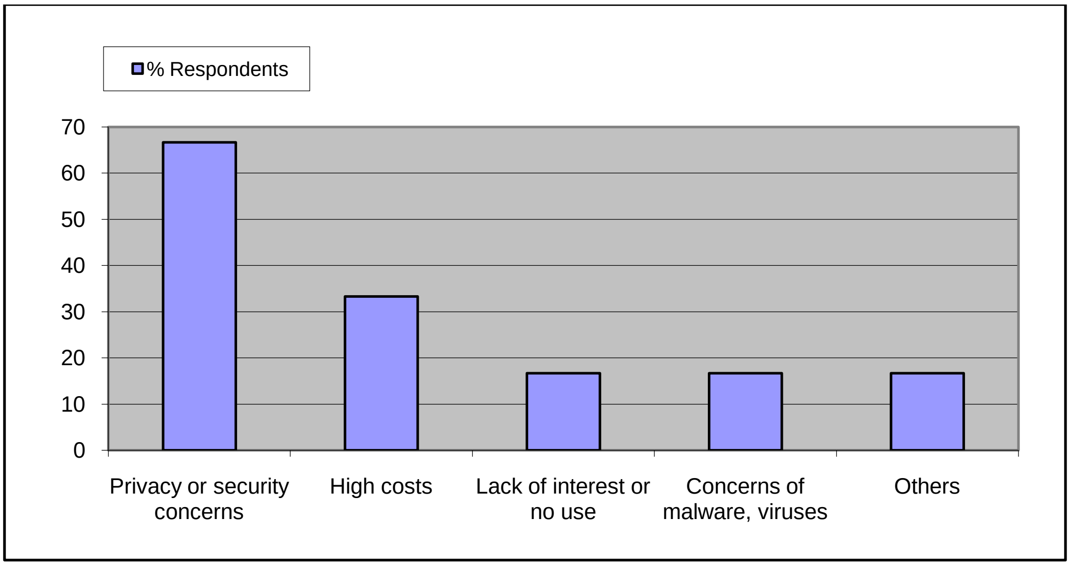

Figure 8.4: Reasons for not using EDI and/or Internet

In question 6, the respondents were asked to indicate how often they used EDI and/or Internet. This question only refers to those respondents that answered "Yes" to question 4. According to the results, 89.7% of the respondents indicated that they were using EDI and/or Internet several times a day, 3.4% only responded that they used this technology at least once per week while 6.9% of the respondents were not sure (refer to figure 8.5).

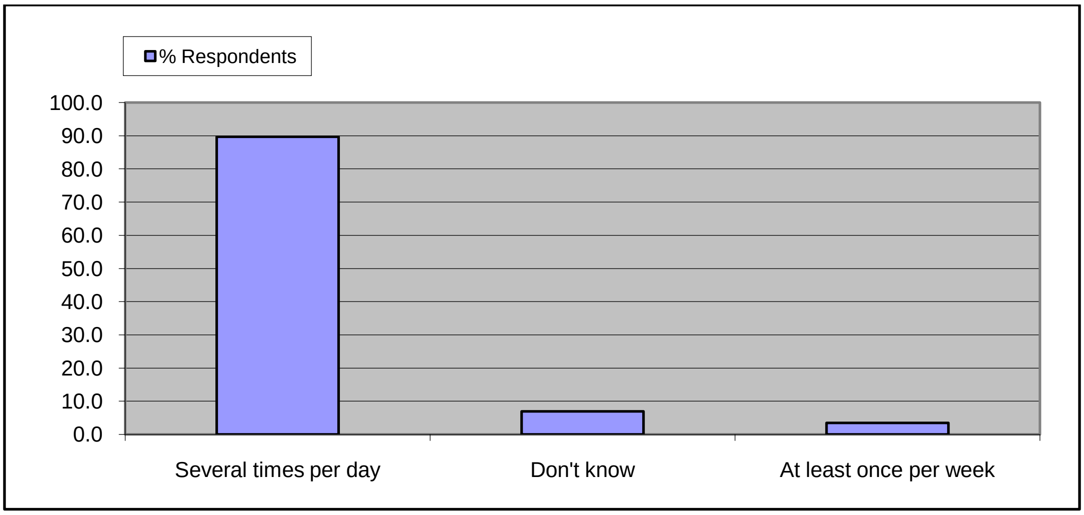

Figure 8.5: Frequency of use of EDI and/or Internet

In questions 7 and 8 of this survey, the respondents were asked to provide details of the main activities involved when they used EDI and/or Internet.According to the findings, 30% of the respondents indicated that payments and receipts of funds constituted the main use of EDI and/or Internet, 26% of respondents used the technology in order to improve the information transfer between suppliers and customers. Purchasing or sales reasons were cited by 25% of respondents that used EDI and/or Internet, 10% integrated systems between customers and suppliers, while the remaining 9% used EDI and/or Internet for other purposes such as marketing intelligence, advertising, booking transport, production management, advanced inventory management and virtual private networks (VPN) (refer figure 8.6).

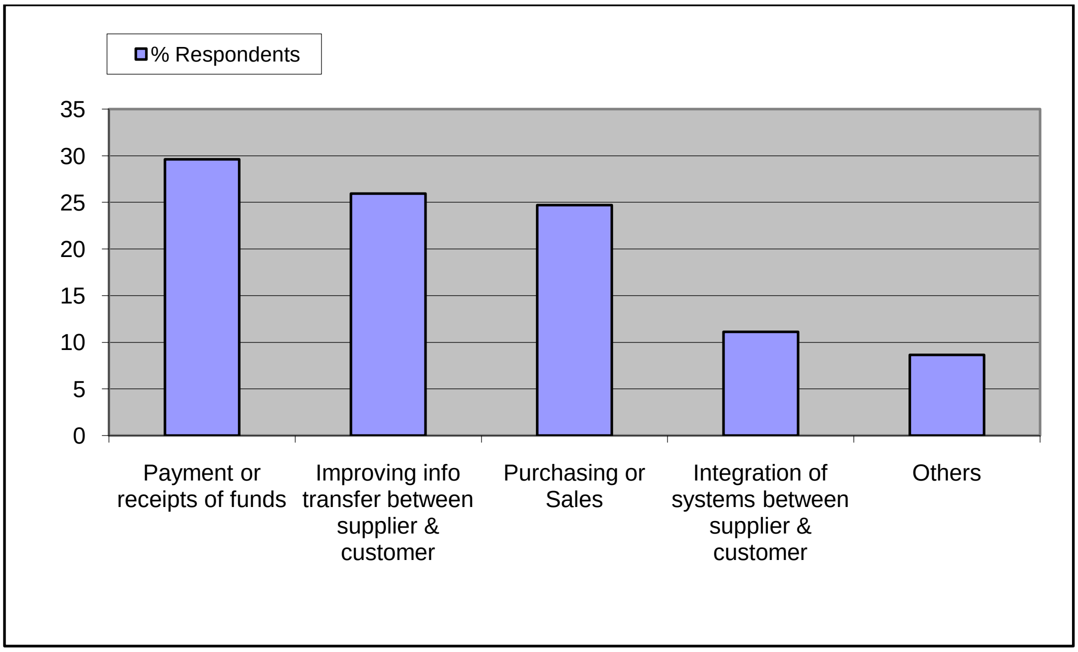

Figure 8.6: Purposes behind use of EDI and/or Internet

The main activities involved in the use of EDI and/or Internet included making or receiving payments (27%), obtaining information on potential suppliers (26%), information exchange between plants (23%), order placement on the part of the purchasing department (9%), order receipting at sales (9%) and others (6%) with the latter including internal order handling, track and trace, technical research, vendor management and marketing activities (see figure 8.7).

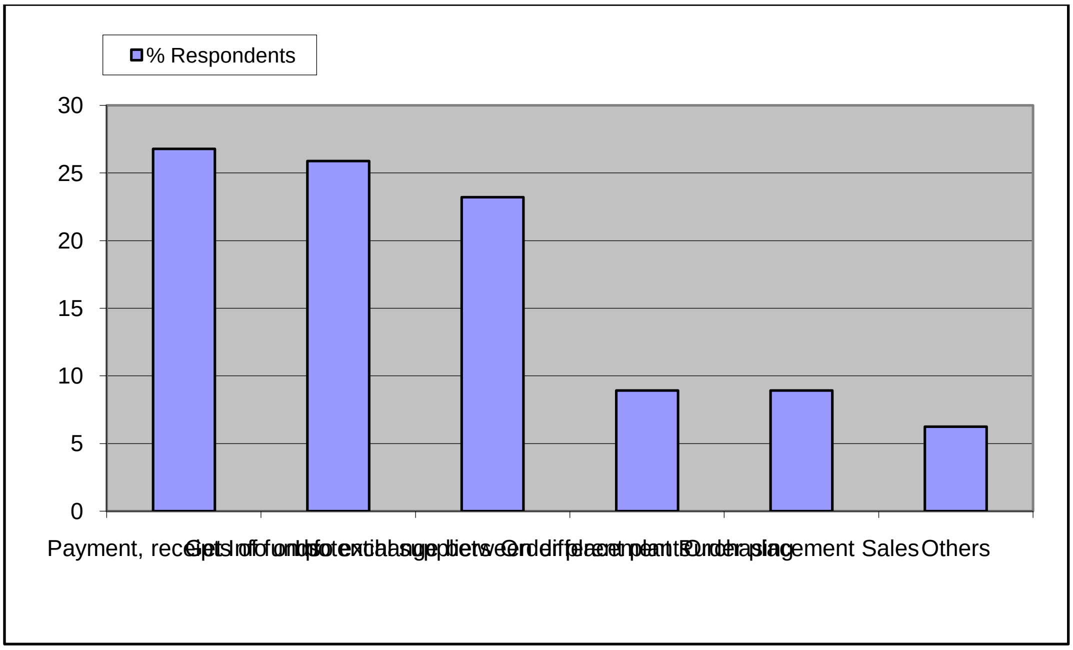

Figure 8.7: Main activities involving EDI and/or Internet use

Question 9 asked the respondents to provide an indication of an estimate of goods sold and purchased annually by means of the Internet or EDI. The results showed that 31.3% of respondents did not either purchase or sell goods via the Internet, whilst 31.2% of respondents did, indeed, purchase and sell goods using the Internet The remaining 37.5% either sold goods or purchased goods only. The value of goods sold ranged from R50 000 to R500 000 000 and the value of goods purchased from R500 000 to R450 000 000.

Question 10 enquired about the channels through which both the orders were placed for purchasing purposes and the orders received by sales personnel. It emerged that the channels that required evaluated included telephone, fax or e-mail, online ordering facility on web, EDI or Internet, e-market places as well as other technologies. Technologies such as the telephone, fax and e-mail require the subsequent transcription of the information into other systems, which typically handle sales orders or purchase orders. Web technologies, EDI and the Internet already provide the possibility of interfacing with both the sales and the purchasing systems. It emerged that 23% of orders were placed by telephone, 57.8% by e-mail or fax, 5.6% using an online web-page, 11.3% by EDI or Internet, 2% on special web-sites and 0.3% using other, non-specified means, whilst 26.2% of orders werereceived by telephone, 61.3% by e-mail or fax, 12% by EDI or Internet and 0.5% on special web-sites (see figure 8.8).

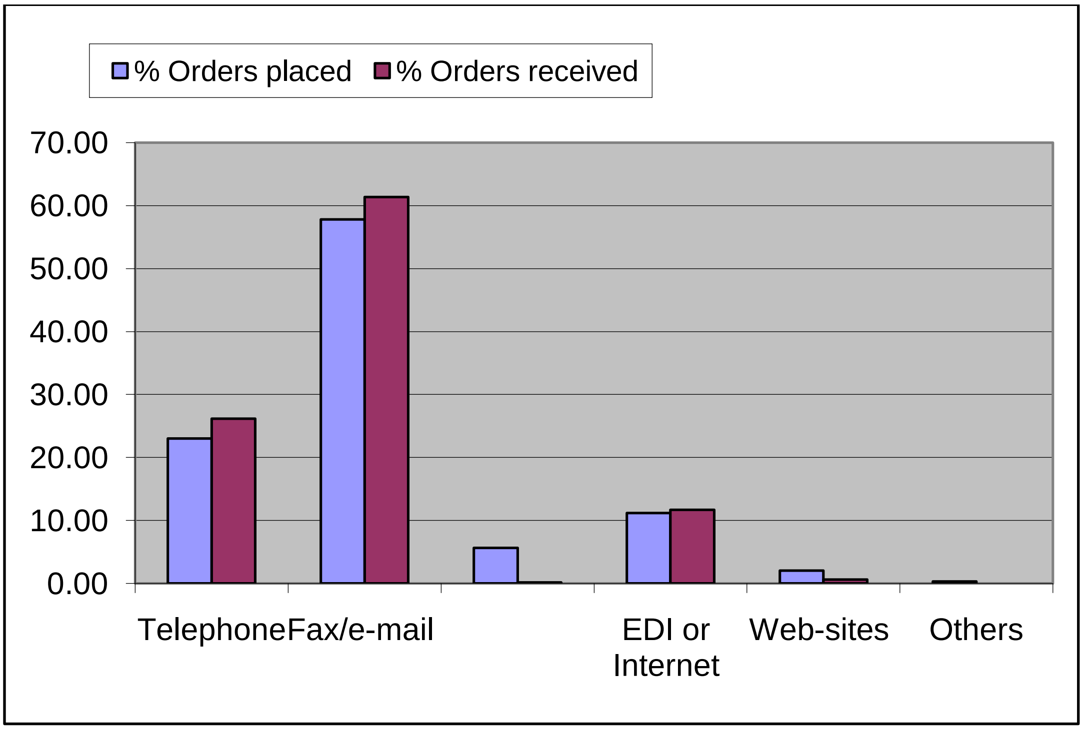

Figure 8.8: Methods of order placement and receipt

The respondents were asked to indicate the location of their suppliers and customers in terms of local or global position, while also indicating the communication requirements of the responding organisations. In particular, global communication or information transfer is more complex across spatial and cultural barriers while global documentation and communication channels are also subject to complex and multiple legal requirements (Mentzer, 2001:49), thus presenting additional barriers to efficient information transfer.

The location of suppliers and customers within the supply chains researched is depicted in figure 8.9. The graph shows a frequency distribution comprising the percentage of local suppliers and customers charted against the percentage of respondentshaving a specific ratio of local to international suppliers and local to international customers. The graph indicates that 10.3% of the respondents have between 0% and 10% local suppliers and between 90% and 100% international suppliers, while 17.2% of respondents have between 90% and 100% local suppliers and between 0% and 10% international suppliers. From a customer perspective, 3.4% of respondents have between 0% and 10% local customers and between 90% and 100% international customers, while 48.3% of respondents have between 90% and 100% local customers and between 0% and 10% international customers.

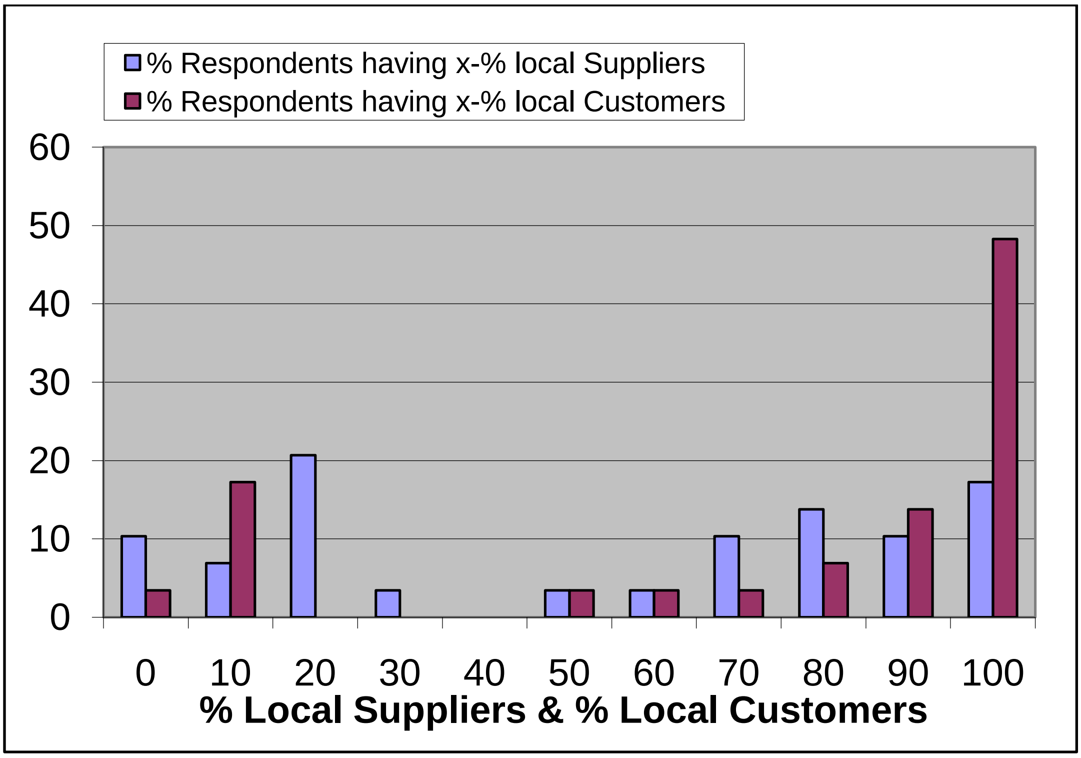

Figure 8.9: Global distribution of suppliers and customers

These figures indicate that there were several organisationswhich deal with foreign suppliers and foreign customers, thus confirming that the telecommunications cable manufacturing supply chains are distinctly global.

Question 12 asked the respondents to rank, in order of importance, up to six identifiable benefits of the use of EDI and/or the Internet in purchasing and sales. The results are presented in figure 8.10.

The reduced transaction time with the *customer* was ranked as extremely important, that is, a median ranking of “1”, followed by the reduced transaction time with the *supplier* − rated with a median ranking of “1.5”. Increased quality of supplier service, lower business cost in purchasing, increased quality of customer service and lower business cost associated with the sales process were also ranked as very important in third position − rated with a median ranking of “2”, which indicates “very important”. The remaining benefits, namely, increased volume or number of suppliers, keeping pace with competitors from a purchasing point of view, increased volume or number of customers, the ability to target suppliers individually, keeping pace with competitors from a sales point of view and the ability to target customers individually were ranked as important in last position − rated with a median ranking of “3”, which indicates the mid-point of the scale. Table 8.1 below summarises the responses to this question.

Table 8.1: Responses indicating summary of benefits of using EDI/Internet in purchasing.

Benefit	Ratings, “1” = most important, “5” = least important				
	1	2	3	4	5
	Percentage of responses received				
Reduced transaction time with customer	4.6	1.5	1.5	0.8	0.4
Reduced transaction time with supplier	4.2	2.3	1.1	0.4	0.4
Increased quality of supplier service	2.3	3.8	1.1	1.1	0.4
Lower business cost − purchasing	1.9	3.1	2.7	0.8	0.4
Increased quality of customer service	3.1	3.1	1.5	0.4	0.8
Lower business cost − selling	2.7	2.3	1.9	1.1	0.4
Increased volume or number of suppliers	0.4	1.9	2.3	1.9	1.1
Keeping pace with competitors’ purchasing	1.9	1.1	3.8	0.0	0.8
Ability to target suppliers individually	1.9	1.5	1.5	1.5	0.8
Increased volume or number of customers	1.1	2.3	2.7	1.1	1.5
Keeping pace with competitors’ selling	2.3	1.5	3.1	0.0	1.5
Ability to target customers individually	2.7	1.1	2.3	1.1	1.1

Figure 8.10: Median ranking of the benefits of EDI and/or Internet as regards purchasing and selling.

Question 13 required the respondents to specify whether their businesses maintained an own web-site. The findings revealed that 75% of the respondents answered in the affirmative while 25% indicated that they did not maintain a web-site.

In question 14, the respondents were asked to choose from ten existing points and/or specify their own, as regards the content of their web-sites. It emerged that the respondents included the following contents on their websites,as per thepercentages indicated:

- Customised website for repeat clients (21%),
- Online aftersales support (21%),
- A privacy seal or stamp (14%),
- Online order tracking (14%),

- A security certification (14%),
- Online ordering facility (7%)
- Online payment facility (7%)

As depicted in Figure 8.11, 75% of respondents maintained a product catalogue and/or a pricelist on their website, 46% kept a privacy policy statement while 25% included facilities with which to collect customer information from the web-site.

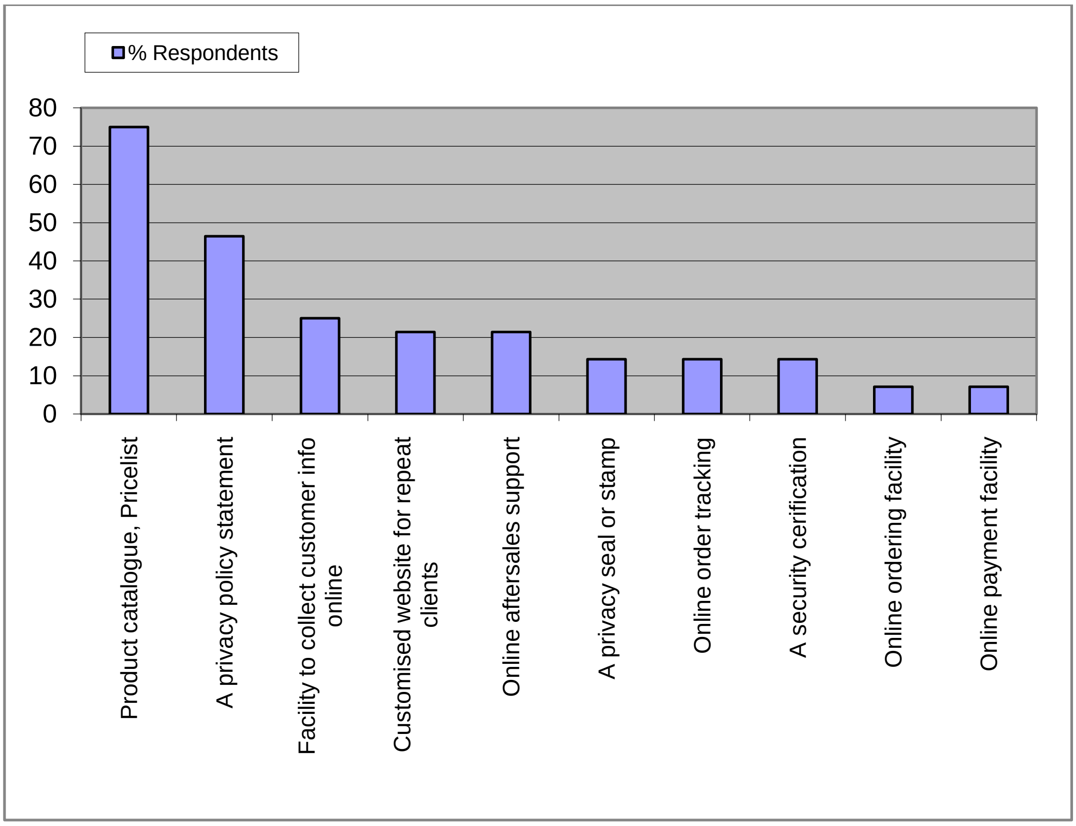

Figure 8.11: Content of business web-sites.

These figures clearly indicate that websites are used extensively by businesses in order to display information about their products and prices. However,it would appear that information integrating technologies, such as online order tracking, online ordering facilities and online payment facilities are used far more seldom.

In question 15 the respondents were asked to indicate how they used EDI for local and international order placement and order receipt. The results, as presented in figure 8.12,show that 55% of the respondents do not use EDI for local order placement while 45% do not use EDI for local order receipt. On the other hand, 9.6% of the respondents make use of EDI for 100% of their local order placement and 26% rely on EDI for 100% of their order receipts.

The results in respect of the use of EDI for foreign order placement and receipt, as presented in figure 8.13, shows that 54.8% and 65% of the respondents respectively do not use EDI for foreign order placement and order receipt with small percentage of 9.7% and 6.45% only using EDI to place and receive 100% of their foreign orders.

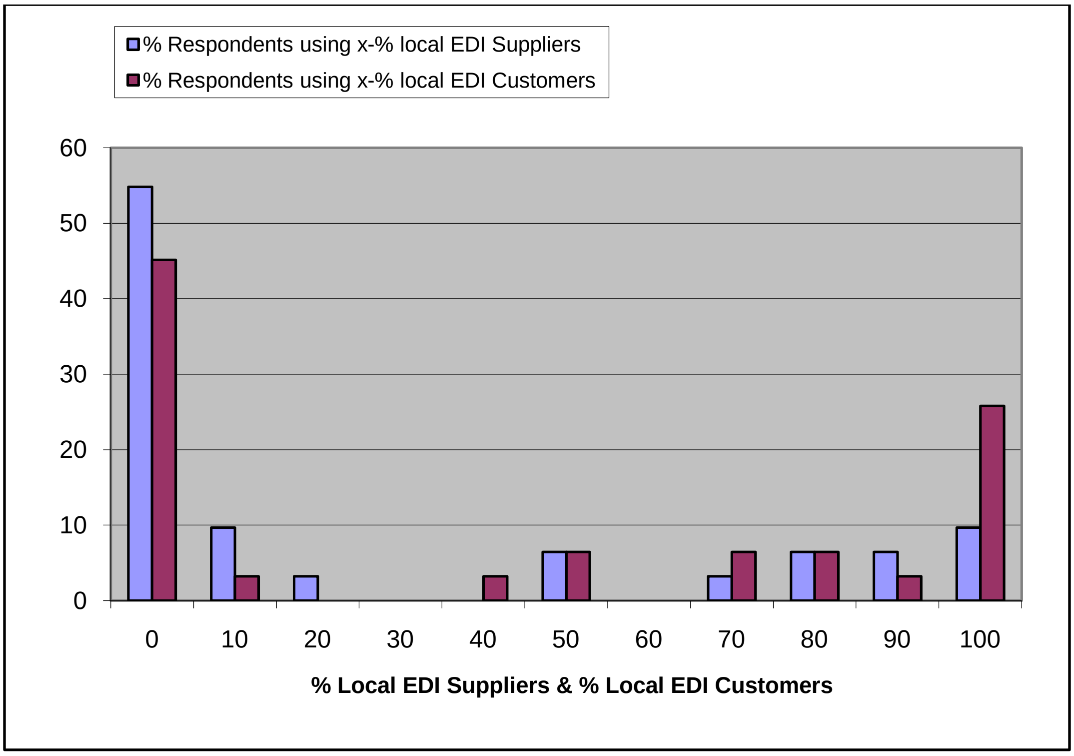

Figure 8.12: Use of EDI and/or Internet for local suppliers and customers.

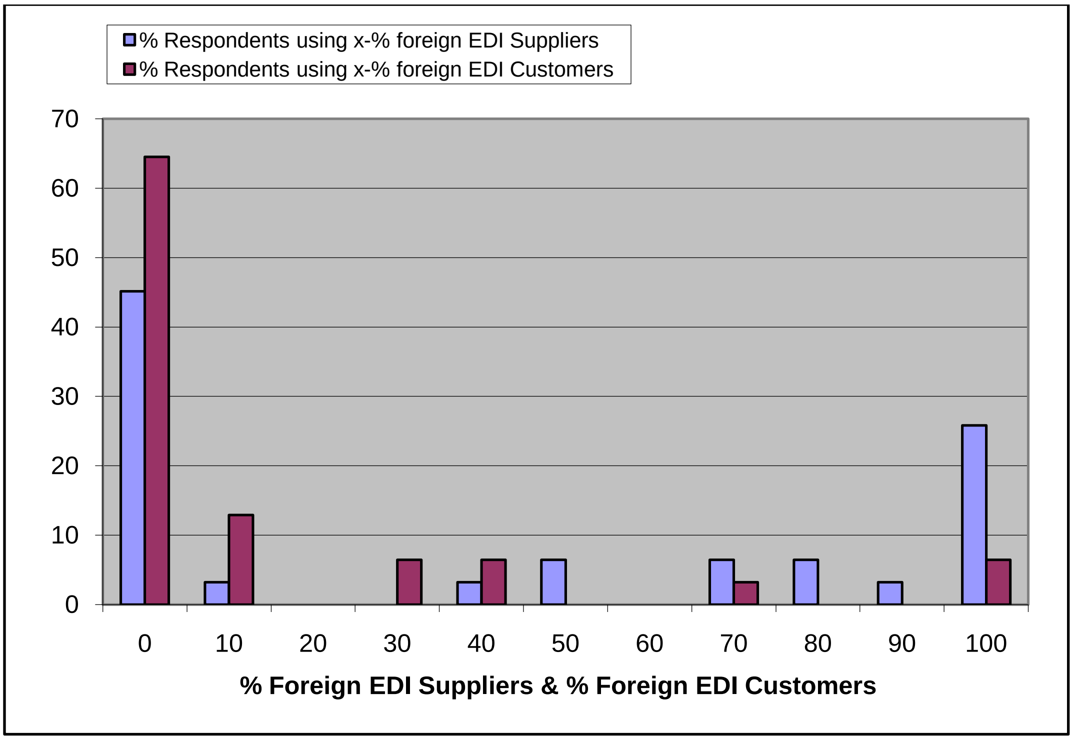

Figure 8.13: Use of EDI and/or Internet for foreign suppliers and customers.

8.2.4 The importance of information flow in SCM

In questions 16 the respondents were asked to rank the importance of efficient information flow in supply chains. The importance of efficient information transfer was rated with a median of 1.25, thus indicating an important ratingthat verged on extremely important. It emerged that 78.1% of the respondents rated the efficient transfer of information as extremely important, 18.8% as very important and 3.1% as important. There were no ratings received for little or no importance (see figure 8.14).

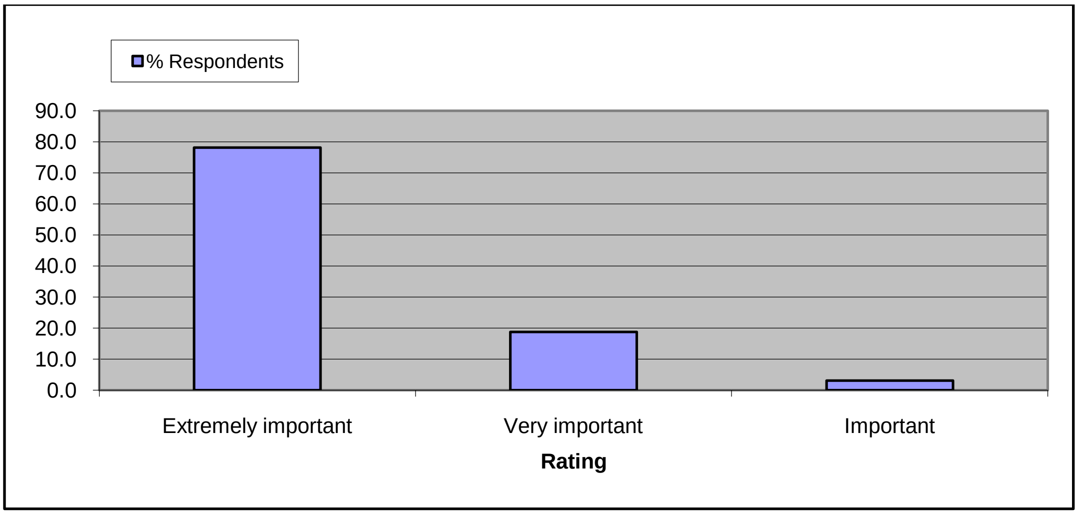

Figure 8.14: Importance of efficient information flow in SCM.

Question 17 investigated whether the measurement of information transfer efficiency in a company/supply chain would add to the transparency of the company/supply chain's performance or, in other words, whether it would provide a better understanding of the performance of a particular company/supply chain at its current level. It transpired that 84.4% of all the respondents were of the opinion that the measurement of information flow efficiency would add to the transparency of the company/supply chain's performance, 6.3% did not think so while 9.4% were not sure.

Question 18 required the respondents to specify whether business performance measurement would benefit from the incorporation of information transfer efficiency into the balanced scorecard (BSC), as a new perspective with a set of key performance indicators. The findings indicated that 72% of all the respondents believed that the addition of indicators of information transfer efficiency to the balanced scorecard would aid business performance measurement, 6% indicated that business performance measurement would not benefit from the incorporation of information flow efficiency into the BSC, while 22% were not sure that this would improve business performance measurement (refer to figure 8.15).

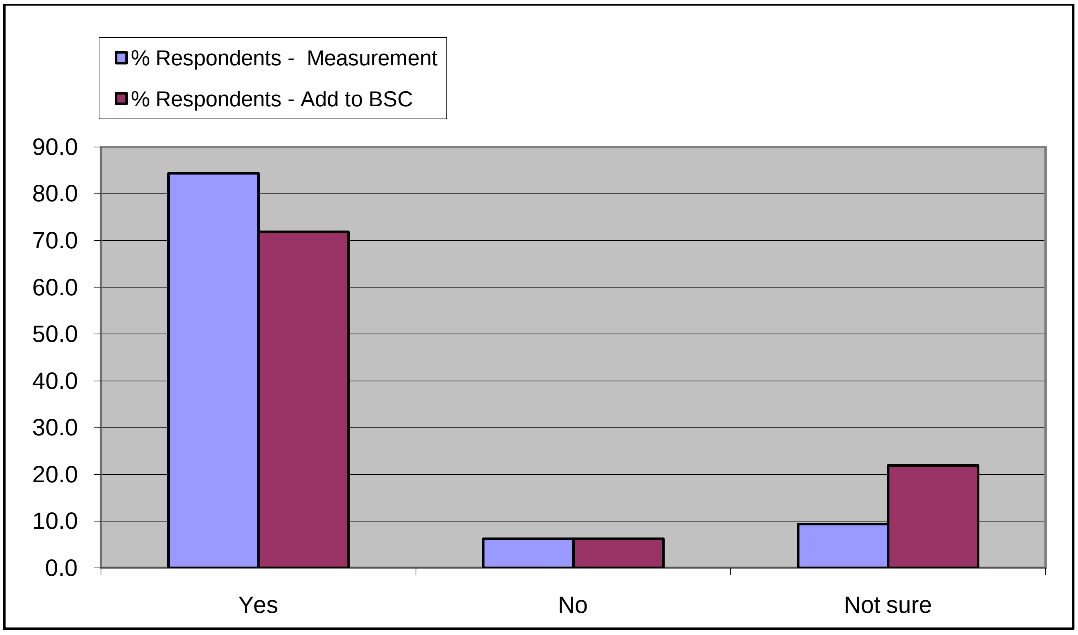

Figure 8.15: Importance of information flow measurement and addition of information flow indicators to BSC.

The results presented above indicate that business leaders perceive efficient information flow as very important and, furthermore, that the measurement of this efficiency would render the performance of the respective company/supply chain more transparent and/or comprehensible. The business leaders consulted in this research study were also of the opinion that the addition of measures of information flow efficiency would improve the way in which business performance is currently measured.

The following section deals with the use of ERP, APS and MES, beginning with question 33 in part 4 of the survey questionnaire. These concepts are closely related to business integration and the use of EDI as discussed above. Question 19 to 32 of the questionnaire, dealing with the importance ratings and rankings of characteristics of information flow, are deliberated on thereafter in paragraph 8.2.7.

8.2.5 The use of ERP, APS and MES

In the fourth section of the survey, the respondents were required to indicate the extent of the use of business process integrating software, such as enterprise resource planning systems (ERPs), advanced planning and scheduling systems (APSs) and manufacturing execution systems (MESs), or combinations thereof.

In answer to question 33, the respondents specified that 44% used ERP systems, 31% used APS systems, 34% used MES systems, while 38% did not make use of any such system. It must, however, be emphasised that respondents used a combination of systems and, hence, the abovementioned figures add up to more than 100% (see figure 8.16). The specific software vendors indicated included large packages such as SAP, PeopleSoft and Infor, medium-sized packages including Pastel, AccPac and Mapics, and smaller and internal, self-provided programmes. In addition, 28% of the respondents indicated that they used combinations of ERP, APS and MES.

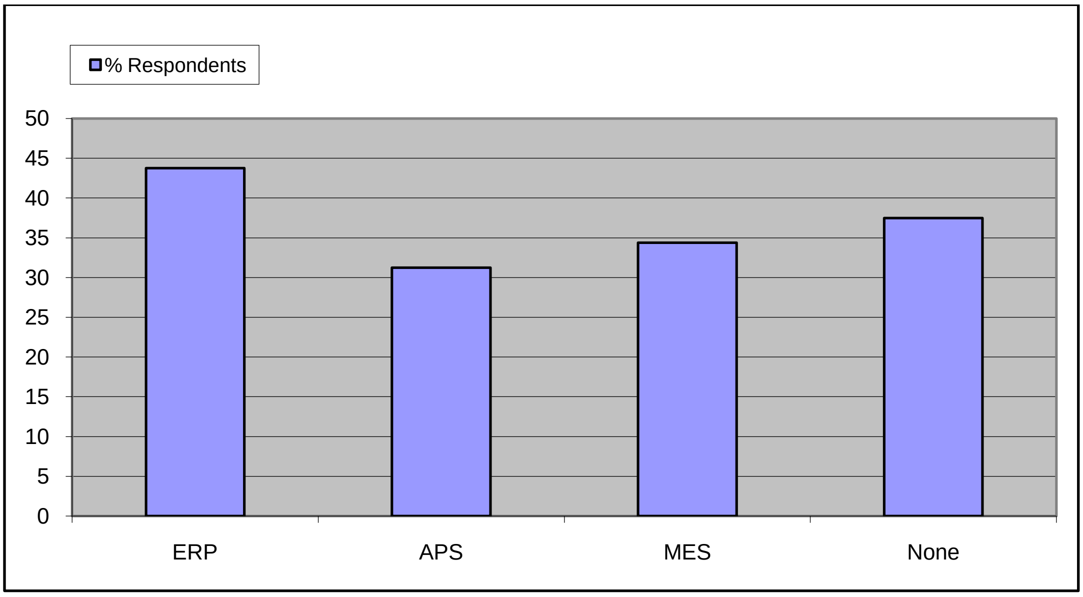

Figure 8.16: Use of ERP, APS, MES systems

In terms of company size by turnover, it emerged that all of the small organisations with a turnover of less than R5m (one respondent in this category) were making use of ERP, APS and MES systems while organisationswith a 14.3% turnover of between R5m and R100m utilised ERP to 14.3% APSand 28.6%MES. 44.4% of organisations with a turnover of between R100m and R1000m used ERP, 22.2% APS and 11.1% MES. 87.5% of organisations with a turnover of more than R1000m employ ERP, 62.5% APSand 62.5% MES(see figure 8.17).

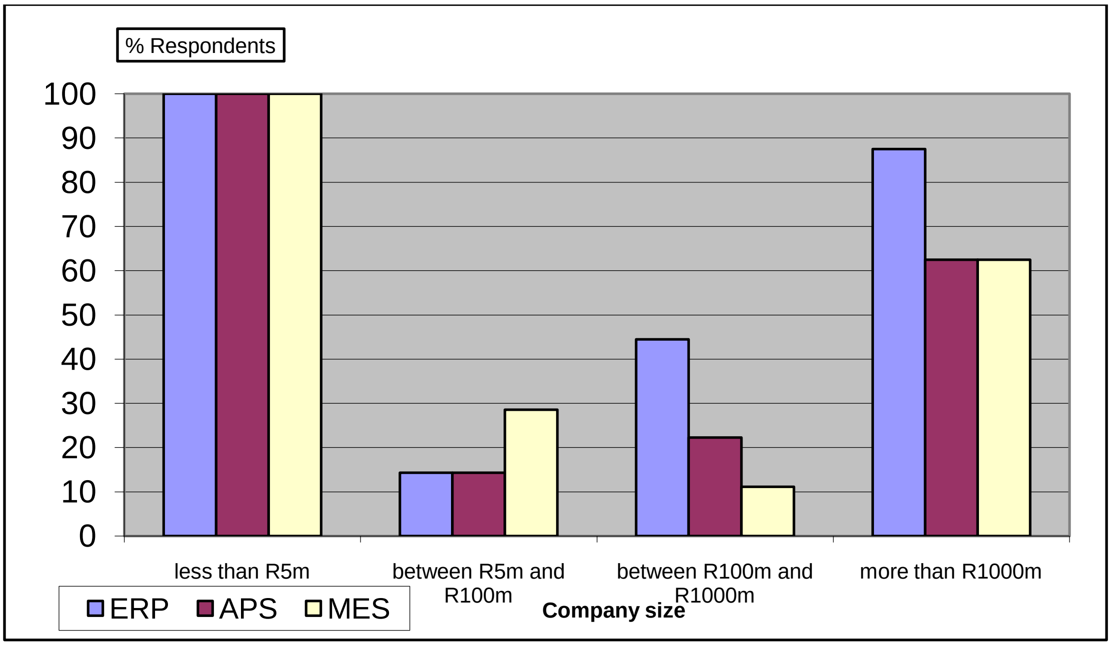

Figure 8.17: Use of ERP, APS, MESsystems in terms of company size

Question 35 probed the number and type of modules offered by the systems that are actually in use, thus providing some idea of the depth of integration across the business. The question provides an exhaustive list of the possible modules commonly found in the ERP, APS and MES software. By implementing different modules of a particular software solution, it is possible to use existing information which has been entered into other modules previously. For example, if a company uses the materials module and plans to implement the productionplanning module, then it will be possible for the productionplanning module to use the material data already entered into the materials module and, thus, re-entry and the double handling of data and information is avoided.

Figure 8.18 depicts the survey results using a Pareto graph. The graph shows that the “Financial Accounting”, “Sales and Distribution” and “Cost Accounting” modules are used by more than 50% of the respondents, with the “Materials Management” and “Production Planning” modules being used by more than 45% of the respondents. The next most popular modules are “Fixed Asset Management” and “Warehouse Management” which are being used by 34% of the respondents. “Supply Chain Planning (SCP)” follows with 31% and “Advanced Planning System” with 28%. All the other modules, which include “QA”, “HR”, “Plant

Maintenance”, “Project Management”, “CRM”, “ATP” and others are used by less than 25% of the respondents.

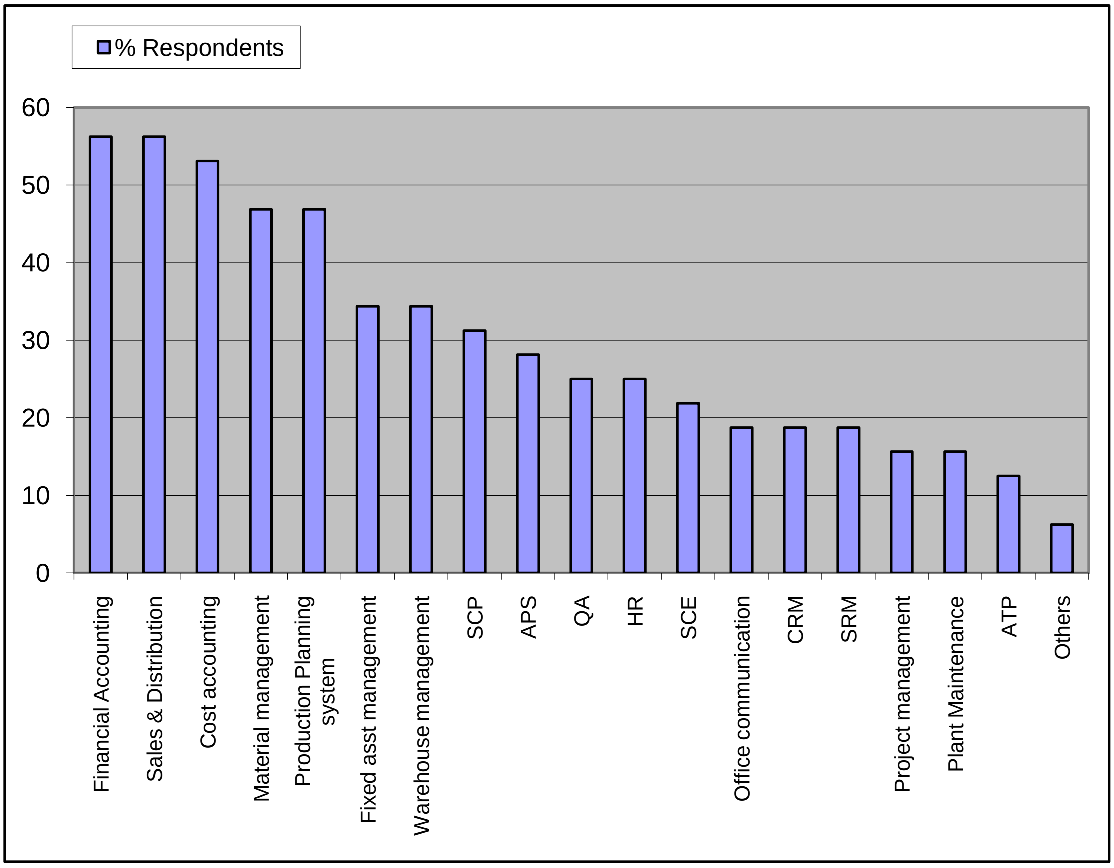

Figure 8.18: Modules of ERP, APS, MES systems in use

Question 36 enquired about the use of technology that is able to automate transactions, for example,*bar-coding* and *radio frequency identification* (RFID). As illustrated in figure 8.19, 44% of respondents employ bar-coding technology, while 3% only utilise RFID, while 56% of all the respondents do not make any use of such technology.

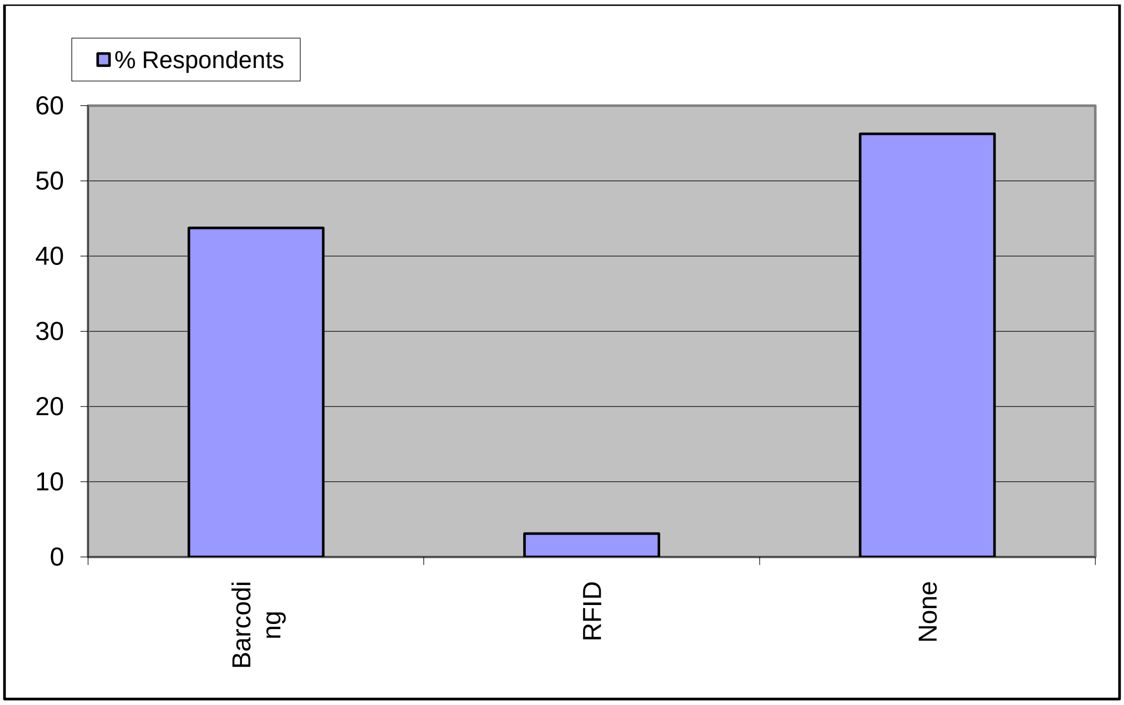

Figure 8.19: Use of bar-coding and RFID

In supply chain management it is important to transfer information, not only within the company, but also to suppliers, intermediaries and customers. Accordingly, question 37 is aimed at finding out whether any of the abovementioned systems which are in use are able to connect either to suppliers, or customers or both. The result of the survey showed that 6% of respondents only are able to connect to their customers' computer systems, while 6% were able to connect to both their suppliers and their customers (see figure 8.20).

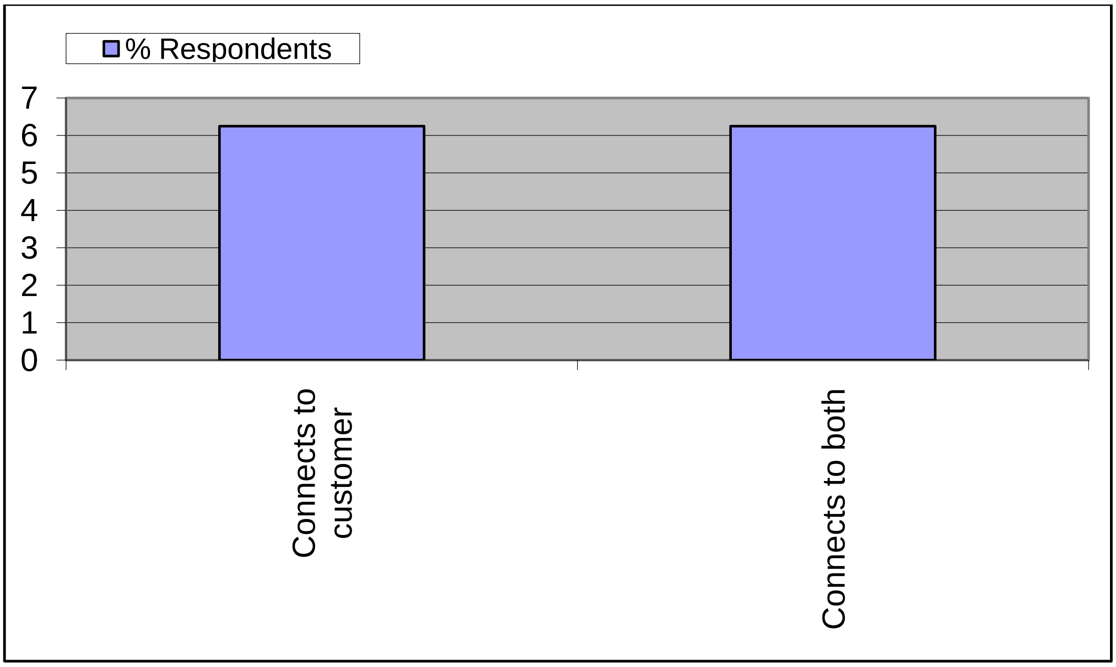

Figure 8.20: Connectivity between supplier and customer software

Question 38 asked the respondents to rate up to 5 benefits of ERP, APS and MES systems by importance. The results of the ranking of the benefits, as per figure 8.21, indicate that “Increases in efficiency” and “Real time information” were accorded the most number “1” ratings, denoting highest importance. “Improved decision making” was ranked mostly in categories “1” and “2”, denoting most important and important, while “Increased adaptability” was ranked the least “important”, with the most rankings in categories “3” and “4”, denoting “neutrality” and “non-importance”.

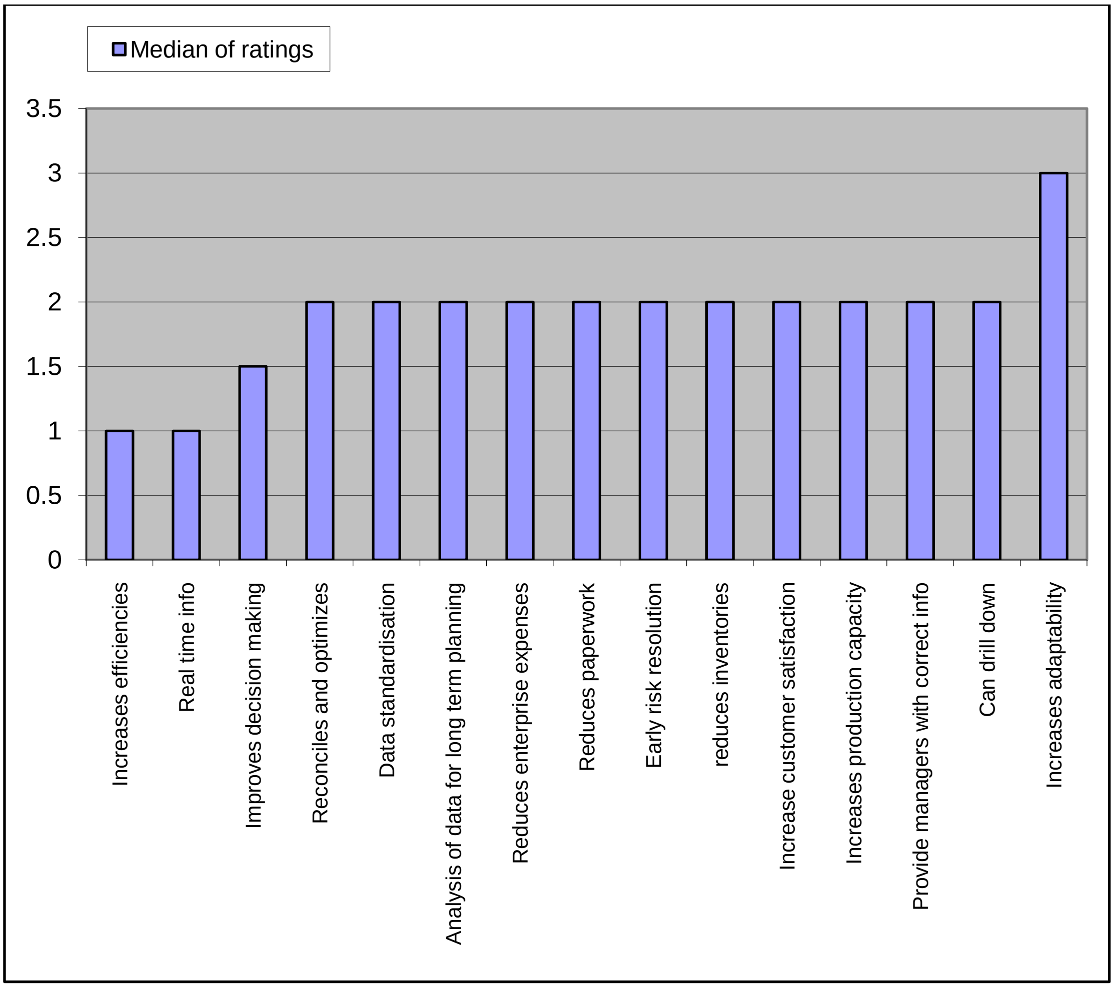

Figure 8.21: Benefits of ERP, APS, MES systems

In question 39, the respondents were required to indicate the degree to which they felt that the ERP, APS, MES systems fulfilled their expectations in assisting them in their tasks. Figure 8.22 depicts that 19% of the respondents felt that their expectations were being fulfilled to a level of between 81 and 100%, 13% of the respondents indicated a 71 to 80% fulfilment, 16% voted for a 61 to 70% fulfilment, 6% for a 51 to 60% fulfilment, 6% for a less than 40% fulfilment, while 41% of respondents were of the opinion that this question was not relevant.

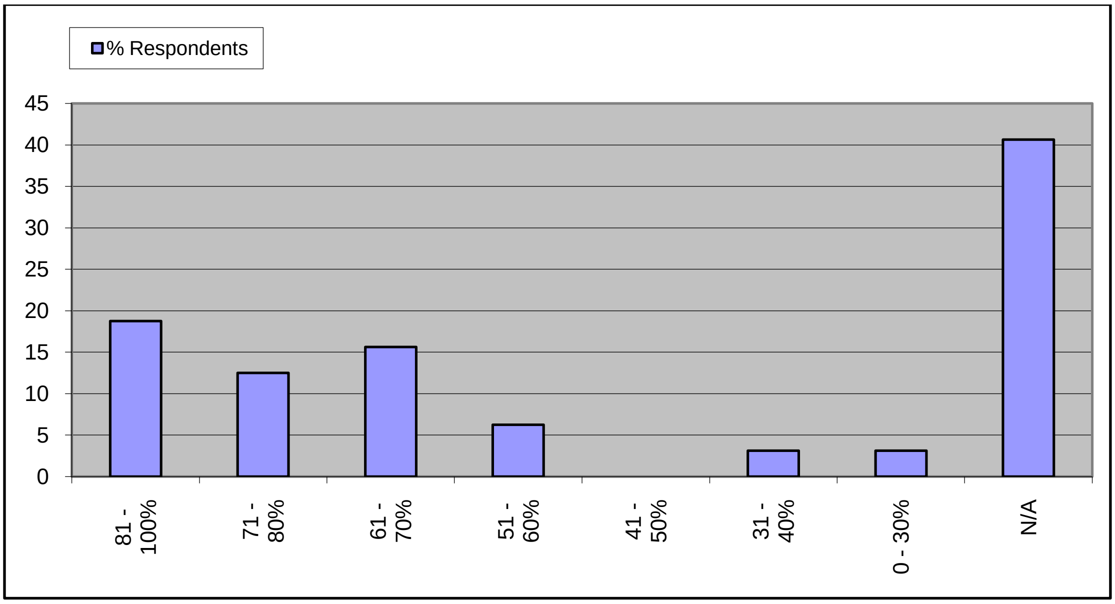

Figure 8.22: Degree of fulfilment of expectations by use of ERP, APS and MES systems.

In the last question of the survey, the respondents were asked to rank the hindrance of the information flow between the modules of ERP, APS and MES and between human personnel and such modules. The result shows that both information flow channels were ranked with a “3”, denoting “average hindrance”.

8.2.6 Summary of the “information systems use” parts 2 and 4 of the survey

Parts 2 and 4 of the survey and sections 8.2.3 to 8.2.5 dealt with the use of EDI and Internet for business purposes, the distribution and location of the suppliers and customers of the respondent organisations including the use of websites, the perception of the importance of information flow and the measurement of information efficiency and the use of enterprise-integrating systems such as ERP, MES and APS. The questions regarding the use of EDI, ERP, MES and APS were specifically included in the survey to explore the extent to which the electronic integration of the information flow within organisations, and between organisations, has been developed.

It emerged that approximately 85% of the respondents make use of EDI and Internet technologies with the same number of respondents accessing these technologies several times per day. The main uses of these technologies centred on the transfer of funds, improving information flow between suppliers and customers and for purchasing and sales. However, when probing the use of EDI and Internet as regards the placing and receipt of orders, it was found that approximately 12% of the respondents only are using the above technologies, thus revealing an extremely low degree of vertical integration of information systems in the telecommunications cable manufacturing supply chains.

The respondents indicated that the main benefits of using EDI and Internet included reduced transaction time between customers and supplier, improved quality of service between customer and suppliers and lower business costs as regards customers and suppliers.

The distribution of suppliers and customers was as follows: 10.3% of the respondents have between 0 and 10% local suppliers and between 90 and 100% international suppliers, while 17.2% of respondents have between 90 and 100% local suppliers and between 0 and 10% international suppliers. From a customer perspective, 3.4% of respondents have between 0 and 10% local customers and between 90 and 100% international customers, while 48.3% of respondents have between 90 and 100% local customers and between 0 and 10% international customers. The use of EDI and Internet technologies for communications with local and foreign suppliers and customers was as follows: 55% of the respondents do not use either EDI or Internet for local order placement while 45% do not receive local orders via EDI, 9.6% of the respondents make use of EDI for 100% of their local order placement and 26% rely on EDI for 100% of their local order receipts (see Figure 8.12). The results for the use of EDI for foreign order placement and receipt, as detailed in figure 8.13, show that 54.8% and 65% of respondents do not use EDI for foreign order placement and order receipt respectively, while a small percentage of 9.7% and 6.45% only use EDI both to place and to receive 100% of their foreign orders respectively.

With regard to the websites, 75% of all the respondents maintained a website, whilst 25% did not. The findings as regards the content of the websites indicated that 75% of respondents maintained a product catalogue and/or a pricelist, 46%

keep a privacy policy statement while 25% included facilities to collect customer information from the website.

Lastly, 84.4% of all the respondents were of the opinion that the measurement of information flow efficiency would add to the transparency of the company/supply chain's performance, while 72% of all the respondents believed that the addition of indicators of information flow efficiency to the balanced scorecard would aid business performance measurement.

Concerning the use of enterprise-integrating systems such as ERP, MES and APS, the findings revealed that 44% of the respondents used ERP systems, 31% used APS systems, 34% used MES systems, while 38% did not make use of any such systems. The specifiic software vendors indicated included large packages such as SAP, PeopleSoft and Infor, medium-sized packages including Pastel, AccPac and Mapics,and smaller and internal, self-developed programmes. In addition, 28% of the respondents indicated that they used combinations of ERP, APS and MES. This result indicates that less than 50% of all the organisations are utilising integrative software in order to achieve either real-time or near real-time information flows.

It also emerged that more than 50% of the respondents were using "Financial Accounting", "Sales and Distribution" and "Cost Accounting" modules, followed by the more than 45% who were using "Materials Management" and "Production Planning". The next most utilised modules were "Fixed Asset Management" and "Warehouse Management" – being used by 34%. "Supply Chain Planning (SCP)" followed with 31% and "Advanced Planning System" with 28%. All other modules, including, inter alia, "QA", "HR", "Plant Maintenance", "Project Management", "CRM" and "ATP" were used by less than 25% of the respondents. This result reveals that approximately one third of respondents only were using integrative software for supply chain related objectives.

Both the fact that less than 50% of the respondents were using integrative software in order to achieve real-time or near real-time information flow and that approximately one third only of the organisationsin the survey were using integrative software for supply chain related objectives points to the fact that the information integration within the relevantorganisations is not real-time and may, thus, impact on the results of the study by influencing the scores of the assessed metrics of information flow efficiency negatively when compared to the values that may be achieved with real-time information flow.

According to the system users the benefits of using ERP, APS and MES systems included“Increases in efficiency”, “Real time information” and “Improved decision making”, while “Increased adaptability” was ranked as the least important benefit.

The findings revealed that 29% of the respondents were of the opinion that between 70% and 100% of their expectations had been fulfilled by their implementing any of the above systems, 41% of the respondents did not comment on this issue while the remaining 30% of respondents were only partly satisfied with the installation of the software.

The above findings indicate that the installation of enterprise integrating software had been focused mainly on the realisation of financial objectives with supply chain related and customer relationship issues featuringless prominently in terms of the perceived importance of the benefits associated with the implementation of the abovementioned software. However, “increased efficiencies”, “real-time information” and “improved decision making”were recognised as the most important benefits arising from ERP, MES and APS systems.

In addition, 56% of all the respondents indicated that they did not make any use of technology to enablethe real-time visibility of transactions, although 44% of the respondents were using bar coding technology, while 3% only were making use of RFID. This result indicates that there is minimal adoption of real-time enabling technology in the industry being researched in this study.

8.2.7 Characteristics of information and information flow: survey results

8.2.7.1. Explorative data analysis

In section 2, starting with question 19, the respondents were asked to rank 13 characteristics of information and information transfer or flow in order of importance. The characteristics were then converted into indicators and metrics for the measurement of information flow efficiency. The respondents were asked to judge the indicators in terms of their importance, in relation to each other, as well as to judge the importance of individual metrics for each of the 13 characteristics or indicators, as proposed in section 6.4.3. As discussed in chapter 1, once evaluated, the characteristics and variables mentioned above will be used as indicators and associated metrics in order to determine the performance of information flow efficiency in the supply chain. Accordingly, these characteristics and variables will be referred to as indicators and metrics in the following sections.

The results of the rankings,in terms of importance, of the indicators of information flow efficiency are presented in table 8.2 and in Appendix 2.1. Each indicator was to be ranked on a scale from“1” to “13”.

The most important indicator was“1”, the second most important “2”, the third most important “3” until the least important indicator wasdesignated by a “13”. The results show that “Accuracy” was ranked as the most important, with a median of 2.5, followed by “Usefulness”, “Relevance”, “Security”, “Accessibility” and “Consistency” with rankings of 4.5 (median), 5 (median), 5.5 (median), 6 (median) and 6.5(median) respectively. “Believability”, “Timeliness and “Responsiveness” were rated with medians of 7, “Repeatability” and “Interpretability” were ranked with medians of 9, while “Acceptability” and “Comprehensiveness” received median ratings of 11, denoting least importance.

Table 8.2: Rankings in terms of importance of the indicators of information flow efficiency

Indicator	Median ranking
Accessibility	6
Interpretability	9
Consistency	6.5
Timeliness	7
Relevance	5
Accuracy	2.5
Security	5.5
Acceptability	11
Usefulness	4.5
Believability	7
Repeatability	9
Responsiveness	7
Comprehensiveness	11

Appendices 2.2 to 2.15 contain the evaluation results of the medians of importance of the metrics relating to each of the indicators as detailed above. These metrics were tested in questions 20 to 32 of the questionnaire. The results are summarised in table 8.3 below.

Table 8.3: Median importance ratings of the metrics for each indicator

Indicator	Metric	Median of importance
Accessibility	Access to information	1
	User friendly access screens	2
	Personalised access	3
	Choice of own information content	3
	Relative cost of accessing information	3

Interpretability	Clearly defined variables in information representation	1
	Understandable classification	2
	Availability of help functions	2.5
	Consideration of multilingualism	4
Consistency	Comparability	2
	Enterprise-wide communication of changes	2
	Clearly defined process of information provision	2
Timeliness	Time taken to retrieve data	2
	Timeous provision of data	1.5
	Time difference between receipt and reading of data	3
	Time difference between receipt of and responding to data	2
	Reporting of late or missing data	2
Relevance	Meeting needs of data presentation	2
	Ability of content to adjust to future needs	2
	Regular review of informationrequirements	3
	Consideration of information priorities	2.5
Accuracy	Correctness	1
	Number of corrections required	2.5
	Quality standards for information	3
	Control of information consistency	2
	Treatment of erroneous data	2
	Specified accuracy levels for information	2
Security	Protection from unauthorised access	1
	Protection from unauthorised change	1
	Regular backups	1

Acceptability	Agreement of all users as regards data presentation	2
	Easily customised information layout	2
	The use of specific layoutsfor specific users	3
Usefulness	Usefulness to user	2
	Dissipation of use of data presentation over time	3
	Usefulness of data to all users, from strategic to operational level	2
Believability	Correctness of data	1
	Number of wrong data incidences	2
	Existence of multiple versions of data	3
	Interchanged old data with newer versions	2
Repeatability	Repeatability of data if reproduced multiple times within days	2
	Period of validity of data	2
	Repeatability if reproduced using different report tools	2
Responsiveness	Time delay between occurrence and reporting of transactions	2
	Real time updating of reports	1
	Real time updating of transaction data	2
Comprehensiveness	Data covering all aspects required	2
	Reports/information covering requirements of all organisational levels	2
	Ability to cascade into next level performance indicator	2

The metrics were each rated on a scale from “1” to “5”, with “1” being the most important and “5” the least important”. Based on the results above, it was possible to detect a bias towards the more important ratings, as none of the metrics were judged as least important and one metric only was judged as having little importance. Accordingly, it may be deduced that the results show that, with the exception of one metric/variable, all the others were rated as important, very important or extremely important.

8.2.7.2 Statistical analysis

8.2.7.2.1. Introduction

The survey questionnaires were analysed using statistical methods with the aid of the MYSTAT program, a student version of the SYSTAT 32-bit program version 12.02.00.

As pointed out in section7.4.4.2, the survey questions onthe ranking and rating of the characteristics of information and information flow that were used as indicators produced ordinal data. In addition, a small (n=32) convenience sample was used. This, in turn, implies it was not possible to use standard statistical procedures involving the mean and standard deviations in order to evaluate the survey data. Instead, it was necessary to apply nonparametric statistics.

In order to evaluate the distribution of the characteristics or indicators of information and information flow efficiency, a box plot diagram was used first to evaluate the spread of the data and any potential outliers. However, outliers were not specifically identified because the answers represented specific preferences of the respondents, which were regarded as important in this study and were, thus, not to be discarded. When computing a measure of location for this data, the medians were used rather than the means.

The selection of the indicators of information flow efficiency was explored by utilising statistical hierarchical clustering procedures. Cluster analysis involves a mathematical method of grouping data based on the inherent similarity or dissimilarity of the data – see explanation in section 8.2.7.2.3. The results of the cluster analysis, in conjunction with the importance rankings, determined the selection of a master set of indicators.

8.2.7.2.2 Box plot graphs

According to Walfish (2006:1–5), the box plot diagram is composed of a central box divided by a vertical line, representing the median of the data. The lower limit of the box represents the lower or 25% (Q1) quartile while the upper limit of the box represents the 75% quartile (Q3). The two lines extending outwards from the box, often termed whiskers or fences, are set at 1.5 times the inter-quartile difference (Q3–Q1). Any observation found outside the fences may be considered as a potential outlier. The box plots of the individual information characteristics are presented in Appendix 2.16. The box plots indicate that three characteristics only contained potential outliers, namely, “Repeatability”, “Interpretability” and “Accuracy”. However, as explained above, no outlier analysis will be performed. Based on the shape of the boxes and the position of the median marker, many of the distributions depicted a wide range of values, in particular, the distributions representing the characteristics of “Relevance”, “Accessibility”, “Acceptability” and “Security”, while the data distributions of “Comprehensiveness”, “Acceptability”, “Accuracy”, “Interpretability”, “Responsiveness” and “Relevance” were either negatively or positively skewed. Accordingly, it was not possible to observe any specific distribution pattern for all the characteristics.

8.2.7.2.3 Hierarchical cluster analysis

Cluster analysis, a mathematical technique for grouping respondents based on similarity between them (Dolnicar, 2003:5–12), requires the calculation of a distance between respondents in a multidimensional space. According to Dolnicar (2003:5–12), most researchers use Ward’s method to evaluate these distances and to agglomerate cases into clusters. This method represents an “analysis-of-variance” type approach and, as it is regarded as efficient, was, thus, also used in this research study.

The cluster agglomeration process began with 13 individual clusters, each containing its own characteristic of information and information transfer. The two characteristics exhibiting the shortest distance between them were included into a new cluster. The shortest distance between this cluster and another indicator formed a larger cluster or, if the next shortest distance existed between two characteristics, a new cluster was formed. This method continued until all the characteristics had been combined into one, single cluster.

An exploration of the associated dendrograms[7] identified the best solution in terms of the number of clusters and the members per cluster. It was possible to identify the number of clusters and, thus, the members per cluster finally chosen, by means of an inspection of the cluster trees, an examination of the content of the clusters and the use of a scree-plot[8]. The results of the clustering procedures are contained in Appendices 2.17 to 2.20.

The analysis using Ward's method is contained in Appendix 2.17. Ward's method produced the first cluster comprising "Repeatability" and "Interpretability". To this cluster "Responsiveness" was added. Another three different clusters comprising "Security" and "Accessibility" and "Accuracy" in the first cluster, "Relevance" and "Usefulness" in the second and "Consistency", "Believability" and "Timeliness" in the third cluster were formed. The cluster consisting of "Security", "Accessibility" and "Accuracy" was then combined with a cluster containing "Relevance" and "Usefulness". Another cluster containing "Consistency", "Believability" and "Timeliness" was added to the cluster comprising "Repeatability", "Interpretability" and "Responsiveness". "Acceptability" and "Comprehensiveness" again formed their own cluster which was, however, associated with the previous cluster.

The associations computed by the clustering algorithm also depend on the number of clusters chosen in order to achieve a sensible cluster schedule. A comparison of the exact cluster memberships is depicted in table 8.4.

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[7]Graphical representation of the cluster tree information.
[8] Plot of cluster distances versus number of clusters

If the above cluster membership schedule is taken into account, it becomes apparent that the cluster agglomeration mechanism did not produce any functional results when examining the “3 cluster” results, because agglomeration algorithm formed clusters containing indicators which exhibited a marked variance in the rankings from neutral rankings, that is, “Consistency”, to highly unimportant rankings, such as “Acceptability”. As shown in the following sections, it was possible to split these rankings of indicators into more meaningful clusters.

On inspecting “4 cluster” results, a cluster containing “Relevance” and “Usefulness”, was formed as well as a cluster comprising “Acceptability” and “Comprehensiveness”.

Moving to “5 cluster” analyses, it appeared that the characteristics of “Acceptability” and “Comprehensiveness” were split into their own clusters.

The “6-cluster” membership schedule depicted further splits, mainly in the section of indicators exhibiting ratings close to the median ranking.

The above analysis offers 4 options in terms of the level of cluster agglomeration. Table 8.5 depictsthe scenarios from sixclusters down to threeclusters which, in turn,requiresthat a decision be taken with regard to the number of clusters that should be chosen in order to identify the characteristics belonging to each cluster.

In order to validate the number of clusters that should be chosen the scree-plot, as presented in Appendix 2.18, was consulted. As mentioned earlier, the scree-plot of a given dendrogram plots the cluster distances against the number of clusters. This has the effect that, the larger the number of clusters, the larger the distances between the clusters. This, in turn, may result in the so-called “elbow effect”, which indicates that, at first, the dissimilarity between clusters grows more slowly than the number of clusters and then, at a certain point,more quickly than the number of clusters, thus leading to a kink in the curve. This kink is taken as the point representing the optimal number of clusters.

The scree-plots of the cluster agglomeration method selected (Ward's method) showed 3 elbows at 5, 4 and 3 clusters. The presence of more than one kink in the scree-plots meant that it was necessary to carry out a physical inspection of the clusters and their members.

When comparing the results of the cluster analysis with the actual importance rankings, as depicted in tables 8.5 and 8.6, it became clear that the clustering procedure had moved together indicators with similar ranking ranges and, thus, rankings of importance (see table 8.4).

Table 8.4: Cluster membership schedule

Indicator	**Cluster membership − Ward's method**			
	6 Clusters	**5 Clusters**	**4 Clusters**	**3 Clusters**
Relevance (5)	1	1	1	1
Usefulness (4.5)	1	1	1	1
Repeatability (9)	2	2	2	2
Believability (7)	3	2	2	2
Timeliness (7)	3	2	2	2
Responsiveness (7)	2	2	2	2
Consistency (6.5)	3	2	2	2
Interpretability (9)	2	2	2	2
Accessibility (6)	4	3	3	3
Accuracy (2.5)	4	3	3	3
Acceptability (11)	5	4	4	2
Security (5.5)	4	3	3	3
Comprehensiveness (11)	6	5	4	2

For example, "Comprehensiveness" and "Acceptability" were ranked as highly unimportant and received the most rankings in the last four importance categories of 10, 11, 12 and 13, thus denoting the least importance. In addition, these indicators also appear together in one cluster in the 4-cluster membership table, as shown in table 8.4.

“Relevance” and “Usefulness” also appeared to have extremely similar rankings in the first five categories of high importance with rankings of “1” to “5”. Both also appeared together in a cluster, as per table 8.4.

The indicator “Accessibility” revealed a wide-spread ranking result, with 28 of 32 rankings spread between the ranking categories of “5” to “11”, thus indicating less than “unbiased” or “neutral” importance, or importance above the midpoint of the measuring scale. The fact that the clustering procedure combined this indicator with “Accuracy” may stem from the fact that this indicator also showed a wide-spread ranking range, despite the fact that 28 of 32 indicators were spread between the ranking categories of “1” and “5”, thus pointing to higher than “neutral” importance. However, the remaining 4 rankings were to be found between the ranking categories of “7” to “11”, thus assigning less than neutral importance to this indicator. This may be interpreted as the cause of the clustering together of these indicators.

The remaining indicators exhibited wide-spread ranking ranges, with the most number of rankings to be found between categories 5 and 12, indicating just above or less than neutral to not important at all. The reason for this wide spread of the individual rankings may be found in the importance of the indicators in the minds of the interviewees with regard to their specific business requirements.

A graphical representation of the spread of the responses concerning the importance of the indicators is presented in Appendix 2.16. On examining Appendix 2, figure 2.17, together with figure 2.16, one might expect “Accuracy” to emerge as the most important indicator, with “Acceptability” and “Comprehensiveness” as the most unimportant indicators. The latter finding may also be expected based on their box plots as contained in Appendix 2.16. Both ranking data distributions are positively skewed, with 50% of their data points at a ranking of 11 and above, which may be seen as a confirmation of the above expectation.

Table 8.5: Actual ranking results of indicators in terms of numbers of rankings received in each ranking category

Indicator (median ranking)	No of rankings received in each ranking category												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Relevance (5)	4	5	4	2	2	3	0	3	1	3	2	1	2
Usefulness (4.5)	5	5	4	2	4	2	2	1	1	1	3	1	1
Repeatability (9)	1	0	0	2	2	1	4	2	5	5	5	4	1
Believability (7)	2	0	3	3	3	2	4	4	3	2	1	3	2
Timeliness (7)	1	2	2	2	3	5	5	3	1	3	1	3	1
Responsiveness (7)	1	2	2	3	0	4	5	3	3	3	2	0	4
Consistency (6.5)	0	2	3	1	6	4	3	5	3	2	0	3	0
Interpretability (9)	1	0	0	1	5	1	4	2	7	5	2	2	2
Accessibility (6)	2	1	5	4	3	2	2	4	1	4	3	1	0
Accuracy (2.5)	9	7	4	5	3	0	1	1	1	0	1	0	0
Acceptability (11)	1	1	2	2	0	3	1	0	1	2	4	4	11
Security (5.5)	3	7	3	2	1	2	1	1	2	1	4	5	0
Comprehensiveness (11)	2	0	0	3	0	3	0	3	3	1	4	5	8

Table 8.6: Actual ranking results of indicators in terms of % of rankings received in each ranking category

Indicator (median ranking)	% of rankings received in each ranking category of total rankings												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Relevance (5)	2.4	3.0	0.6	1.2	0.6	0.6	0.0	0.6	1.2	5.3	0.6	1.8	1.2
Usefulness (4.5)	3.0	3.0	0.0	0.0	1.2	1.2	1.2	0.0	0.6	4.1	0.6	4.1	0.0
Repeatability (9)	2.4	2.4	0.0	1.8	1.2	1.2	1.8	0.0	3.0	2.4	1.2	1.8	0.0

Believability (7)	1.2	1.2	1.2	1.8	1.2	1.8	0.6	0.6	2.4	3.0	1.2	1.2	1.8
Timeliness (7)	1.2	2.4	1.2	1.8	1.8	0.0	3.6	3.0	1.8	1.8	0.0	0.6	0.0
Responsiveness (7)	1.8	1.2	0.6	1.2	3.0	2.4	2.4	0.6	1.2	0.0	1.8	1.2	1.8
Consistency (6.5)	0.0	1.2	2.4	2.4	3.0	3.0	1.8	2.4	1.2	0.6	0.6	0.6	0.0
Interpretability (9)	1.8	0.6	1.2	2.4	1.8	1.8	3.0	1.2	2.4	0.6	0.0	0.6	1.8
Accessibility (6)	0.6	0.6	3.0	1.8	0.6	1.8	1.8	4.1	0.6	0.6	0.6	1.2	1.8
Accuracy (2.5)	1.8	0.6	3.0	1.2	1.8	1.8	1.2	3.0	2.4	0.0	1.2	0.6	0.6
Acceptability (11)	1.2	1.8	3.0	0.6	0.6	1.2	0.0	1.2	1.8	0.6	2.4	2.4	2.4
Security (5.5)	0.6	0.6	2.4	1.8	1.8	0.0	1.8	1.2	0.6	0.0	2.4	3.0	3.0
Comprehensiveness (11)	1.2	0.6	0.6	1.2	0.6	2.4	0.0	1.2	0.0	0.0	6.5	0.0	4.7

Table 8.6 presents the same data as table 8.5, but in a percentage form to facilitate greater understanding.

Based on the above, acceptable clusters formed. As a result of the fact that most of the elbows shown in the scree-plots are centred on 4 clusters, it may be inferred that the cluster analysis was successful in producing a suitable clustering of information and information transfer characteristics at 4 clusters. As regards the aim ofthis research study, namely, to identify information flow efficiency indicators, this result implies that it may be possible to identify four “factors”, based on the four clusters distinguished, as the characteristics contained in each clusterthat indicate a common group, for example usability.

8.2.7.2.4 Conclusion

In this section of the survey, the respondents were asked to evaluate the importance of 13 characteristics of information and information transfer in relation to each other. The responses to the questions that followed offered various measurable variables or metrics for each characteristic for assessment in terms of the overall importance of the measurable variables or metricsfor the particular characteristic or indicator.

The results of the explorative data analysis revealed that the characteristics of information and information transfer that had been evaluated produced one most important characteristic, namely, “Accuracy” and two characteristics with the least importance, namely, “Acceptability” and “Comprehensiveness”. All the other characteristics were located between the two extreme values. This result was confirmed by the hierarchical cluster analysis, which produced distinct clusters from the median rankings of the characteristics. Using Ward’s method of cluster agglomeration the number of clusters of 4 was found to be the most appropriate. The 4 clusters were shown to comply with the requirements set forth for this analysis. The membership of these clusters was as follows:

- Cluster 1: Usefulness (4.5), Relevance(5)

- Cluster 2: Repeatability (9), Believability (7), Timeliness (7), Responsiveness (7), Consistency (6.5), Interpretability (9)

- Cluster 3:Accessibility (6), Security (5.5), Accuracy (2.5)

- Cluster 4:Acceptability (11), Comprehensiveness (11)

Based on the cluster analysis, as well as the importance rankings, it was decided to retain the following indicators:“Accessibility”, “Consistency”, “Timeliness”, “Relevance”, “Accuracy”, “Security” and “Usefulness”.

As regards the metrics for each indicator of information flow efficiency, the most important metrics only were retained in order to render the data handling and evaluation more meaningful. The same principal which had been used with the indicators of information flow efficiency was applied. The overall median for all metrics is “2” while all those metrics with a median rating of “3” and above should be discarded. The metrics were rated in terms of their importance on a scale from “1” to “5”, with “1” being most important and “5” denoting no importance at all.
Ifthe information contained in table 8.3 is evaluated in this manner then the indicators and metrics, as depicted in table 8.7, are retained.

Table 8.7: Retained indicators and metrics of information flow efficiency

Indicator	Metric	Median of Importance
Accessibility	Access to information	1
	User friendly access screens	2
Consistency	Comparability	2
	Enterprise-wide communication of changes	2
	Clearly defined process of information provision	2
Timeliness	Time taken to retrieve data	2
	Timeous provision of data	1.5
	Time difference between receipt and responding	2
	Reporting of late or missing data	2
Relevance	Meeting needs of data presentation	2
	Ability of content to adjust to future needs	2
	Consideration of information priorities	2.5
Accuracy	Correctness	1
	Control of information consistency	2
	Number of corrections required	2.5
	Treatment of erroneous data	2
	Specified accuracy levels for information	2
Security	Protection from unauthorised access	1
	Protection from unauthorised change	1
	Regular backups	1
Usefulness	Usefulness to user	2
	Usefulness of data to all users from strategic to operational level	2

The above table represents the list of the final indicators and measurable metrics for information flow efficiency. These indicators and metrics were obtained from the characteristics of information and information transfer and will be applied in the actual measurement of information flow efficiency.

8.2.8 Conclusion

The results of the survey instrument were discussed in section 8.2. The conclusions that may be drawn from these results are presented in the paragraphs below.

The use of EDI and Internet in businesses enables connectivity between the relevant business with this connectivity improving the speed of interaction and, therefore, the speed with which decisions are made. However, as the survey shows, a few of the respondents only, that is, approximately 12% use EDI and the Internet for the purposes of order placement and receipt. This finding provides evidence of an extremely low degree of vertical integration of information systems in the telecommunications cable manufacturing supply chains.

The distribution of suppliers provides an overview of the globalisation with which a South African telecommunication cable manufacturer has to deal in terms of communication and efficient information flow. In particular, global communication or information flow is more complex across spatial and cultural barriers. Global documentation and communication channels are also subject to complex and multiple legal requirements with this, in turn, presenting additional barriers to an efficient information flow.

The investigation into the use of systems such as ERP, MES and APS, was based on the evidence that these systems are intended to improve intra-organisational information integration by providing an electronic platform that attempts to integrate all the functions of a business.

Both the fact that less than 50% of the respondents use integrative software in order to achieve real-time or near real-time information flow as well as the fact that approximately one third only of the organisations taking part in the survey use integrative software for supply chain related objectives point to the reality that the information integration within the respondent organisations is not real-time and may, thus, impact on the results of the study by influencing the scores of the assessed metrics of information flow efficiency negatively as compared to the values that may be achieved with real-time information flow.

All of the technologies mentioned above are intended to provide tools with which to improve and promote the efficient flow of information both between supply chain partners and within an organisation, thus enabling the speedier availability of the information required and, therefore, a more rapid approach to decision making. Faster decision making would enable the supply chain concerned to perform in a way that would resemble more closely a real-time environment. However, as a result of the low information integration, as detailed above, the results of this study are expected to indicate low, actual, information flow efficiency.

Further questionsin part 3 of the survey questionnaire were designed to ascertain the perceptions of the supply chain partners regarding the importance of information flow efficiency in supply chains and, in addition, their opinion as to whether information flow efficiency should be measured and included in a BSC framework. These questions relate directly to the purpose of this study as it is the aim of this research to provide indicators and associated metrics for the measurement of information flow efficiency.

As shown in tables 8.5 and 8.6, the indicators received varying and mostly wide-ranging rankings. These rankings were evaluated using a clustering procedure, as well as by inspection of the actual rankings. This assisted in reducing the amount of data to be handled, by excluding those indicators that were ranked at categories indicating lesser importance than neutrality and which attracted a category “7” score. Table 8.7 depicts the remaining indicators and metrics. The indicators and metrics selected were tested in a case study (see next section) in an attempt to measure the information flow efficiency in organisationsand supply chains, as outlined in chapter 7.

8.3 EXPLORATORY TESTING OF THE MEASUREMENT OF INFORMATION FLOW EFFICIENCY

8.3.1 Introduction

This research study aimed at identifying and selecting indicators and associated metrics for information flow efficiency. These indicators and associated metrics were identified by selecting suitable performance measurements applicable to information flow, based on the characteristics of information quality (Hales, 2005:12), performance measurements and general business process performance measurements and the drivers thereof, as described in section 6.4. A survey in the form of a questionnaire was designed and administered in order to ascertain the opinions of the respondents as regards the importance of each of the indicators and associated metrics that were to be assessed. Explorative data analysis techniques, such as statistical cluster analysis and box plot graphs, were used to distinguish the important indicators and associated metrics from the less important ones.

The resultant indicators and associated metrics that had been ranked and rated as important, as depicted in table 8.7, were tested in 25 organisations for the purpose of measuring information flow efficiency. These 25 organisationswere part of the original set of respondent organisations that had taken part in the survey.

An attempt was made to test the indicators and associated metrics in an effort to measure information flow efficiency by conducting personal interviews with the participants of the assessment sessions, using an interview question guide (see Appendix 3) based on the indicators and metrics that had been developed and then reduced in number. The actual testing was conducted as detailed in section 7.5.

The following sections will outline the construction of scales against which the information flow efficiency metrics were evaluated.

8.3.2 Indicators and metrics selected as drivers of information flow efficiency

The indicators and metrics for the measurement of information flow efficiency proposed in this research are time-related and quality and usability aspects of both electronic and paper-based business systems. Time, as well as the quality and usability of human interaction with electronic or mechanic systems, impact on information flow efficiency as a result of the effectiveness and efficiency with which tasks may be carried out using such systems. Accordingly, this time, quality and usability may be considered as drivers of information flow efficiency. *Time* clearly impacts on the efficiency of information flow because information may flow more slowly than expected or required, thus resulting inthe retarded availability of the information and leading, in turn, to slower decision making. *Quality* impacts on information flow efficiency by impeding the interpretability of the required information, thus initiating queries and slowing the information requireddecision making. The *usability* of systems, interfaces and computer software also influences information flow efficiency in a similar manner to the time factors mentioned above. Poor usability extends the time before information becomes accessible, thus impeding decision making. Usability has been defined by ISO 9241–11(1998) in Bevan (2008:14) as: “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use”.

According to Bevan (2008:14), this definition implies that, for a product to be usable, the users should be able to use a system in order to achieve their goals in an acceptable amount of time. As depicted in figure 1.5, the design characteristics, as detailed in sections 1.2.6.2 to 1.2.6.4, constitute the prerequisites with which information and the flow of information must comply so as to have the capability to produce metrics that comply with the same design characteristics. Accordingly, it may be concluded that design characteristics drive, or are the key factors of, efficient information flow. Hence, an assessment of the compliance of the abovementioned key factors or design characteristics will provide a measurement of the quality and efficiency of information and information flow.

8.3.3 The use of semantic differential scales

As regards evaluating and scoring the metrics identified by this study, severalwriters, including Page-Bucci (2003:1–12), Finstad (2006: 185–188) and Hashim andSultan (2009:166–175), propose the use of Likert-type scales varying from 3 to 7 points. This principle has also been described in conjunction with the use of the system usability scale (Finstad; 2006:185–188). However, Treiblmaier andFilzmoser (2009: 1–24) assert that the use of continuous rating scales is significantly better suited to the evaluation of survey questions. The main reasons for this recommendation may be found in the fact that there may not be any guarantee that the data generated by using Likert-type scales may be usable for the application of statistical techniques. In addition, the labels chosen for scaling tend to influence the responses presented by the individuals interviewed. Furthermore, the expansion or constraint of scales may also influence the respondent's behaviour. Accordingly, Treiblmaier andFilzmoser (2009: 1–24) propose the use of a continuous scale, especially as regards computer-based surveys.

Further research undertaken by Joshi andTripathi (2008:1–8) reveals that a continuous scale of 0–100% may be utilised to evaluate user experience metrics involving questions requiring subjective answers. User experience metrics are those metrics that measure how comfortable the user feels with a system, interface or software product, how efficiently the user is able to operate any of the above-mentioned products and how effectively the products may be handled. This directly impacts on how quickly information becomes available and, therefore, on information flow efficiency.

Based on the opinions of the above researchers, this research study adopted the use of a continuous scale ranging from 0 to 100%. Scores were allocated in such a way that a 100% score would be recorded if the requirement exposed by the metric to be assessed could be met in the best possible manner, was fully present and/or carried out to the total satisfaction of the expert. A 0% score would be allocated if the requirements of a metric were not met The use of experts ensured that values between 0 and 100% were assigned for the degree to which the requirement of a metric was metIn order to assess the compliance of the metrics with therequirements, a time scale was used, as discussed in section 8.3.4.2 below, for time related metrics, as well as a subjective scale based on set anchor points – see section 8.3.4.

8.3.4 The basis for the use of time as an evaluation criterion

8.3.4.1 The duration of information transfer/flow

The requirement as regards the measurement of time and duration was based on the necessity of moving towards a real-time supply chain. According to Trebilcock (2006:1–3), a real-time supply chain is required as supply chain processes do not necessarily occur in the same building anymore, but may be spread out globally. Various technologies are, thus, indispensable in order to bring the final product to the customer when it is required. Real-time information is, therefore, essential.

Accordingly, the basis for the measurement of time and duration was established while taking into consideration the current technological possibilities, current practices for the transfer of information and the times required for the transfer of information, as well as the times that would render the information received either old or useless.

With current technology, it is possible to send information electronically, by means of fax, e-mail, and the Internet, or as a transaction directly into ERP, APS or MES. However, in the absence of the technology, it is also possible for information to be written or typed manually, sent by post or transferred by a carrier.

The electronic transfer of information may be further broken down into direct or immediate transfer and batch-transfer and combinations thereof (Nadhan & Weldon, 2004:4). Direct transfer is achieved immediately, whilst batch-transfer involves a scheduled and intermittent transfer of information at predetermined intervals. The time schedules required for each of the above methods differ significantly (Nadhan & Weldon, 2004:1–14).

The literature remains largely silent on the actual time required to carry out certain transactions. However, the time required to perform transactions may vary widely, because of the complexity involved. This complexity arises as a result of the possible influence of several factors, including the type of hardware and equipment used to carry out the physical transaction, the nature of the transaction itself in terms of the time required to perform the transaction, the information flow between the parties subject to the transaction and the integration of the equipment responsible for the transaction with the computer system recording the transaction. There is a limited amount of information only on the duration of activities within computer hardware provided in the literature. With regard to the information flow between humans and computers, as well as between humans, and between computers in a business environment, the literature does not provide any details relating to possible time standards for the abovementioned activities. Accordingly, in order to provide reasonable time standards, the researcher's own expert experiences, as applicable in his own company, were applied. It must, however, be acknowledged that the application of the researcher's own time standards comprises a shortcoming of this research study, as other experts in this field may apply different time standards and, as such, the time standards presented may not be generalisable.

The time standards arrived at will be discussed in the following section.

8.3.4.2 Scales for time-related information

The basis for time measurement was found in the current technological possibilities, current practices and the times that rendered the information received either old or useless. On this basis, and on the basis of the practices in the researcher's own company, it was found that average modern technology provides for periods of up to ten minutes for the receipt of global information sent via channels in real-time, such as e-mails. However, not all systems operate in real-time with several, older, batch driven systems providing information on a periodic basis, which ranges from updates occurring every 30 minutes to every 24 hours. In view of the fact that information updates are definitely late or unusable after a time period of 48 hours, the scores were set in such a way that 48 hours represented a

0% score, 24 hours a 50% score, 12 hours a 75% score, 8 hours a 80% score and 1 hour a 90% score. The best possible score or the “100%” score was set to a time period of ten minutes or less. The time scale spans from a real-time scenario, through batch systems using short, almost real-time update periods, to batch systems using long update intervals, as explained above.

The scale point labels will be adjusted for organisationseither not using technology, or using out-dated technology.

For example, in paper oriented systems, both the anchor point and the interval point labels will be adjusted to the accessibility of the information contained in an existing filing system. As a case in point, the access to an index detailing where to find the appropriate information required would be assessed according to the time scale approach as described above, but utilising the new scale anchor point and interval point labels.

In certain cases the time factors differed according to the categories of information. For example, some respondents replied that their financial information was easily accessible, while also stating that it was difficult to access current production information. In these cases, the respondents were asked to provide an estimate of the percentage the financial information comprised in terms of all the information with which the company had to deal. The relevant score was then applied to the relevant category of information only, thus resulting in a weighted average for the particular metric of information flow efficiency being measured.

8.3.5 The scoring of information flow metrics inclusive of other (non-time related) metrics

The non-time related indicators and metrics deal specifically with the quality and usability issues of electronic and paper-based business systems. The quality and usability of human interaction with electronic or mechanic systems impact on the information flow efficiency as a result of the effectiveness and efficiency with which tasks may be carried out using systems, as described in section 8.3.2 above. As discussed in section 1.2, it is essential that information be accurate and comprehensive, and provided in a timely manner. However, efficient information flow, accuracy, reliability and comprehensiveness are directly associated with the effective interoperability between the various applications and entities handling the information. Achieving interoperability means faster information flow, and an effective decision-making process (Tyrinopoulos, 2004:101).

In this study, the human-to-electronic interaction relates to the interaction with computer systems, whilst the human-to-mechanical system relates to the interaction with mechanical storage systems, filing cabinets and drawers. In this regard, usability has been efficiently defined in ISO 9241–11(1998) (Bevan (2008:14) as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use". According to Bevan (2008:14), this definition implies that, for a product to be usable, the users should be able to use a system in order to achieve their goals within an acceptable amount of time.

The non-time based metrics considered in this section and requiring a subjective assessment were rated by experts in the organisations, as described in section 7.5.

The following sections define the 100% and 0% scale anchor points for each retained metric and associated with the retained and selected indicators. The following metrics had to be assessed on an individual information category basis, for example, information such as financial information, and operational, logistics and order information. A weighted average for the score was, thus, recorded.

8.3.5.1 Accessibility

The accessibility of information is the first indicator In an attempt to define accessibility more accurately so as to be able to provide clear scale anchor points, it was necessary to refer to the literature. However, the only clear definition found in the literature referred to accessibility in information technology terms, as follows.

Accessibility forms part of the definition of usability in the draft standard ISO/IEC CD 25010.2(2008). According to Bevan (2008:14), accessibility may be defined as "the degree of usability in use for users with specified disabilities".

However, the aim of this indicator is not only to evaluate "the degree of usability in use for users with disabilities", but for users in general. In addition, this study is concerned with the efficiency of the flow of information which is, in turn, influenced by the accessibility to information. Impeded access to information hinders the efficient flow of information in terms of the availability of the information. Hence, this indicator has the capability of evaluating the information flow efficiency in terms of the efficiency with which information may be accessed.

8.3.5.1.1 "Access to information should not have any obstacles"

As proposed in section 6, it is essential that accessibility to information not be encumbered by any obstacles. Obstacles may take the form of computer screens which are difficult to manoeuvre around in, or, in less developed, more paper intensive systems, there may be unlabelled and unindexed drawers in whichthe information is kept, or the information may not have been sorted. Such obstacles impede the access to such information, and the process of accessing all the information required may be time consuming. In the most ideal situation, access to information should be real-time, requiring the least amount of effort to access the desired information, for example, the press of a button in computerised scenarios, or the opening of a drawer/file in cases where older, paper-based systems are used. The "real-time" aspect was, thus, added to the assessment statement. The first metric was, therefore, formulated as follows:

8.3.5.1.2 "Access to information must be real-time"

As regards electronic systems this statement would take into consideration how quickly respondents were able toaccess the necessary screens in order to retrieve the relevant/required information. The press of a button, online, with the striving for real-time data provision, was taken as the most favourable position, with a 100% score. In the case of paper systems, this statement relates to the efficiency of an index or other formalised access with the 100% score being awarded if it were possible to access such information with the opening of a drawer. A 0% score would have been allocated if it were cumbersome either to access the correct screens from which the required information could be obtained, or if the screens were cluttered, thus making the correct choice difficult. In the case of paper systems, the 0% score would have been awarded if there were no documented procedures and indices detailing the correct access method.

8.3.5.1.3 "Access screens must be user-friendly"

The second metric was developed around the second, proposed measurable question, as per section 6.4.3. This question revolved around the user friendliness of the access screens for information retrieval. User-friendliness may also differ with the type of information which is required to be displayed, for example, financial information. This question attempted to assess how well the screens of electronic systems are structured in order to facilitate quick manoeuvrability through the screens, with sufficient assistance available to enableeven an untrained person to negotiate his/her way successfully aroundthe different screens. In such a case a 100% score would be awarded. However, if screens were cluttered and an intensive search were necessary to find the required option, then a 0% score would be awarded.

Similar logic may be applied to paper-based systems, in terms of which the availability of indices and easy manoeuvrability through the contents of the storage elements or drawers attracted a 100% score, whilst intensive searching for indices and drawers resulted in a 0% score.

8.3.5.2 Consistency

The second retained indicator concerned the consistency of information. According to Joshi andTripathi (2008:2), the Purdue Usability Testing Questionnaire is based on eight metrics relating to human-computer-interaction (HCI). These eight metric include "Consistency". Joshi and Tripathi (2008:2) refer specifically to the example of consistency as relating to consistency if all frequent and critical tasks are unchanged from earlier version. Although this example refers to the consistency between tasks only, as regards the measurement of information flow efficiency,the concept of consistency must be expanded to include the consistency of information itself.

Information may be obtained from either one system only or from a number of integrated or standalone systems. The fact that information may be duplicated in different areas of an organisationas a result of the integration of systems not being seamless, may lead to inconsistent information within the organisation. This, in turn, may lead to incorrect decisions and actions which will impact on the information flow efficiency.

8.3.5.2.1 "Information must be comparable"

The first metric associated with the indicator "Consistency" dealt with the comparability of information. In order to be able to assess how comparable information is, it was important to examine the various sets of information produced throughout the different business areas, and to evaluate whether the same information generated in different business areas yielded either the same or different content. The evaluation statement was, therefore, phrased as follows:
"Information must be comparable, irrespective whether the information was drawn from different entry points into the system or from different systems."

It is essential that no outofdate copies of the same set of information be kept in the overall system. If this were, indeed, the case a 100% score was awarded. However, if out-of-date copies were present a 0% score was awarded. These scale anchor points were used for both computerised, as well as for paper-based, business systems.

8.3.5.2.2 "Enterprise-wide changes must be communicated in real time"

The second metric associated with "Consistency" is"Enterprise-wide changes must be communicated in real time".

Seamless integration also refers to the capability of the system or systems to effect changes immediately in all relevant spheres of the functions of the business software as well as in the paper systems. The emphasis of this metric is, thus, on the immediate propagation of changes throughout the business system. There should be noor, at worst,extremely short time delays only, in order to ensure that information flows efficiently. The aspect of real-time was, thus, added to the metric statement so as to assure that the importance of time was clearly understood by the expert respondents.

The respondents were asked to judge how quickly information changes could be processed throughout their system(s). The basis of time measurement (described in section 8.3.4.2), but using the amended description of real-time, and allowing for a time lag of up to 10 minutes, was used as an evaluation criterion.

8.3.5.2.3 "Clearly defined processes of information provision must exist"

The problem associated with a process which is not clearly defined is the fact that personnel are free to provide reports and figures in any format they prefer. This, in turn, may lead to confusion and uncertainty, as the defined rules of interpreting data may not be applicable and it may not be possible to apply them.

The third metric for the indicator of "Consistency" centred on the statement that "Clearly defined processes of information provision must exist".

Data and reports adhering to the laid down rules for the provision of consistent data were awarded 100% while the lack (total) of standards for the provision of information attracted a 0% mark.

8.3.5.3 Timeliness

The third retained indicator is "Timeliness". Timeliness is clearly related to the efficiency of the concept of usability, as stated by Hashim andSultan (2009:168). In particular,Hashim and Sultan (2009:168) refer to"time to achieve one's task" and “time spent on errors”. Four metrics were identified which assist in the assessment of this indicator.

8.3.5.3.1 “How long does it take to retrieve information/data”

The first metric of the indicator of “Timeliness” refers to the time taken actually to retrieve the data, once access to the data has been gained. As in the case of information access, it is essential that information retrieval take place as quickly as possible in order to minimise any delays in the flow of information. In order to provide a clear understanding of the importance of time to the expert respondents, the aspect of real-time was added to the original metric statement.

The first metric was, thus, formulated as follows: “The time taken to retrieve data in real-time”.

The basis of time measurement, as described in section 8.3.4.2,was used as an evaluation criterion.

8.3.5.3.2 “The provision of data and information must be on time”

“The provision of data and information must be on-time” was the second metric associated with this indicator. This metric relatesspecifically to the time difference between the provision of data and the period allowed for the provision of data. The respondents were required to assess the timeous provision capability of data for each category of information as discussed in section 7.5.6. The basis of time measurement, as described in section 8.3.4.2, was used as an evaluation criterion.

8.3.5.3.3 “What is the time difference between the receipt of information and responding to the information”

The third metric proposed in section 6.4.3 dealt with the time differences between the receipt of information and actually reading and responding to the information received, for example,via e-mail or fax. The importance of this metric lies in the delays which may be created by not immediately reading and responding to information received. In order to create an efficient flow of information, it is essential that the abovementioned delays should be as short as possible and, thus, to emphasise the importance of this aspect to the expert respondents, it was added to the original metric statement.

The third metric statement was formulated as follows: “The time difference between the receipt of information and responding to this information in real time”. This metric attempted to measure how quickly a company was able to react to queries received, while taking into account the fact that personnel would not always be available either on the telephone or on e-mail. The time scale, as described in section 8.3.4.2 and using the amended description for real-time, providing for a time lag of up to 10 minutes, was used to assess performance.

8.3.5.3.4 “Is late or missing information/data communicated”

The fourth metric of the indicator “Timeliness” emphasised the importance of the timeous reporting of erroneous or missing information. In an ideal situation erroneous or missing information would be identified either immediately or in real-time, before any person or software program would have had the opportunity to use or to continue without the information, and, thus, possibly arrive at incorrect decisions, statistics or other information that may be used for decision making. For the convenience of the expert respondents, the real-time aspect was included in the original metric statement.

Accordingly, the fourth metric was thus formulated as follows: “The reporting of late or missing data must be real time”.

As mentioned above, special emphasis was placed on the actual process of discovering the fact that reports and/oronline data contained incorrect data or that data had gone missing, and how quickly this was reported and rectified. The time scale, as described in section 8.3.4.2, was used to assess individual performance.

8.3.5.4 Relevance

The fourth indicator identified was “Relevance”. This indicator was described only indirectly by Hashim andSultan (2009:168) as an aspect of the efficiency metrics. Hashim and Sultan (2009:168) referred specifically to the measurement of commands not called upon by the user, thus rendering them irrelevant to the user. This study, however, deals with the efficiency of the information flow and not with the efficiency of specific software only. Nevertheless, the efficiency of information flow involves the overall efficiency with which information flows through HCI, software and humans. Accordingly, the concept of the metric “Relevance” may be applied to the measurement of information flow efficiency with the emphasis on the provision of the correct information.

8.3.5.4.1 “Information representation must meet the user’s needs”

The first metric assessed the following, namely, “Information representation must meet the user’s needs”.

The assessment of this metric included the relevance of data that was either displayed on a particular screen or represented in a specific report for a particular person. The need to search for the data or information required, either in a report or onscreen, reduces the efficiency with which information flows. A 100% score was awarded if the information presented met all the needs of the user, that is, displayed all the data which the user needed to see and in the form in which the user required the data. On the other hand, a 0% score was awarded if the needs of the user regarding the information were not met, that is, the information displayed was not in the form required nor did it contain the content as required. In other words, the information was not relevant to the user.

8.3.5.4.2 “Information representation must be able to adjust to future needs”

The second metric associated with this indicator was as follows: “Information provision must be able to adjust to future needs”. In this case the emphasis was on how quickly systems were able to adjust to new business scenarios, for example, as the addition of a new product or even a new product line. The time basis, as discussed in section 8.3.4.2, was applied. This time basis was used to evaluate this metric as it may happen that a new product could be produced with the existing equipment. However, the current business system, comprising information systems, humans and HCI, may have to be set up to cater specifically for the handling of the new product. Should the business system not be able to meet the requirements of the new products, valuable time would be lost in launching the product into the market environment, and this may compromise the innovative capacity of the organisation.Accordingly, time is essential as regards the ability of information systems to adjust to the information requirements of new products.

8.3.5.4.3 "Information priorities must be considered"

The third metric dealt with "Information priorities must be considered".

The main issues in this case concerned the selective provision of information to users in different functions and areas, thus rendering the interpretation of information, access to information and the needs of information presentation both more individualised and simpler. If the system took into account the information priorities of each user, or group of users, then a 100% score would be awarded while the opposite would result in a 0% score.

8.3.5.5 Accuracy

The fifth indicator of information flow efficiency dealt with the "Accuracy" of information. According to the initial definition, as detailed in section 6.4.3, "Accuracy" is represented by the degree of conformity of measure to either a standard or a true value. In addition, "Accuracy" is also the dominant description of the effectiveness of usability in use, as per the definition contained in ISO 9241-11. Effectiveness may be described as "accuracy and completeness". "Accuracy" may influence the flow of information should inaccurate information be fed into a business system. It is essential that inaccurate information be detected and, once detected, that it also be corrected. However, the process of correction does not necessarily reverse any decisions that may have made, based on the incorrect or inaccurate information. Time delays may, thus, occur, and these maycompromise the efficient flow of information. Based on this fact, “accuracy” constitutes a crucial aspect of the measurement of information flow efficiency as it is directly related to the efficiency with which information can flow.

8.3.5.5.1 “Information/data must always be correct”

The first metric is “Data/information must always be correct”. The respondents were required to judge the degree of accuracy of their overall information with 100% correctness being awarded a 100% score. A 0% score would be awarded if the information were incorrect to the extent that had an adverse effect on the decision-making process.

8.3.5.5.2 “Information/data consistency must be controlled”

The second metric investigated “Information consistency must be controlled”.
It was regarded as important that organisations should provide mechanisms to limit, and even exclude, the possibility of incorrect data entering their systems. As mentioned in section 8.3.2 above, incorrect data may lead to delays in the time with which information is able to flow and this, in turn influences information flow efficiency. The actual inconsistency was compared to 100% consistent data, which was awarded a 100% score. The 0% score was obtained if the respondent agreed that the information was largely inconsistent.

8.3.5.5.3 “Number of corrections required to amend information/data must be zero”

The third metric enquired about “Number of correction required to amend information/data must be zero”. As indicated in the section above, corrections mean that the wrong data is present, and that this data needs to be changed to reflect true values. Time delays in the flow of information are a direct consequence of this process of correction. In addition, decisions made previously may have to be reversed, and this requires additional flow of information that would not,initially, have been required.

"No corrections" required to the system's data would be awarded a 100% while continuous changes required would be awarded a 0% score.

8.3.5.5.4 "Erroneous information/data must be dealt with immediately"

The fourth metric dealt with the procedure of "Erroneous information/data must be dealt with immediately". In particular, issues such as the way in which erroneous data was handled and how quickly the underlying problems were resolved were covered.

Of importance was also the time required to ensure that the same erroneous data did not occur again. If there waseither no erroneous data, or if the system was able to detect erroneous data immediately, then a score of 100% score would be awarded. However, a 0% score would be awarded if erroneous information existed and/or the likelihood of this erroneous data being detected was negligible.

8.3.5.5.5 "Accuracy levels for information/data must be specified"

The fifth metric tested whether the organisation specified accuracy levels."Accuracy levels for information must be specified".The assessment of this question took into account the availability of procedures that prescribed the degree of accuracy applicable to different types of information. The inherent prescription of data accuracy by electronic systems was interpreted as implying that such procedures did, indeed, exist even if this were notspecifically detailed in the procedures. However, where the system allowed for adjustment of the accuracy of data, then the procedures would have to explainthe way in which the system needed to be adjusted in order to satisfy the requirements of the company. The existence of procedures regulating the accuracy levels of all the data would be awarded a 100% mark while the lack of procedures and system prescribing accuracy levels would result in a 0% score.

8.3.5.6 Security

The sixth indicator involved the security of electronic as well as paper systems. Hashim and Sultan (2009:168,175) describe security as a pillar of the "ISO Consolidated Usability Model" with special attention being accorded to the ability of the system to prevent unauthorised access (Hashim & Sultan, 2009:172). Hashim and Sultan (2009:172) concentrated on a metric based on a system which required that a password be entered. However, the ISO model also refers to access audibility, access controllability, the prevention of data corruption and data encryption. Based on the abovementioned possible metrics the following metrics were deduced for the measurement information flow efficiency.

8.3.5.6.1 "Information/data must be protected from unauthorised access"

The first metric took into account the following: "Data/information must be protected from unauthorised access".The main reason for investigating this issue is the fact that unauthorised access may lead to either the corruption or the deletion of access structures, such as passwords as well as complete data sets. This, in turn, may hamper, or even invalidating, the decision making process of an organisation as, such occurrences may lead to a loss of time in the ability to transmit the correct information in real-time. A 100% mark would be awarded if access were restricted in such a way that only personnel who were meant to access the system were able to do so. On the other hand, a 0% score would be awarded if all persons were able to enter the system freely.

8.3.5.6.2 "Information/data must be protected from unauthorised change"

The second metric investigated "Information/datamust be protected from unauthorised change". In this scenario, unauthorised access may lead to changed data. Similar to the sectionabove, a 100% score would be awarded if personnel specified by the organisationonly were able to change data. Should it be possible to change the data freely, a 0% mark was awarded.

8.3.5.6.3 “Information/data must be backed up regularly”

The third metric is “Data/information must be backed up regularly”.It is possible that the corruption of data resulting from unauthorised access, change and other means may cripple an organisation’s activities. It is, thus, important to make backups of the latest state of the affairs of a company on an ongoing basis. During the interviews with the expert respondents, the IT managers of different organisations were asked to comment on the frequency they believed appropriate for back-ups. All replied that they considered a daily backup to be sufficient. Accordingly, if a company carried out back-up activities on a daily basis, a 100% score was awarded while information/data that was not backed up receive 0%.

8.3.5.7 Usefulness

The seventh indicator retained tested the “Usefulness” of information. In this case, the term “usefulness” refers to the usability of the information representation, whether on paper or on screen. Usability is defined in terms of effectiveness, efficiency and satisfaction (Bevan, 2008: 2) and includesthe error-free completion of tasks, the speedy performance of tasks and the satisfaction derived from executing tasks. In terms of the usability of information representation, these requirements may be translated into the following metrics.

8.3.5.7.1 “The information/data presented must be useful to the user”

The first metric is “The information/data presented must be useful to the user”.This metric relatesspecifically to the usefulness of the sets of information available to the user in either the electronic or paper systems, for example, is the user overwhelmed by additional information which he/she does not require, or is there too little information available to the user to enable him/her to make informed decisions. In both cases the user would not be able either to carry out his/her task or to make the necessary decisions effectively and efficiently, and this may also lead to a state of dissatisfaction. A 100% score was awarded if all the information provided wasboth useful and sufficient for the user while a cluttered and difficult to understand information presentation received a score of 0% score.

8.3.5.7.2 “Information/data must be useful to all users, from a strategic to an operational level”

The second retained metric considered “Information/data must be useful to all users, from a strategic to an operational level”.This metric was concerned specifically with the usefulness of data to the different organisational levels within the organisation. Some systems may be regarded as more efficient on the operational level by their dealing efficiently with transactional data, while other systems may provide key performance indicators for the different functions of anorganisation. Some systems are also able to provide data and information for strategic decision making, without the need to download the data into a spreadsheet system in order to perform further calculations to arrive at business trends and other strategically important information. If a system wasequally strong on all levels it was awarded 100%, while selective usability and the necessity of additional work in order to render the information useful were awarded 0%.

8.3.6 Measurement results

The 22 metrics associated with the seven indicators retained were assessed in the organisations as detailed above and described in section 7.5. The results are presented in table 8.8.
The organisations are shown in the top row and are numbered from 1 to 25. The “underscorenumber” additions to some of the company numbers provide an indication of the number of interviews conducted at the particular company. Thus, where there are no additions, one interview only took place.

The bottom row depicts the averages of figures in each of the columns. As shown in table 8.8, the individual and average results of the information flow efficiency metrics assessed vary both between and within organisations. In particular, the fact that the scores vary within organisations provides evidence of the fact that the experts in eachcompany assessed the metrics in different ways. It is, therefore, possible that the results of single interviews may be skewed to indicate either a better or a worse performance, depending on the opinion of the experts. It, thus, appears sensible to insist on more than one interview per organisation in order to achieve more balanced assessments of each metric. However, it was not possible to interview more than one respondent in all the organisations. In total, 17 organisations had one person available only, fourorganisations had two persons available, threeorganisations had three persons available and one company had four persons available for interview.

Therefore, in the cases in which more than one interview was conducted, the scores obtained for each metric were averaged. The results are presented in table 8.9. Table 8.9 also depicts the individual averages for each indicator, summarised in the “Average”row for each indicator, the combined total averages of all the metrics for each company, displayed in the “Averages 1”row, and the combined averages of all metrics,for each company, excluding the metrics of the indicators “Timeliness” and “Consistency”, presented in the “Averages 2”row.

Table 8.8: Results of the measurements of information flow efficiency

Indicator	Company	1_1	1_2	1_3	2_1	2_2	3_1	3_2	4	5	6_1	6_2	7	8	9	10	11	12_1	12_2	12_3	13_1	13_2	13_3	14	15	16	17	18	19_1	19_2	20	21	22	23	24	25_1	25_2	25_3	25_4
	Metric	**Scores**																																					
Accessibility	Access to information	75	60	40	50	80	100	80	85	60	100	100	85	65	95	65	90	50	80	90	95	95	80	60	85	45	70	90	70	75	75	70	65	80	95	50	70	70	75
	User friendly access screens	100	85	60	80	60	100	60	50	60	80	100	75	50	80	60	50	100	100	100	100	80	80	80	50	40	50	95	60	90	95	65	50	70	95	20	60	80	65
Consistency	Comparability	70	50	40	50	90	70	90	90	90	100	90	97	30	100	75	90	100	90	100	90	95	80	60	90	80	25	90	80	95	80	45	95	50	100	50	75	80	70
	Enterprise-wide communication of changes	50	40	60	50	90	100	50	50	90	100	100	100	80	100	100	80	50	85	95	85	60	90	40	85	75	75	90	85	70	70	100	70	90	80	40	50	50	50
	Clearly defined process of info provision	90	90	100	70	100	100	90	100	50	100	100	100	100	90	94	100	100	95	100	95	95	95	80	90	75	30	80	85	70	80	100	60	90	90	60	40	30	55
Timeliness	Time taken to retrieve data	60	60	70	80	100	100	85	100	75	100	100	90	90	100	70	95	100	95	100	90	100	80	75	90	75	40	90	85	80	85	65	80	80	80	80	80	50	65
	On-time provision of data	50	40	50	100	80	50	78	90	50	48	100	60	50	90	90	70	90	75	90	83.3	80	90	80	75	80	50	85	25	80	60	70	85	60	85	50	40	50	60
	Time difference between receipt and responding	65	60	50	25	75	60	50	80	75	25	100	95	50	25	70	75	85	85	100	85	90	80	80	95	60	70	75	40	75	50	85	70	100	95	50	70	80	50
	Reporting of late or missing data	60	80	50	50	50	60	90	75	50	80	0	85	60	90	70	90	60	85	85	85	85	80	10	50	80	50	80	60	60	75	90	95	70	0	50	70	60	40
Relevance	Meeting needs of data presentation	100	80	75	80	100	80	75	80	100	100	100	100	70	100	80	100	100	100	95	100	95	75	50	85	70	60	100	75	70	80	90	75	90	100	60	60	70	70
	Ability of content to adjust to future needs	85	60	70	100	85	50	25	95	100	100	100	100	50	100	90	70	95	92	90	80	50	80	100	100	90	90	95	35	70	90	90	80	80	100	60	90	90	70
	Consideration of information priorities	90	85	70	85	100	0	100	100	50	100	100	100	80	100	100	90	100	100	100	100	100	90	90	95	50	75	100	65	80	70	85	90	80	100	90	80	80	50
Accuracy	Correctness	50	60	95	100	90	50	85	95	100	99	87	98	95	95	90	85	95	80	95	98	95	90	95	100	75	80	95	95	70	85	80	100	70	90	90	75	80	80
	Control of information consistency	60	60	60	100	100	75	100	75	90	50	0	95	90	100	94	100	100	100	90	90	95	90	75	95	80	40	95	70	75	100	100	95	60	80	10	60	40	70
	No of corrections required	50	60	95	100	90	50	15	95	100	95	87	98	95	95	95	85	95	80	95	98	95	90	95	95	75	80	95	95	70	85	80	95	70	90	10	75	80	80
	Treatment of erroneous data	90	80	60	100	85	70	100	75	80	80	90	97	70	80	85	100	65	95	95	85	95	90	80	95	65	80	90	90	75	80	75	90	70	70	50	95	70	65
	Specified accuracy levels for info	100	90	60	60	55	70	85	100	100	50	100	100	90	95	75	90	85	100	100	100	80	95	80	95	65	65	100	90	90	90	80	60	80	100	30	85	70	40
Security	Protection from unauthorised access	40	40	70	90	90	100	100	95	30	50	75	100	50	50	95	100	100	94	85	100	95	95	65	75	85	25	100	65	70	95	90	95	70	90	70	90	60	50
	Protection from unauthorised change	40	40	70	90	90	100	100	95	30	50	80	100	50	50	100	100	100	94	85	100	95	100	65	70	85	25	100	65	70	95	90	95	70	90	70	90	60	50
	Regular backups	80	100	90	100	100	100	95	100	30	100	100	100	100	30	100	100	100	92	85	95	95	100	90	95	90	90	100	65	70	95	100	95	60	90	70	90	70	60
Usefulness	Usefulness to user	90	80	85	80	100	80	100	90	100	80	100	95	80	100	80	100	100	100	100	100	95	90	80	95	60	60	100	85	65	70	80	80	80	100	80	80	70	70
	Usefulness of data to all users from strategic to operational level	60	80	70	80	60	100	100	95	70	95	100	75	70	100	75	75	50	70	85	80	80	80	100	70	75	45	100	60	70	80	60	70	70	90	80	66.5	60	65
Averages		**70.7**	**67.3**	**67.7**	**78.2**	**85.0**	**75.7**	**79.7**	**86.8**	**71.8**	**81.0**	**86.8**	**93.0**	**71.1**	**84.8**	**84.2**	**88.0**	**87.3**	**90.3**	**93.6**	**92.5**	**88.4**	**87.3**	**74.1**	**85.2**	**71.6**	**58.0**	**93.0**	**70.2**	**74.5**	**81.1**	**81.4**	**81.4**	**74.5**	**86.8**	**55.5**	**72.3**	**65.9**	**61.4**

Table 8.9: Final averaged results of the measurements of information flow efficiency

Measure	**Company**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
	Variable																									
Accessibility	Access to information	58	65	90	85	60	100	85	65	95	65	90	73	90	60	85	45	70	90	73	75	70	65	80	95	66
	User friendly access screens	82	70	80	50	60	90	75	50	80	60	50	100	87	80	50	40	50	95	75	95	65	50	70	95	56
	Average	**70**	**68**	**85**	**68**	**60**	**95**	**80**	**58**	**88**	**63**	**70**	**87**	**88**	**70**	**68**	**43**	**60**	**93**	**74**	**85**	**68**	**58**	**75**	**95**	**61**
Consistency	Comparability	53	70	80	90	90	95	97	30	100	75	90	97	88	60	90	80	25	90	88	80	45	95	50	100	69
	Enterprise-wide communication of changes	50	70	75	50	90	100	100	80	100	100	80	77	78	40	85	75	75	90	78	70	100	70	90	80	48
	Clearly defined process of information provision	93	85	95	100	50	100	100	100	90	94	100	98	95	80	90	75	30	80	78	80	100	60	90	90	46
	Average	**66**	**75**	**83**	**80**	**77**	**98**	**99**	**70**	**97**	**90**	**90**	**91**	**87**	**60**	**88**	**77**	**43**	**87**	**81**	**77**	**82**	**75**	**77**	**90**	**54**
Timeliness	Time taken to retrieve data	63	90	93	100	75	100	90	90	100	70	95	98	90	75	90	75	40	90	83	85	65	80	80	80	69
	On-time provision of data	47	90	64	90	50	74	60	50	90	90	70	85	84	80	75	80	50	85	53	60	70	85	60	85	50
	Time difference between receipt and responding	58	50	55	80	75	63	95	50	25	70	75	90	85	80	95	60	70	75	58	50	85	70	100	95	63
	Reporting of late or missing data	63	50	75	75	50	40	85	60	90	70	90	77	83	10	50	80	50	80	60	75	90	95	70	0	55
	Average	**58**	**70**	**72**	**86**	**63**	**69**	**83**	**63**	**76**	**75**	**83**	**88**	**86**	**61**	**78**	**74**	**53**	**83**	**63**	**68**	**78**	**83**	**78**	**65**	**59**
Relevance	Meeting needs of data presentation	85	90	78	80	100	100	100	70	100	80	100	98	90	50	85	70	60	100	73	80	90	75	90	100	65
	Ability of content to adjust to future needs	72	93	38	95	100	100	100	50	100	90	70	92	70	100	100	90	90	95	53	90	90	80	80	100	78
	Consideration of information priorities	82	93	50	100	50	100	100	80	100	100	90	100	97	90	95	50	75	100	73	70	85	90	80	100	75
	Average	**79**	**92**	**55**	**92**	**83**	**100**	**100**	**67**	**100**	**90**	**87**	**97**	**86**	**80**	**93**	**70**	**75**	**98**	**66**	**80**	**88**	**82**	**83**	**100**	**73**
Accuracy	Correctness	68	95	68	95	100	93	98	95	95	90	85	90	94	95	100	75	80	95	83	85	80	100	70	90	81
	Control of information consistency	60	100	88	75	90	25	95	90	100	94	100	97	92	75	95	80	40	95	73	100	100	95	60	80	45
	No of corrections required	68	95	33	95	100	91	98	95	95	95	85	90	94	95	95	75	80	95	83	85	80	95	70	90	61
	Treatment of erroneous data	77	93	85	75	80	85	97	70	80	85	100	85	90	80	95	65	80	90	83	80	75	90	70	70	70

Measure	Company	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Specified accuracy levels for information	83	58	78	100	100	75	100	90	95	75	90	95	92	80	95	65	65	100	90	90	80	60	80	100	56
	Average	**71**	**88**	**70**	**88**	**94**	**74**	**98**	**88**	**93**	**88**	**92**	**91**	**92**	**85**	**96**	**72**	**69**	**95**	**82**	**88**	**83**	**88**	**70**	**86**	**63**
Security	Protection from unauthorised access	50	90	100	95	30	63	100	50	50	95	100	93	97	65	75	85	25	100	68	95	90	95	70	90	68
	Protection from unauthorised change	50	90	100	95	30	65	100	50	50	100	100	93	98	65	70	85	25	100	68	95	90	95	70	90	68
	Regular backups	90	100	98	100	30	100	100	100	30	100	100	92	97	90	95	90	90	100	68	95	100	95	60	90	73
	Average	**63**	**93**	**99**	**97**	**30**	**76**	**100**	**67**	**43**	**98**	**100**	**93**	**97**	**73**	**80**	**87**	**47**	**100**	**68**	**95**	**93**	**95**	**67**	**90**	**69**
Usefulness	Usefulness to user	85	90	90	90	100	90	95	80	100	80	100	100	95	80	95	60	60	100	75	70	80	80	80	100	75
	Usefulness of data to all users from strategic to operational level	70	70	100	95	70	98	75	70	100	75	75	68	80	100	70	75	45	100	65	80	60	70	70	90	68
	Average	**78**	**80**	**95**	**93**	**85**	**94**	**85**	**75**	**100**	**78**	**88**	**84**	**88**	**90**	**83**	**68**	**53**	**100**	**70**	**75**	**70**	**75**	**75**	**95**	**71**
Averages 1		**69**	**82**	**78**	**87**	**72**	**84**	**93**	**71**	**85**	**84**	**88**	**90**	**89**	**74**	**85**	**72**	**58**	**93**	**72**	**81**	**81**	**81**	**75**	**87**	**64**
Averages 2		**72**	**86**	**78**	**88**	**73**	**85**	**95**	**74**	**85**	**86**	**89**	**91**	**91**	**80**	**87**	**70**	**62**	**97**	**73**	**86**	**82**	**82**	**73**	**92**	**67**

On inspecting the scores depicted in table 8.9, it becomes apparent that the results vary between the organisations for each of the information flow efficiency metrics assessed. The variances are presentedin table 8.10 below

Table 8.10: Variances of metric scores between organisations

Metric	Minimum score	Maximum score
Access to information	45	100
User friendly access screens	40	100
Comparability	25	100
Enterprise-wide communication of changes	40	100
Clearly defined process of information provision	30	100
Time taken to retrieve data	40	100
On-time provision of data	47	90
Time difference between receipt and responding	25	100
Reporting of late or missing data	0	95
Meeting needs of data presentation	50	100
Ability of content to adjust to future needs	38	100
Consideration of information priorities	50	100
Correctness	68	100
Control of information consistency	25	100
Number of corrections required	33	100
Treatment of erroneous data	65	100
Specified accuracy levels for information	56	100
Protection from unauthorised access	25	100
Protection from unauthorised	25	100

change		
Regular backups	30	100
Usefulness to user	60	100
Usefulness of data to all users from strategic to operational level	45	100

The above table depicts a wide variance between the minimum and maximum scores between the organisations for each metric, with the scores ranging between 0 and 100%. In particular, one metric, namely, “Reporting of late or missing data” shows a variance of between 0 and 95%, fivemetrics depict a variance between 25 and 100%, threemetrics between 30 and 100%, sixmetrics between 40 (38%, 40% and 45%) and 100%, threemetrics between 50 and 100%, threemetrics between 60 and 100% and 1 metric between 68 and 100%.

The metric scores, as detailed in table 8.7, tend to depict higher scores, as depicted in figure 8.23 below. Figure 8.23 represents a pareto graph of the metric scores as per table 8.9.

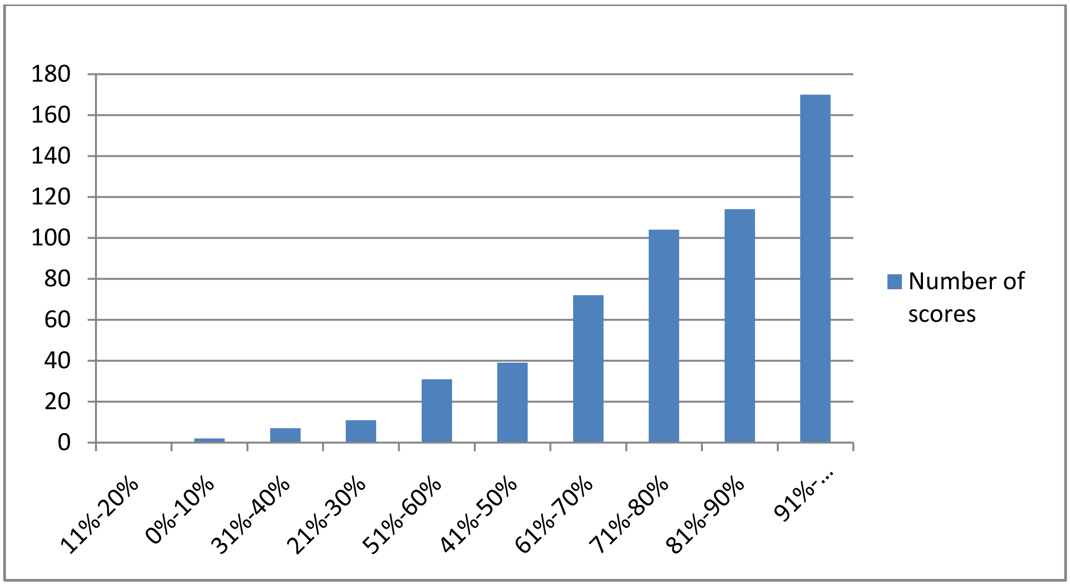

Figure 8.23: Pareto graph of metric scores

Figure 8.23 indicates that 460 scores out of 550 total scores − 83.6% − are rated higher than 50%, pointing to a skewed distribution of scores. This skewed distribution may be a result of information bias, which arises when respondents are particularly concerned with the outcome of the scoring process. In this case, the experts may have been concerned about the performance of their own organisations and they may have thought that they were performing better in certain instances than might really have been the case. The total number of scores of 550 was derived from multiplying the number of organisations (25) by the number of metrics (22).

The fact that low scores were ascribed to some metrics when these metrics were assessed in certain organisations, serves as an indication that the scales for the metrics chosen are able to differentiate between different levels of performance of information flow efficiency.

However, another important factor must also be assessed. The indicators “Timeliness” and “Consistency” and their associated metrics were included in the final list of indicators and metrics on which the measurement of information flow efficiency was based. The indicators “Timeliness” and “Consistency” were ranked at a median of scores of “7” and “6.5” respectively, being at or close to the midpoint of the ranking scale, ranging from “1” to “13”, and, thus, indicating neutral importance. As a result of the neutral importance finding rather than a higher level of importance it is, therefore, important also to explore the effect that the inclusion of these indicators and metrics had on the results of the research. Accordingly, table 8.9 also depicts the averages of the information flow efficiency measured, excluding the assessed metrics belonging to the indicators “Consistency” and “Timeliness”, as they appeared in the last row labelled “Averages 2”.

The figures of the reduced data set again revealed varying performances of information flow efficiency across the different organisations, although indicating a higher average than the previous averages of the full data set which had comprised all the retained indicators and metrics. The most significant difference between the two sets of samples was found in the case of company 14, where the reduced data set average was 6.2 percentage points higher than the average of the full data setIn addition, two exceptions became apparent in the cases oforganisations 16 and 23, where the reduced data set produced averages of 1.6 and 1.2 percentage points lower than the averages of the full data set

This fact emerged from the analysis of the metric scores. A pareto graph, depicted in figure 8.24, for all the metrics, excluding the metrics of the indicators “Timeliness” and “Consistency”, shows that 371 scores out of 382 total scores − 97.1% −were rated higher than 50%, pointing to an even more skewed distribution of scores.

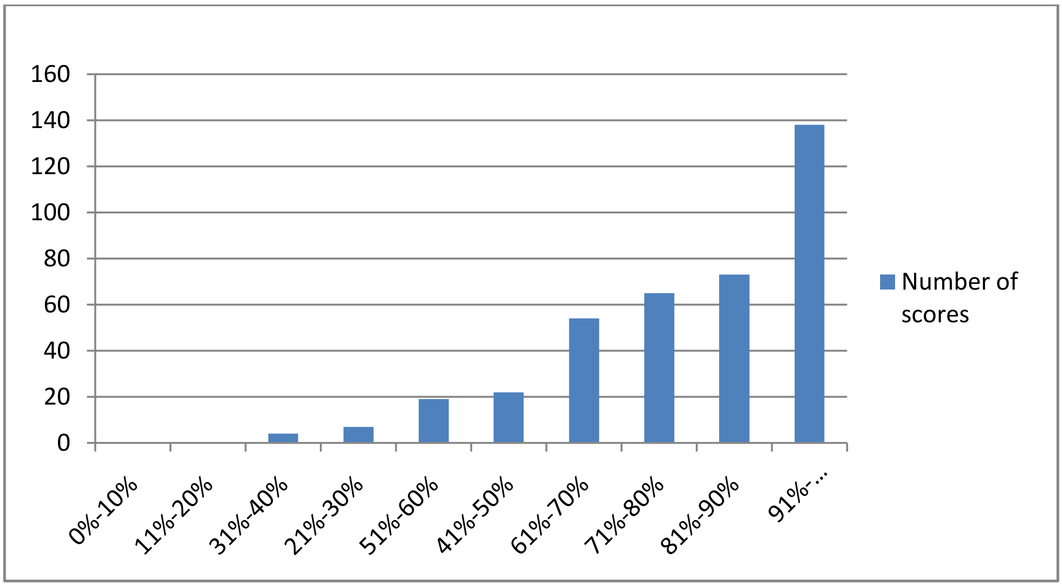

Figure 8.24: Pareto graph of metric scores of reduced data set

It is, therefore, apparent that the metrics of the time and consistency related indicators were, in general, rated lower, thus reducing the number of scores rated higher than 50% from 97.1% to 83.6%. This result indicates that the additional metrics produced significant results and should not be discarded. This fact, however, contradicts the importance ranking of the individual indicators. In particular, the indicators “Timeliness” and “Consistency” were ranked at a median of scores of “7” and “6.5” respectively, being at or close to the midpoint of the ranking scale, ranging from “1” to “13”, thus indicating neutral importance. It must, however, be emphasised yet again that this research study was carried out under certain constraints, with the resultant limitations on the results and their interpretations. The limitations will be reviewed in the following section.

It also became apparent during the interviews with the company experts that the financial information was easily accessible and available in useable formats. In addition, many of the organisationswere using some type of ERP system which made access to order information easy while the information stored was also complete and, in the main, without errors. The areas in which many of the organisationsinterviewed were experiencing problems included real-time production and logistics data.

The above findings point to a desire on the part of the organisations to improve their internal integration, with the main emphasis on finance and materials management. However, it would appear that real-time production monitoring has been overlooked.

8.4 SUMMARY OF THE RESULTS

This research endeavoured to identify indicators and associated metrics with which to assess the efficiency of information flow. In an effort to achieve this goal, a literature study was performed to identify the way in which information flow and its efficiency,theoretically, influence the performance of a supply chain. A further literature study undertaken aimed at ascertaining the state of possible measurements of information flow efficiency. The information collected proved that the existing measuring methodologies were either highly specialised or not suitable for the aim of this research.

Accordingly, a survey instrument was designed (see Appendix 1) to establish the importance of the characteristics related to information quality and business process performance measurement. These characteristics were then converted into indicators and metrics of information flow efficiency.

The characteristics that relate to information quality and business process performance measurement were used as indicators and metrics of information flow efficiency for the following reasons:

- Firstly, the literature provided no all-encompassing instrument of measuring information flow efficiency.

- Secondly, it was possible to identify the abovementioned characteristics as drivers of information flow efficiency, as discussed in section 1.2.6.3.

The assessed importance of the above characteristics was statistically evaluated by applying a cluster analysis. Cluster analysis seeks to identify homogenous subgroups of the variables in a population. The use of this technique, together with other explorative analysis techniques in this research study, made it possible to segregate the important characteristics from the less important ones in order to limit the amount of data to be handled and to focus on what isimportant according to the respondents. After eliminating the least important characteristics, the remaining characteristics were used as indicators of information flow efficiency. A number of associated metrics were established for each indicator, based on their median importance ratings.

Furthermore, this survey also established the level of information integration in the organisations and supply chains of a specific telecommunications cable manufacturing organisation in South Africa. This aspect was included in this research as the level of information integration impacts on the efficiency of the information flow; the lower the degree of the information integration, the lower the efficiency of the information flow.

However, the level of information integration was not considered as an indicator of information flow efficiency because the integration of information is an extremely complex phenomenon which, in itself, depends on a large number of variables or metrics and this would require a study on its own.

The survey results showed that 84.4% of all the respondent organisations made use of EDI and Internet with 62% of all the respondent organisations making use of ERP systems, APS or MES or combinations thereof. The latter technologies are used mainly to integrate the businesses internally, as was evident from the modules in use, whilst EDI and the Internet may be used to integrate businesses externally, with other divisions of the businesses themselves, and their customers and/or suppliers.

However, considering the way in which the technologies are used in real terms, the survey results showed that, in total, 80.3% of the respondent organisationswere using telephone, fax and e-mails to transmit and receive orders while 11.2% of respondent only were integrated with their suppliers or customers. This means that orders received by each of the organisationswere not integrated and had to be printed and/or re-entered into the respective computer systems in use. In terms of the use of EDI and Internet it appears that the only real external integration currently achieved involved the transmission of funds between organisations.

As regards the internal integration, although 62% of the respondent organisationswere employing ERP, MES and APS systems or combinations thereof, 19% only of the respondents had realised their expectations to a level of 81 to 100% with all the other organisationsindicatingvarying degrees of dissatisfaction with the implementation of these systems.

In view of the findings mentioned above, as well as the hindrance to the information flow within systems and between systems and humans, it must be concluded that information does not flow efficiently within organisations and/or supply chains.

Despite the fact that this research was aimed at a statistical sample of an entire industry, there was a significant level of non-response and, thus, it was possible to take a small convenience sample of the abovementioned supply chains only.

The intention of the survey was to rank the indicators of information flow efficiency and the associated metrics in terms of their perceived importance on the part of company leaders of the supply chains of a specific telecommunications cable manufacturer in South Africa. The suppliers and intermediaries of this telecommunications cable manufacturer comprised South African and international organisations.

The results of the above process resulted in seven indicators and 22 associated metrics being retained. The indicators retained included“Accessibility”, “Consistency”, “Timeliness”, “Relevance”, “Accuracy” and “Usefulness”.

Scales for the assessment of the metrics associated with the indicators were then developed. The scales for the assessment of the non-time related metrics, including those associated with “Consistency”, “Relevance”, “Accuracy” and “Usefulness”, were based on the measurement of the usability of software and human-computer interfaces, whilst the scales for the time related metrics had to be developed from the experiences of the researcher, as the literature had not provided any useable criteria.

In this case study, the metrics associated with each indicator were used to assess the information flow efficiency in 25 organisations of the abovementioned supply chains. The expert judgment of managers in the supply chain was used to arrive at scores for each metric.

The results of the assessment revealed varying scores for each metric, although the distribution of the results was skewed to higher scores.This statistic may be explained by the fact that 62% of all the respondent organisationshad implemented ERP, APS and MES systems,while 84.4% used EDI and Internet, in an attempt to integrate the businesses both internally and externally, although the emphasis was on the financial function. Despite the fact that this integration was limited as regardsthe different types of information, such as financial, logistical, production and order information, nevertheless, the organisations that had implemented these systems had achieved a better information flow than the other organisations which had not implemented any of these systems. This fact is particularly important as the financial function, in particular, is under continuous scrutiny, as required by law. The financial departments of all organisations are subject to semi-annual audits and are required to act prudently in the performance of their tasks in terms of other public acts, such as the Sarbannes-Oxley Act, as well as in the views of their stakeholders.

These facts,as well as the finding of this research that financial information, in particular, was easily accessible and available in useful formats, might explain the fact that that some of the metrics scored higher than expected, thus leading to a skewed distribution.

Another reason for the skewed distribution may be found in the use of Likert-type importance and semantic differential scales. These scales do not provide an equal distance between each of the points on the scales, they may provide little discrimination between rating points, and they may fail to measure the true attitude of the respondents if the respondents are concerned with making a good impression or meeting the expectations of the interviewer. Accordingly, the use of these scales may lead to bias in the research results.

The results also indicated that the proposed indicators and metrics are probably capable of identifying differences in the performance of information flow efficiency, as was shown by the score differences of the metrics between the organisations.

However, generalisation is not possible because of the limitations imposed by the poor response to the initial information survey,thus resulting in a much smaller sample size being used. In addition, the limitations of the sampling method used, as outlined above, and the use of expert opinions, which may not coincide for each metric measured in each company, also play a role in the fact that generalisation of the results is not possible .

A further limitation may be found in the scale construction with 0%-100% scales being used in this study for the assessment of time-related, as well as the non-time related, indicators and metrics. It was not possible to establish any other basis for the anchor points of the scales other than the researcher’s own experience,both in this field and in his own company, and this may have led to bias in the results. Moreover this could be the subject of further research.

As a result of the fact that the experts differed either in each case or in each company, it may be assumed that the experts of one company may possibly have voted differently from the experts of another company. The disadvantages of using experts include the fact that experts are subject to similar biases as are ordinary lay people, although they may not be influenced either in the same manner or in the same context. In addition, expert opinions may be superficial and imprecise, because the experts may not be able to express their uncertainty in terms of the subject to be judged and this, in turn, may lead to a non-credible basis in the decision making process.

In view of the abovementioned limitations, further research is clearly required to validate the set of proposed indicators and metrics and the associated scales. Of specific importance is a larger and more representative sample in order to assess the importance of the indicators by means of a statistical factor analysis and, thus, to arrive at meaningful factors for the assessment of information flow efficiency. This is also valid as regards the importance rating of the individual metrics.

Furthermore, it is essential that specific guidelines be developed for the assessment of the metrics identified. This could take the form of specific questions being asked and/or a specific panel of experts assessing the answers received. Provision could also be made for an audit structure in terms of which each metric could be assessed against a set standard or a target in each of the organisations.

In addition, the survey instrument should also be used to validate the scale construct and to arrive at a universal set of scales against which to assess the metrics. This set of scales would also have to be perceived as true.

Lastly, future research should aim at providing recommendations on how to combine the scores of the metrics assessed within each indicator in order to arrive at an overall index value of information flow efficiency.

8.5 LIMITATIONS OF THE RESEARCH

The purpose of this research study was to identify indicators and associated metrics in order to assess information flow efficiency. It was expected that the information flow efficiency would be assessed using the metrics identified for each indicator, and comparing these indicators with the percentage scales developed for this purpose.

When computing the results, both the individual averages for each indicator and an overall average were calculated. However, this process did not take into account either the number of metrics per indicator or the relative importance of each indicator.

In interpreting the results it was found that an assessment of information flow efficiency was possible using the metrics developed. These metrics were associated with the relevant indicators, as discussed in section 8.3.5. However, the results also exhibitedcertain contradictions in terms of the importance ranking of the two specific indicators of “Timeliness” and “Consistency” and their associated metrics. These contradictions manifested when the effect of these two indicators was compared when information flow efficiency was assessed, both with and without these metrics (see section 8.3.5). The rationale for including these indicators and their associated metrics is to be found in the fact that, although the importance ranking indicated that these indicators should have been excluded, time represents an important factor as regards efficient information flow, while consistent information provision represents an important factor that influences the efficient flow of information (Loshin, 2009:3–9; Tyrinopoulos, 2004:101).

It appears that the additional metrics had a significant effect on the information flow efficiency rating and this may be attributed to the fact that the two indicators comprised seven metrics, a third of the original 22 metrics. In addition, the scores of the additional metrics were lower relative to some of the other metrics.

It is also not possible to generalise the results because of the limitations imposed by the poor response to the initial information survey, thus resulting in the use of a much smaller sample size than had originally been anticipated.

Furthermore, the sampling method, which constituted a convenience sample with a purposive intent, limits the applicability of the results to the specific supply chain investigated as well as introducing bias into the indicator rankings and metric scores in each of phases of the case study.

Another limitation comprised the use of expert opinion in the form of different experts in each case or company. It is possible that the experts from one company may possibly have voted differently from the experts of another company, if presented with the relevant of the second company.

A further limitation may be found in the scale construction. Despite the fact that a scientific foundation was found for the use of 0 to100% scales for some of the time-related, as well as the non-time related indicators and metrics − which dealt mainly with the usability of the human-computer interfaces and software and its outputs −it was not possible to establish any basis other than the researcher’s own experience both in this field and in his own company as regards the anchor points of the scales which were used to assess the time-related and the non-time-related metrics. This fact may have led to bias in the metric scores, which may have tended towards better results than should have been expected. In addition, the scales which were used to evaluate the importance of the indicators proposed and the associated metrics were ordinal scales, either of the Likert response format or a forced ranking nature. It is clear that these scales do not provide an equal distance between each of the points on the scales.

8.6 CONCLUSIONS

Throughout this thesis the emphasis was on the concepts of supply chains and their management, the theory of information, the basic notions of information systems and models of business performance measurement. The application and combination of these theories made it possible to develop indicators and associated metrics for the determination of the information flow efficiency in supply chains − see figure below.

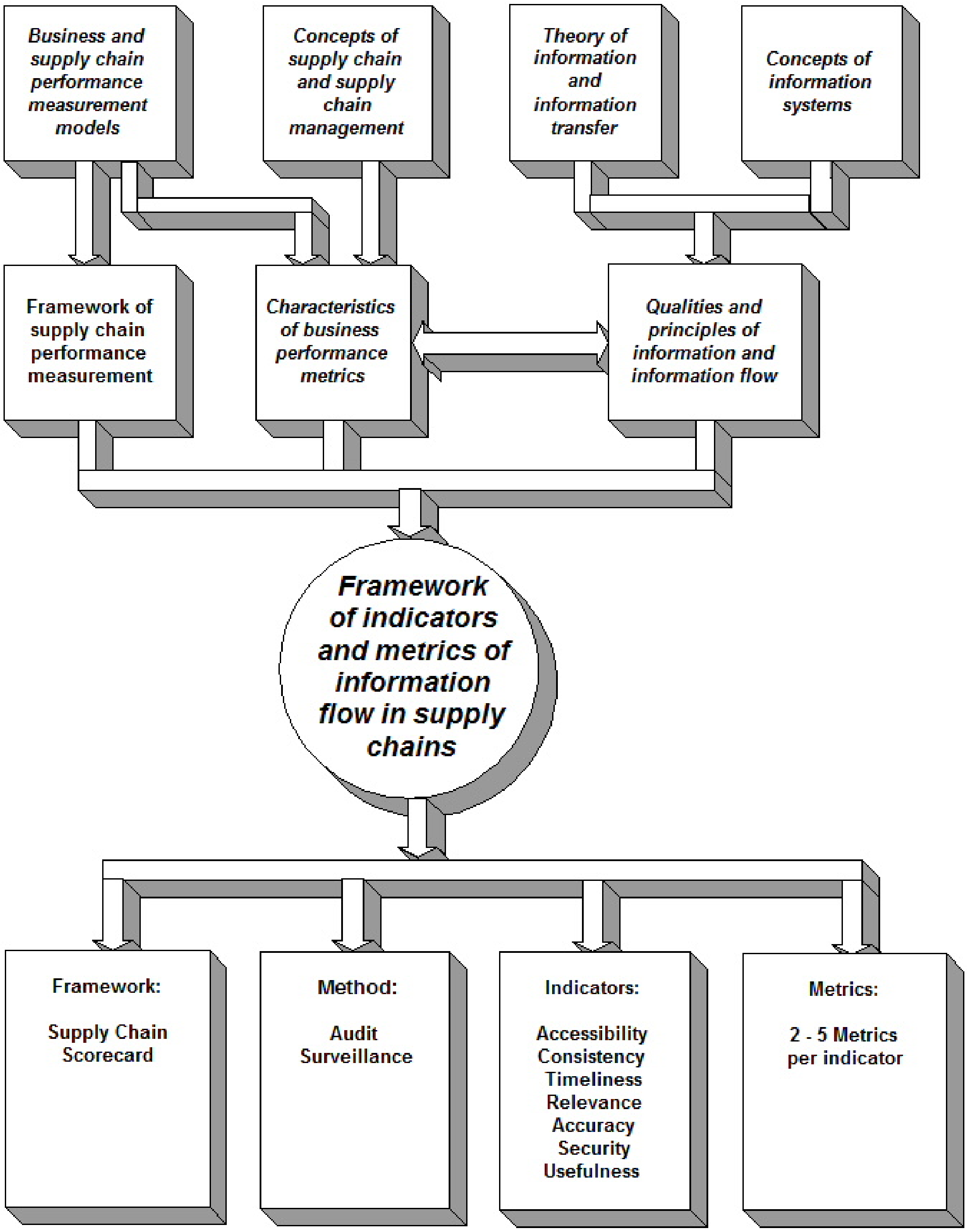

Figure 8.25: The development of indicators and metrics for the assessment of information flow efficiency

However, as a result of the inherent limitations of this research study, the results of this study are applicable to the unit of study only, namely, the specific telecommunications cable manufacturing supply chain as discussed. Accordingly, this thesis does not claim the overall applicability of the indicator and metrics framework presented, but acknowledges inherent limitations. Nevertheless, the study has laid an important foundation in terms of the ability to assess information flow efficiency. The latter is necessary in order to gain a better understanding of the performance of supply chains at a time in which real-time information flow and electronic integration are becoming strategic business success factors.

The indicator and the associated metrics framework presented do, therefore, make a significant contribution to enhancing the understanding of the management of supply chains as regards the role that performance plays in the information flow efficiency of both organisations and supply chains.

8.7 RECOMMENDATIONS AND FURTHER RESEARCH

This research study identified indicators and metrics for the purpose of evaluating information flow efficiency in supply chains. However, as pointed out above, the research is subject to limitations. It would, thus, be of value to eliminate these limitations. In particular, the following issues should be considered for further research:

- The extension of the survey to a much broader and more representative respondent base, as well as the use of descriptive statistics

- The confirmation of the proposed indicators and metrics based on this broader and more representative respondent base

- The establishment of the importance of the indicators per industry sector

- The confirmation of the scale anchor points in the broader supply chain base and/or industry sector

- The formulation of questions to assess each of the metrics without requiring the use of experts

- The creation of a weighting system for both the indicators and metrics

It is further recommended that research be conducted into establishing a generally valid set of indicators and metrics for the implementation of a supply chain scorecard,while taking into account issues listed above. A consideration of the various industry sectors could lead to a weighted system of indicators and metrics, with established weights for each industry.

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APPENDIX 1: SURVEY QUESTIONNAIRE

INFORMATION SYSTEMS USE 2008-06

How to use this form

No data entered in this page

Using an Excel form:

Navigating the form
This form is in several parts or sections that correspond directly to the parts or sections in the paper ## Information Systems Use 2008-06##.

In this spreadsheet each section is in a separate worksheet.

Move around the form using normal window controls - mouse, cursor keys, etc.
Specific keys can also be used:

TAB	Next answer box
Ctrl + PageDown	Next worksheet or use Excel sheet tabs
Ctrl + PageUp	Previous worksheet or use Excel sheet tabs
Shift + F5	Find word in a particular worksheet or part
Tab scroll buttons	Scroll to hidden work sheet tabs
Alt + Enter	New paragraph within text block (such as Comments)

Entering data into the form
All white fields within this form are fields in which data can be entered - they do not accept formulas. All other, grey, fields are locked.

Saving and re-opening the form
To save the form when completed, or when partially completed so you can return to it later, save the files as you would save any ordinary spreadsheet.

Printing the form
The form can be printed worksheet by worksheet or as a whole. For a single worksheet, print as you would any document. To print the entire form, ensure the entire workbook option is selected in the print window.

How to submit this form to the corresponding author
You may send this Excel Worksheet directly to one of the following e-mail addresses, or post a printout to the following address, or fax the form to the following fax number, or use the

e-Mail addresses:	cmaurer@cbi-electric.com luisam@absamail.co.za
Postal address:	C. Maurer 44 Pitts Avenue Sunnyridge 1401
Fax Number:	012 381 1409

End of How to use this form

INFORMATION SYSTEMS USE 2008-06

In correspondence, please quote this number ▼

Purpose of Collection
The prime purpose of the Information Use Survey is to derive a set of information use and information transfer measures, relative to the Republic of South Africa, based on information available and the opinions of business leaders from businesses operating nationally as well as internationally. This data is used in the development of information transfer measures that would assist in describing the company or aggregate supply chain performance. The results will be analysed statistically and used by the corresponding author, as part of a doctoral thesis, in the correlation analysis between supply chain performance and information transfer measures as obtained in both the public and private companies.

Collection Authority
The information asked for is collected on a completely voluntary basis. To assist the researcher in his task, youre kindly requested to complete and return this survey on or before the due date mentioned below

Confidentiality
Your completed form remains confidential to the Researcher and the University of South Africa.

Due Date
Please complete this form and return it to the corresponding author by
31 January 2009.

Help Available
If you have any problems in completing this form, or feel that you may have difficulties meeting the due date, please contact the corresponding author by:

Telephone	**Facsimile**	**Mail**
012 381 1409 083 260 3305	012 250 2247	C. MAURER 44 PITTS AVENUE SUNNYRIDGE 1401

e-mail
cmaurer@cbi-electric.com
luisam@absamail.co.za

Claus Maurer
Doctoral Researcher and corresponding author

Person the researcher should contact if any queries arise regarding this form

Name		Telephone Number	
Date		Facsimile Number	

End of Front page

General instructions

No data entered in this page

Please read this first

- Please try to answer each question. Else leave answer boxes blank where you have no response or data to enter.
- Please do not use 'nil', 'n/a' or '-'
- Information reported on this form should be as accurate as possible.
- If exact figures are not available, please provide careful estimates.
- Please read the instruction boxes and notes provided with each question

End of General instructions

Part 1 - General information

1 Period covered by this information

Note
- The information required on this form should be based on the calendar year ended 30 December 2006.

2 Number of persons working for this business during the last year ending in December 2007

Instruction
- Please indicate applicable option with an "X".

(a) 10 or less ... ... ☐

(b) more than 10 and up to and including 100 ... ... ☐

(c) more than 100 and up to and including 500 ... ... ☐

(d) more than 500 and up to and including 1000 ... ... ☐

(e) more than 1000 ... ... ☐

(f) Of the **employees** reported above, please estimate the number of employees mainly working in the Information and Communication Technology field

Including
- Help desk staff
- Information Technology managers
- Electronics engineers working for IT
- Network engineers/administrators
- Software engineers/administrators

Excluding
- Data entry and call centre staff

Number ☐

Note
- Careful estimates of Information and Communication Technology employees are acceptable.

3 Annual sales for this business during the last year ending in December 2007

Note
- An answer of this question based on a sales figure for the last financial year will also be acceptable.

Instruction
- Please indicate applicable option with an "X".

(a) R5 million or less ... ... ☐

(b) more than R5 million and up to and including R100 million ... ... ☐

(c) more than R100 million and up to and including R1000 million ... ... ☐

(d) more than R1000 million ... ... ☐

End of Part 1 - General Information

Part 2 - Information Systems Use

4 Does this business use the Internet or EDI for conducting its business?

Note
• EDI and Internet include extranets, LAN's and WAN's, excluding conventional e-mail. If your company uses Internet or EDI please answer this question and move to question 6.

Instruction
• Please indicate applicable option with an "X".

(a) Yes ... ... ☐

(b) No ... ... ☐

5 Reasons for not using the Internet or EDI for business purposes

Instruction
• Please indicate all applicable options with an "X". If your company does not use EDI or Internet please answer this question and then move to question 10.

(a) Costs are too high ... ... ☐

(b) Lack of confidence or skills ... ... ☐

(c) Lack of interest or no use for Internet or EDI ... ... ☐

(d) Privacy or security concerns ... ... ☐

(e) Concerns of malware and viruses ... ... ☐

(f) Others, please specify ... ... ☐

6 Frequency of Internet or EDI use for business purposes

Instruction
• Please indicate applicable option with an "X".

(a) Multiple times per day... ... ... ☐

(b) Once per day ... ... ☐

(c) At least once per week ... ... ☐

(d) At least once per month but not every week ... ... ☐

(e) Don't know ... ... ☐

7 For which purposes does this business use the Internet or EDI

Instruction
• Please indicate all applicable options with an "X".

(a) Purchasing or Sales... ... ... ☐

(b) Payment of accounts or receipt of funds... ... ... ☐

(c) Improving information transfer between suppliers and customers ... ... ☐

(d) Integration of ERP or legacy systems between suppliers and customers ... ... ☐

(e) Others, please specify ... ... ☐

Part 2 - Information Systems Use continued

8 What are the main activities for which this business uses the Internet or EDI

Instruction
- Please indicate all applicable options with an "X".

(a) Order placement for purchasing ... ☐
(b) Order placement for sales ... ☐
(c) Payment of accounts or receipt of funds... ☐
(d) Obtaining information on potential suppliers ... ☐
(e) Information exchange between different plants ... ☐
(f) Others, please specify ... ☐

9 If this business sold or bought goods and services over the Internet, what was the total value of the Internet transactions for the last 12 months ending 30 December 2007?

Note
- An answer of this question based on a transaction figure for the last financial year will also be acceptable.

(a) Value of goods and services sold for the last 12 month period ... R ,000
(b) Value of purchased goods and services for the last 12 month period ... R ,000

10 How does your business place and receive orders?

Instruction
- Please break down order receipts into the categories below, as a percentage of total order value.

	Order placement (Purchasing)	Order receipt (Sales)
(a) Via telephone ...	%	%
(b) Via fax or e-mail ...	%	%
(c) Via online ordering facility on your website...	%	%
(d) Through EDI or Internet ...	%	%
(e) Through other websites (i.e. specialised e-market places ...	%	%
(f) Other technology please specify ...	%	%
	%	%
	= 100%	= 100%

11 Where are the suppliers and customers of your business located?

Instruction
- Please provide a percentage breakdown of the number of your suppliers and customers for both categories below.

Note
- Please consider the local branches of international suppliers and customer as within country suppliers or customer, whilst the overseas branches count as outside the country suppliers or customers.

	Suppliers	Customers
(a) Within the country ...	%	%
(b) Outside the country ...	%	%
	= 100%	= 100%

Page 2 of Part 2 - Information systems use

Part 2 - Information Systems Use continued

12 Which benefits, if any, did your business realise through Internet or EDI purchasing and selling?

Instruction

- Please rank the importance of benefits, "1" marking the highest importance and "5" denoting the least importance of the benefit

	Purchasing					Selling				
Importance of attribute	1	2	3	4	5	1	2	3	4	5
(a) Reduced transaction time										
(b) Increased quality of customer service...										
(c) Lower business costs										
(d) Increased sales volume and/or number of customers										
(e) Keeping pace with competitors										
(f) Able to better target customers individually...										
(g) No benefits realised										
(h) Others, please specify										

13 Did your business have a web site by 30 December 2007?

Instruction

- Please indicate applicable option with an "X".

(a) Yes ... ... ☐

(b) No ... ... ☐

14 Did your business' web site have any of the following by 30 December 2007?

Instruction

- Please indicate all applicable options with an "X".

(a) Product catalogue or price list ... ... ☐

(b) Customised web page for repeat clients ... ... ☐

(c) Facility for collecting customer information on line... ... ... ☐

(d) A privacy policy statement... ... ... ☐

(e) A privacy seal or certification ... ... ☐

(f) An on line ordering facility for your business' products ... ... ☐

(g) Facility for on line payment ... ... ☐

(h) Provision of on line after sales support ... ... ☐

(i) On line order tracking ... ... ☐

(j) A security certification ... ... ☐

(k) Others, Internet technology please specify ... ... ☐

15 Please provide a breakdown of the percentage of your Internet or EDI orders placed and received, by location.

Instruction

- Please provide a percentage breakdown of the orders for the categories below, by total Internet or EDI order value

	Orders placed	Orders received
(a) Within the country	%	%
(b) Outside the country	%	%

End of Part 2 - Information systems use

Part 3 - Characteristics of information and information transfer and their importance

16 **In your opinion, how important do you believe is the efficient transfer of information in the success of supply chain management ?**

Instruction
- Please mark the applicable option, "1" marking the highest importance and "5" denoting the least importance of the attribute

Importance of attribute	1	2	3	4	5
(a) Importance of the efficient transfer of information in the supply chain	☐	☐	☐	☐	☐

17 **In your opinion, would the measurement of information transfer efficiency in a company/supply chain add to the transparency of that company's/supply chain's performance?**

Instruction
- Please indicate applicable option with an "X".

(a) Yes ... ... ☐

(b) No ... ... ☐

(c) Not sure ... ... ☐

18 **In your opinion, would business performance measurement benefit from the incorporation of an information transfer efficiency measure into the Balanced Score Card (BSC) as a new perspective with a set of key performance indicators?**

Instruction
- Please indicate applicable option with an "X".

(a) Yes ... ... ☐

(b) No ... ... ☐

(c) Not sure ... ... ☐

Part 3 - Characteristics of information and information transfer and their importance

19 **Which importance would you place on each of the following characteristics of information. Please rank the following characteristics by importance.**

Instruction

- Please rank the most important characteristic with a "1", the second most important with a "2", the third most important characteristic with a "3" and continue until the least important characteristic is marked with a "13"

Importance of characteristic	1	2	3	4	5	6	7	8	9	10	11	12	13
(a) Relevance … … … … … …													
(b) Usefulness … … … … … …													
(c) Repeatability … … … … …													
(d) Believability … … … … …													
(e) Timeliness … … … … … …													
(f) Responsiveness … … … …													
(g) Consistency ……… … … …													
(h) Interpretability… … … … …													
(i) Accessibility … … … … … …													
(j) Accuracy … … … … … … …													
(k) Acceptability (buy-in) … … …													
(l) Security … … … … … … …													
(m) Comprehensiveness … … …													

Part 3 - Characteristics of information and information transfer and their importance

20 Please rate each of the following characteristics with reference to information acessibility, in order of importance.

Instruction
- Please mark the applicable option, "1" marking the highest importance and "5" denoting the least importance of the characteristic.

Importance of characteristic	1	2	3	4	5
(a) Access to information					
(b) User friendly access screens for information retrieval					
(c) Personalised information access					
(d) Choice of own information content by the user					
(e) Relative cost of accessing information/data					

21 Please rate each of the following characteristics with reference to information interpretability, in order of importance.

Instruction
- Please mark the applicable option, "1" marking the highest importance and "5" denoting the least importance of the characteristic.

Importance of characteristic	1	2	3	4	5
(a) Clearly defined variables in the information/data representation					
(b) Understandable classification /division of information/data					
(c) Availability of help function to explain how data/information is derived...					
(d) Consideration of multilinguality					

22 Please rate each of the following characteristics with reference to information consistency, in order of importance.

Instruction
- Please mark the applicable option, "1" marking the highest importance and "5" denoting the least importance of the characteristic.

Importance of characteristic	1	2	3	4	5
(a) Comparability of data/information of same nature obtained from different sources					
(b) Enterprise-wide communication of changes to data/info presentation...					
(c) Clearly defined process of information/data provision/derivation					

23 Please rate each of the following characteristics with reference to information timeliness, in order of importance.

Instruction
- Please mark the applicable option, "1" marking the highest importance and "5" denoting the least importance of the characteristic.

Importance of characteristic	1	2	3	4	5
(a) Time taken to retrieve information/data					
(b) On-time provision of information/data					
(c) Time difference between receipt and reading of e-mail/faxes					
(d) Time difference between receipt and responding to e-mail/faxes					
(e) Reporting of late or missing information/data					

Part 3 - Characteristics of information and information transfer and their importance

24 Please rate each of the following characteristics with reference to information relevance, in order of importance.

Instruction
• Please mark the applicable option, "1" marking the highest importance and "5" denoting the least importance of the characteristic.

Importance of attribute	1	2	3	4	5
(a) Meeting needs of info/data presentation (or too much/little data)					
(b) Ability of info/data presentation and content to adjust to future needs...					
(c) Regular review/feedback programm of information/data needs					
(d) Consideration information/data priorities					

25 Please rate each of the following characteristics with reference to information accuracy, in order of importance.

Instruction
• Please mark the applicable option, "1" marking the highest importance and "5" denoting the least importance of the characteristic.

Importance of attribute	1	2	3	4	5
(a) Correctness of data/information					
(b) Number of corrections required to information/data produced					
(c) Existence of quality standard for information/data collection/presentation					
(d) Control of internal and external data/information consistency					
(e) Treatment of erroneous data					
(f) Specified accuracy levels for data/information					

26 Please rate each of the following characteristics with reference to information security, in order of importance.

Instruction
• Please mark the applicable option, "1" marking the highest importance and "5" denoting the least importance of the characteristic.

Importance of attribute	1	2	3	4	5
(a) Protection of detailed information/data from unauthorized access...					
(b) Protection of detailed information/data from unauthorized change					
(c) Regular back-up of detailed information/data					

27 Please rate each of the following characteristics with reference to information acceptability, in order of importance.

Instruction
• Please mark the applicable option, "1" marking the highest importance and "5" denoting the least importance of the characteristic.

Importance of attribute	1	2	3	4	5
(a) Agreement of all users of data/information with presentation/layout/content					
(b) Easily customisable/personalised data/information layout					
(c) The use of data/information presentation by specific users of data/information					

Part 3 - Characteristics of information and information transfer and their importance

28 Please rate each of the following characteristics with reference to information usefulness, in order of importance.

Instruction
- Please mark the applicable option, "1" marking the highest importance and "5" denoting the least importance of the characteristic.

Importance of attribute	1	2	3	4	5
(a) Usefulness of all data/information contained in presentation to user					
(b) Fading of the use of a specific data\information presentation over time					
(c) Usefulness of info/data produced to all users from strategic to operational level					

29 Please rate each of the following characteristics with reference to information believability, in order of importance.

Instruction
- Please mark the applicable option, "1" marking the highest importance and "5" denoting the least importance of the characteristic.

Importance of attribute	1	2	3	4	5
(a) Correctness of data/information...					
(b) Number of incidencesof wrong data/information in reports/presentation					
(c) Existence of multiple versions of data on PC's, network, paper archives					
(d) Interchanged older data/information with newer versions					

30 Please rate each of the following characteristics with reference to information repeatability, in order of importance.

Instruction
- Please mark the applicable option, "1" marking the highest importance and "5" denoting the least importance of the characteristic.

Importance of attribute	1	2	3	4	5
(a) Repeatability of data/information if reproduced multiple times within days					
(b) Period of validity of data/info compared to time required to produce					
(c) Repeatability of data/information if reproduced from different report tools					

31 Please rate each of the following characteristics with reference to information responsiveness, in order of importance.

Instruction
- Please mark the applicable option, "1" marking the highest importance and "5" denoting the least importance of the characteristic.

Importance of attribute	1	2	3	4	5
(a) Time delay between transaction occurrance and report					
(b) Real time updating of reports/information as soon as data/information changes					
(c) Real time updating of transactional data					

32 Please rate each of the following characteristics with reference to information comprehensiveness, in order of importance.

Instruction
- Please mark the applicable option, "1" marking the highest importance and "5" denoting the least importance of the characteristic.

Importance of attribute	1	2	3	4	5
(a) Information/data produced covering all required aspects/variables					
(b) Reports/information covering requirements at all organisational levels					
(c) Ability to cascade data/info upwards into next level performance indicators... ...					

End of Part 3 - Importance and attributes of information and information transfer

Part 4 - Enterprise Resource Planning (ERP), Advanced Planning and Scheduling (APS) Systems and Manufacturing Execution System (MES) Use

33 Does this business make use of an ERP System and / or an APS?

Instruction
- Please indicate applicable option with an "X".

(a) Yes, ERP system is in use ... ☐
(b) Yes, APS system is in use ... ☐
(c) Yes, MES system is in use ... ☐
(d) No ... ☐

34 If this business uses an ERP APS and/or MES, please indicate the vendor(s)

[ ]

35 If this business uses an ERP, APS and/or MES, please indicate all modules in use

Instruction
- Please indicate all applicable options with an "X".

(a) Financial accounting ... ☐
(b) Cost accounting ... ☐
(c) Fixed asset management ... ☐
(d) Sales and Distribution ... ☐
(e) Project management ... ☐
(f) Material management ... ☐
(g) Warehouse management ... ☐
(h) Production Planning system ... ☐
(i) Quality management systems (incl. Safety and Environment management) ... ☐
(j) Plant maintenance system ... ☐
(k) Office communication ... ☐
(l) Advanced Planning and Scheduling system ... ☐
(m) Available to promise (ATP) module ... ☐
(n) Customer Relationship management (CRM) ... ☐
(o) Supplier Relationship management (SRM) ... ☐
(p) Supply chain execution (SCE) ... ☐
(q) Supply chain planning (SCP) ... ☐
(r) Human resources (HR) ... ☐
(s) Others, please specify ... ☐

[ ]

36 Does this business make use of Barcoding or RFID for recording of transactions?

Instruction
- Please indicate all applicable options with an "X".

(a) Barcoding is used ... ☐
(b) RFID is used ... ☐
(c) None of the above are used ... ☐

Part 4 - Enterprise Resource Planning (ERP) and Advanced Planning, Scheduling (APS) Systems and Manufacturing Execution system (MES) Use

37 Does your ERP system, APS or MES automatically connect with any of the following

Instruction
- Please indicate all applicable options with an "X".

(a) Your supplier's computer/ERP/APS/MES systems ... ... ☐

(b) Your customer's computer/ERP/APS/MES system ... ... ☐

38 ERP, APS and/or MES provide some benefits. Please rank up to 5 benefits that you consider most important, by importance, ranking from 1 - 5.

Instruction
- Please rank the benefits with a number from "1" to "5", "1" marking the most important and "5" denoting the least important benefit

Importance of attribute	1	2	3	4	5
(a) Reconciles and optimizes the conflicting goals of different divisions/departments					
(b) Increaes efficiencies by standardizing business processes...					
(c) Real time information throughout all functional areas of a business					
(d) Data standardisation and accuracy accross organisation					
(e) Analysis of data and reporting can be used for long term planning					
(f) Reduces enterprise expenses					
(g) Reduces paper work					
(h) Early risk resolution, early gap and error detection...					
(i) Increases adaptability to changing work conditions					
(j) Reduces inventories, personnel, total logistics-, manufacturing-, procurement cost					
(k) Increases customer satisfaction					
(l) Improves decision making capabilities					
(m) Increases production capacity					
(n) Provides managers with the right information at the right time to predict trends etc					
(o)Top management can drill down into information without depending on employees					
(p) Others, please specify					

39 To which percentage did your business realize its expectations in terms of business systems improvement through the implementation of ERP, APS and/or MES?

Instruction
- Please indicate applicable option with an "X".

(a) 81% to 100% ... ... ☐
(b) 71% to 80% ... ... ☐
(c) 61% to 70% ... ... ☐
(d) 51% to 60% ... ... ☐
(e) 41% to 50% ... ... ☐
(f) 31% to 40% ... ... ☐
(g) 0% to 30% ... ... ☐
(h) not applicable ... ... ☐

40 To which extent do you believe the information flow to be hinderded between the modules of the ERP/APS/MES and the modules and the associated personnel?

Instruction
- Please rank the extent with a number from "1" to "5", "1" marking the most most hindered and "5" denoting the least hindered extent.

Extent of attribute	1	2	3	4	5
(a) Extent of hinderance of information flow between modules of ERP/APS/MES					
(b) Extent of hinderance of info flow between modules and associated personnel					

End of Part 4 - ERP and APS systems use

Part 5 - Time taken and comments

41 Please provide an estimate of the time taken to complete this form

Including
- The time actually spent reading the instructions, working on the questions and obtaining the information
- The time spent by all employees in collecting and providing this information

Hrs Mins

42 Please provide comments
- on any of the information you have supplied on this form
- on any questions which caused problems
- if you would like to suggest improvements to this form

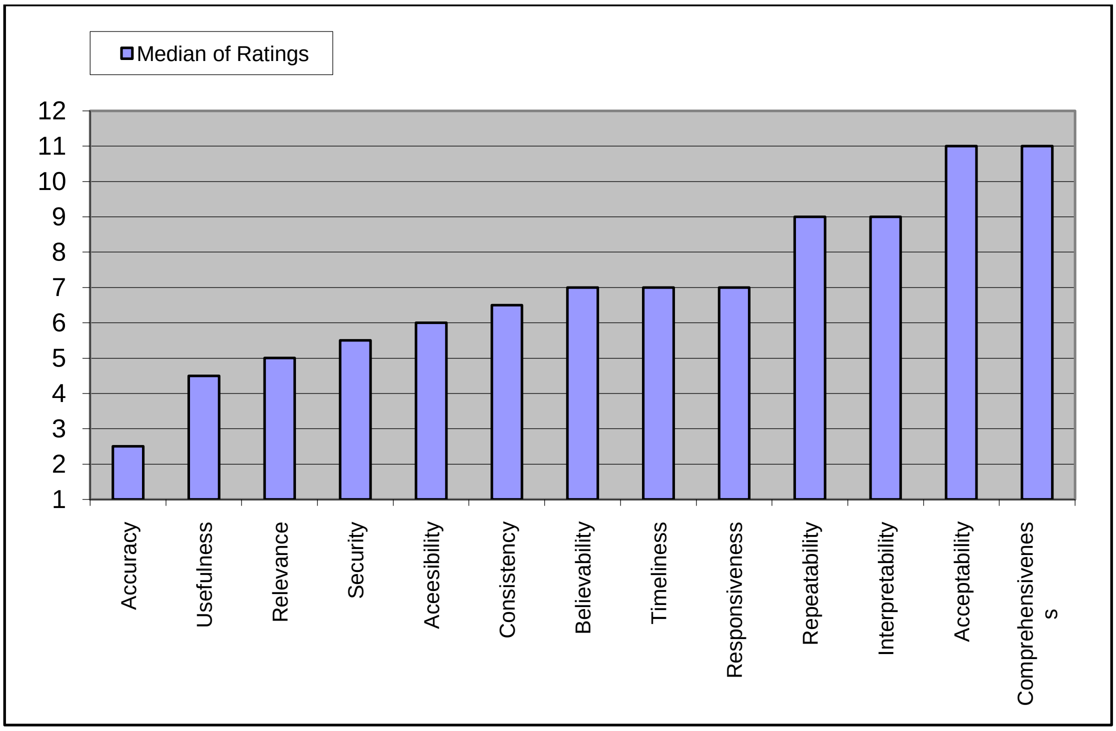
(hold the Alt key and press Enter to start a new line)

End of Part 5 - Time taken and comments

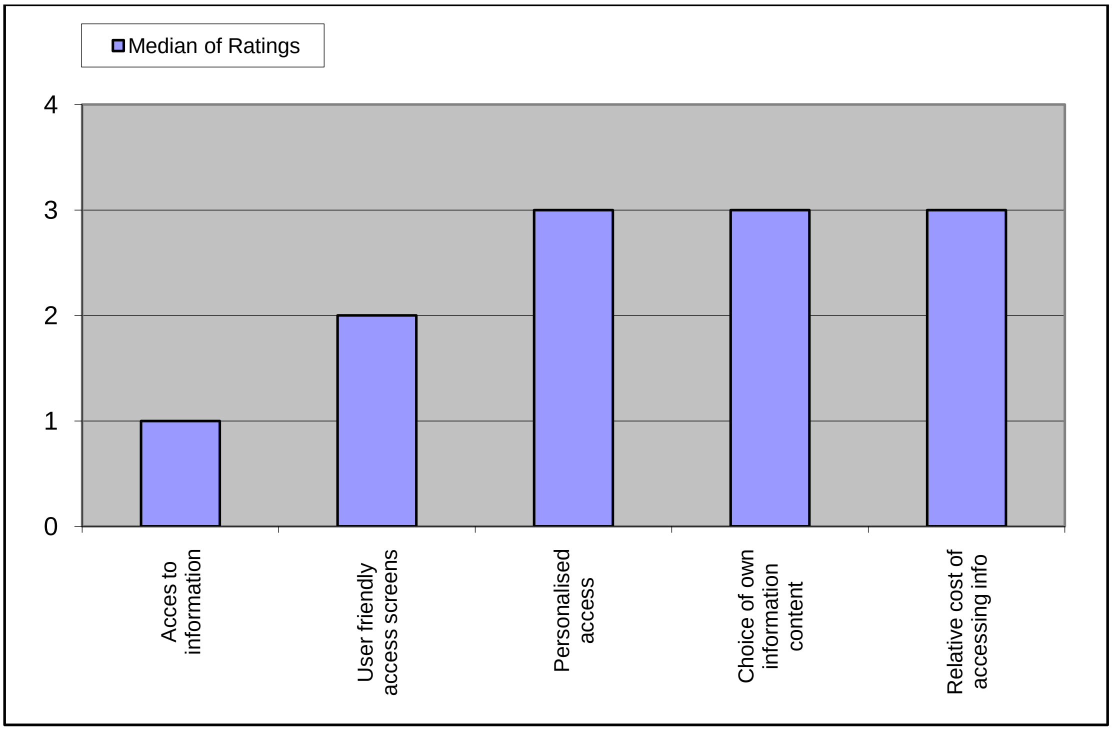
A Thank You Note

The researcher would like to thank you for the time taken to complete this form and for the contribution you have made to the research work

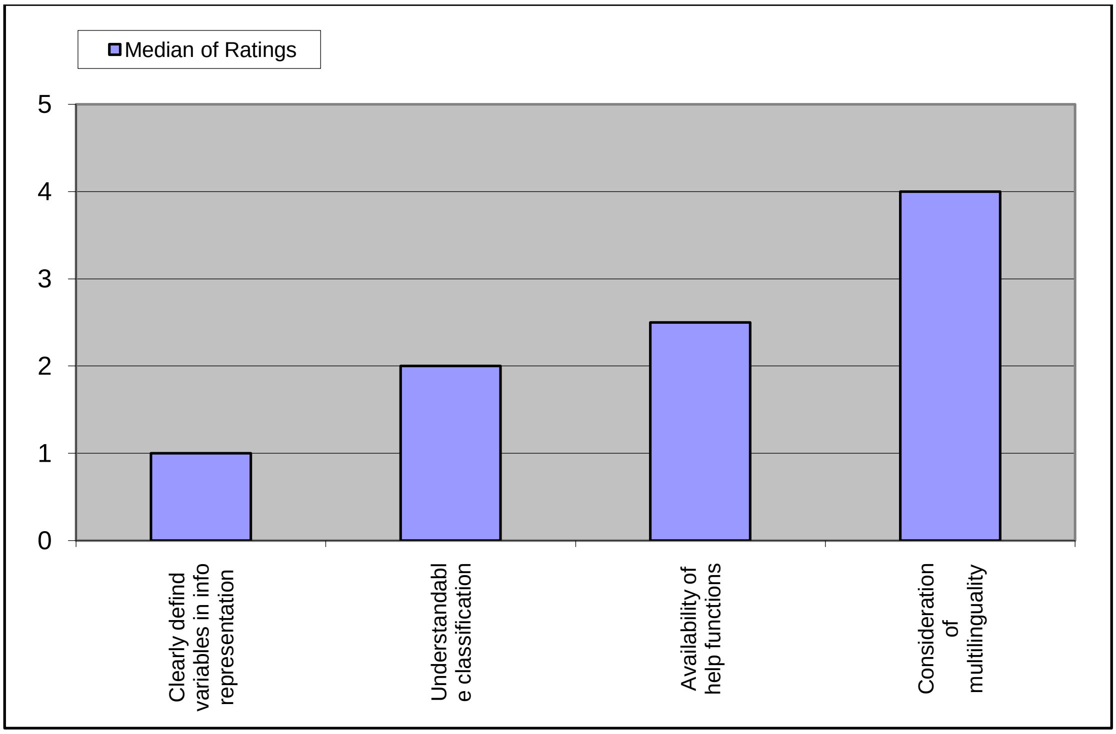
APPENDIX 2: RATINGS OF IMPORTANCE, BOX PLOTS AND CLUSTER TREE



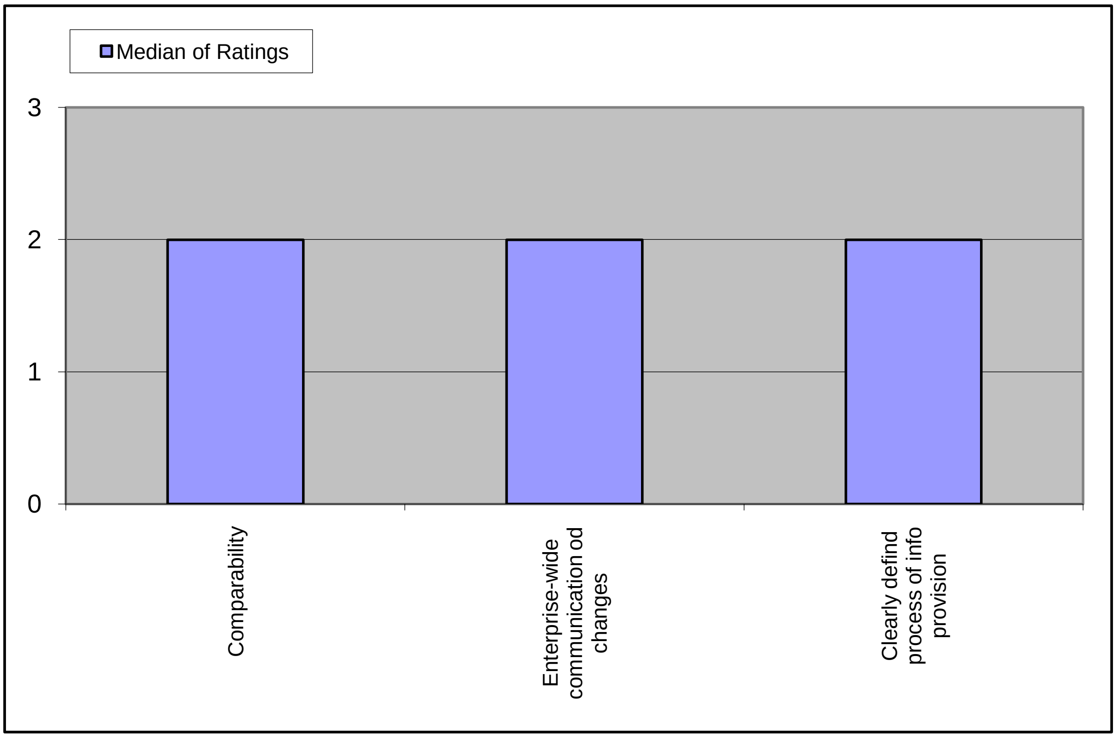
Appendix 2.1: Importance of characteristics of information flow



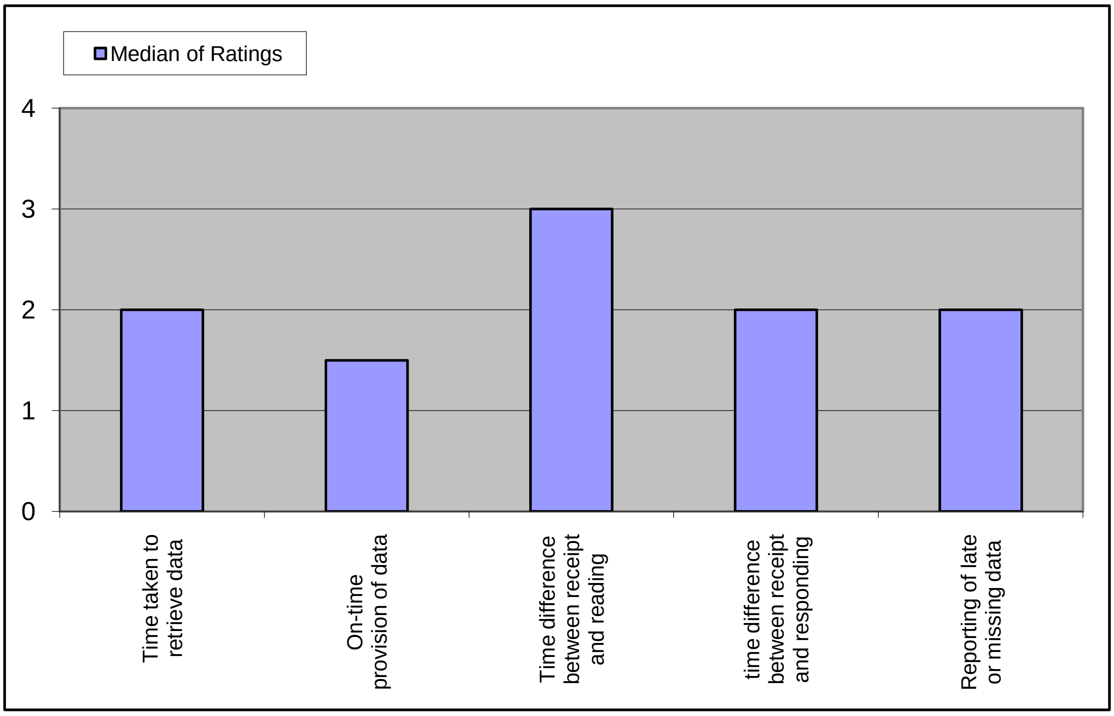
Appendix 2.2: Importance of variables of accessibility



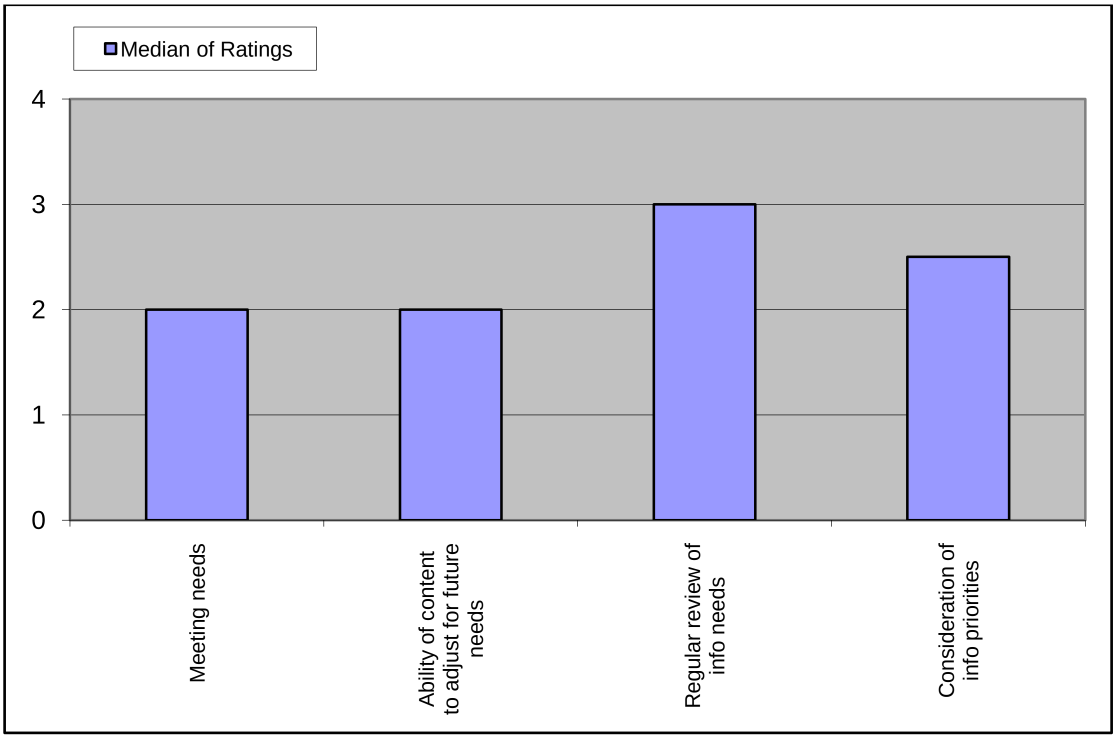
Appendix 2.3: Importance of variables of interpretability



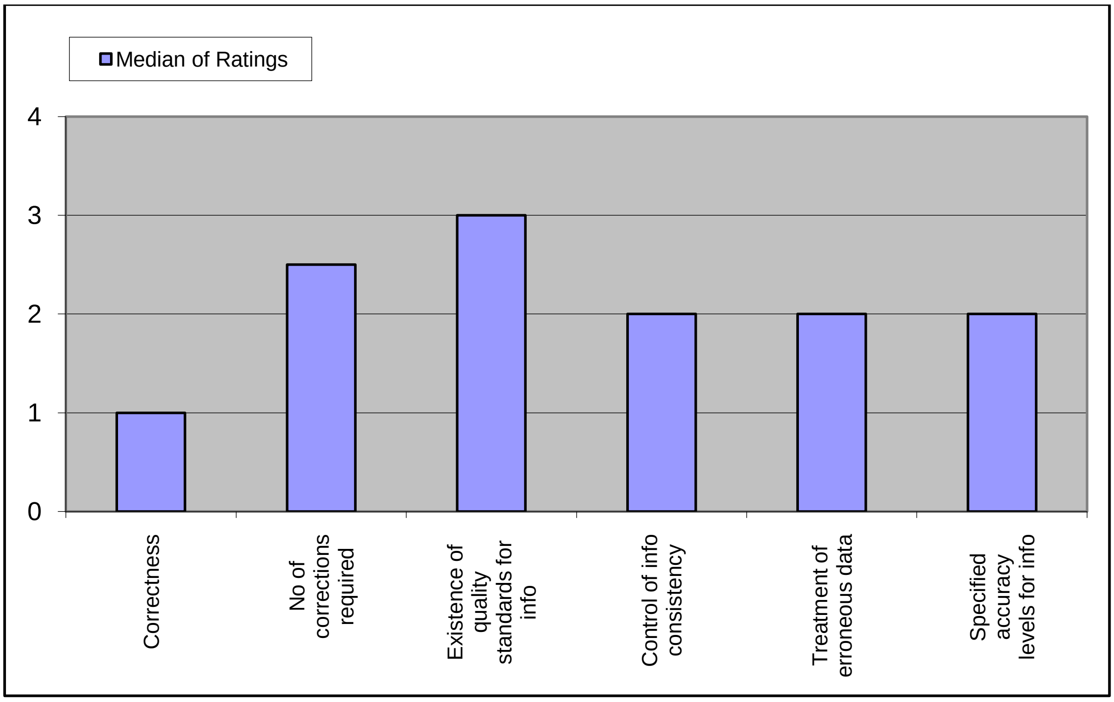
Appendix 2.4: Importance of variables of consistency



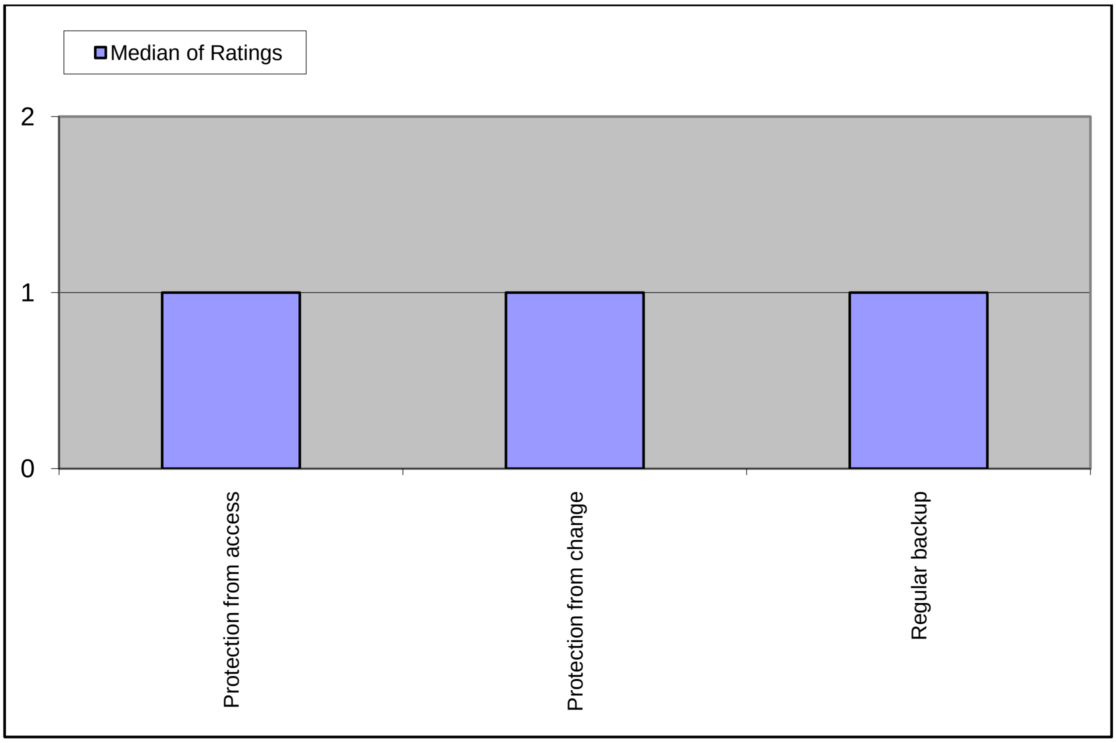
Appendix 2.5: Importance of variables of timeliness



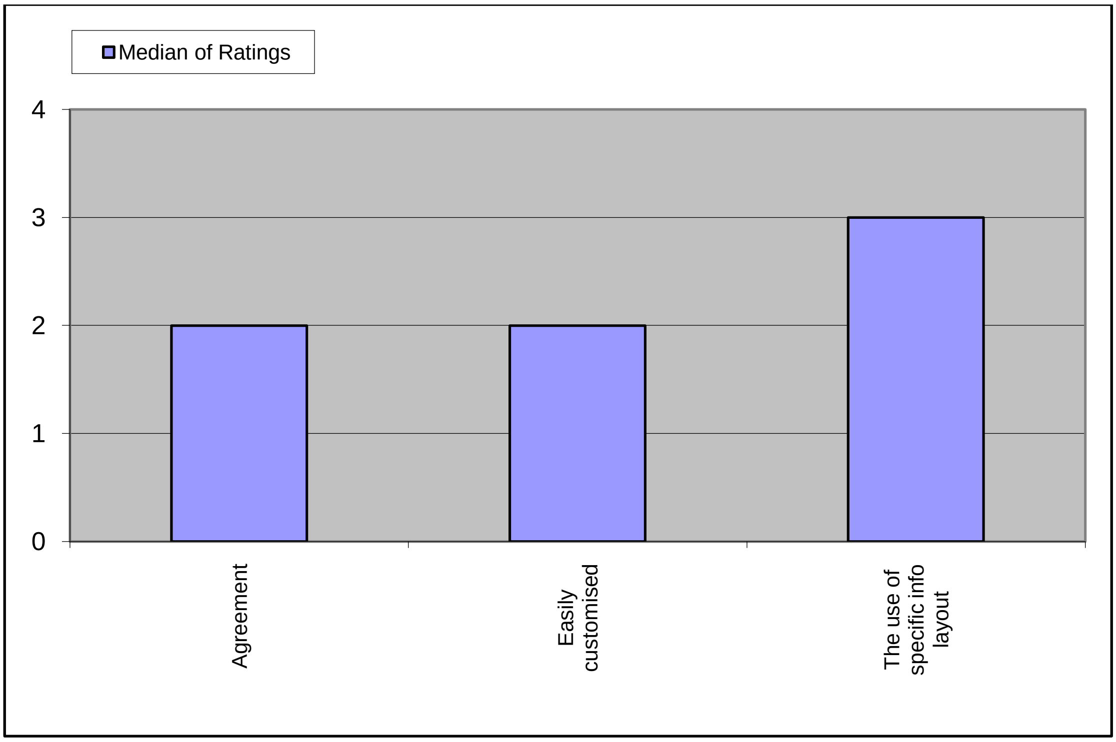
Appendix 2.6: Importance of variables of relevance



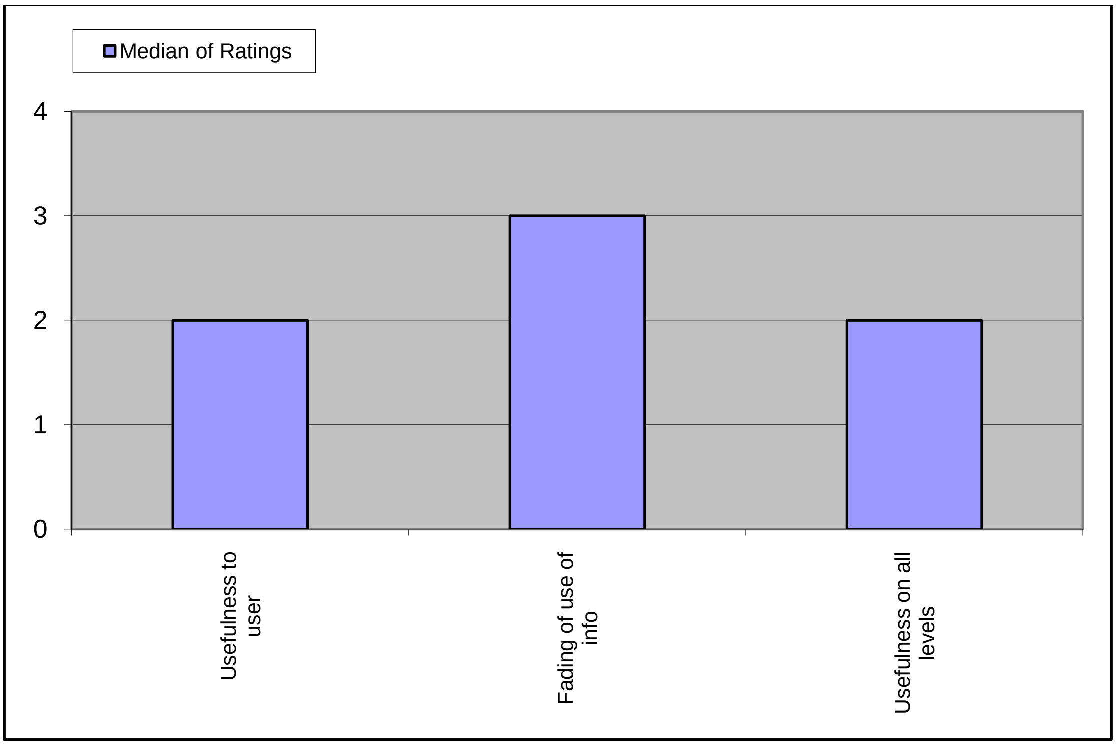
Appendix 2.7: Importance of variables of accuracy



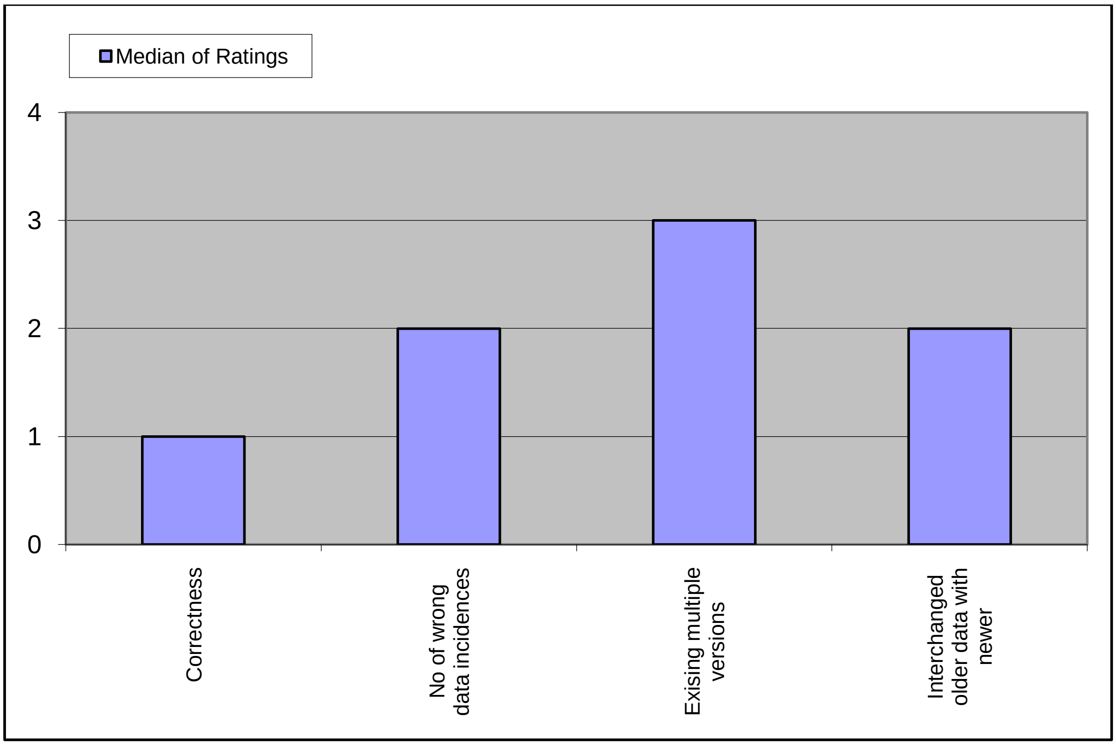
Appendix 2.8: Importance of variables of security



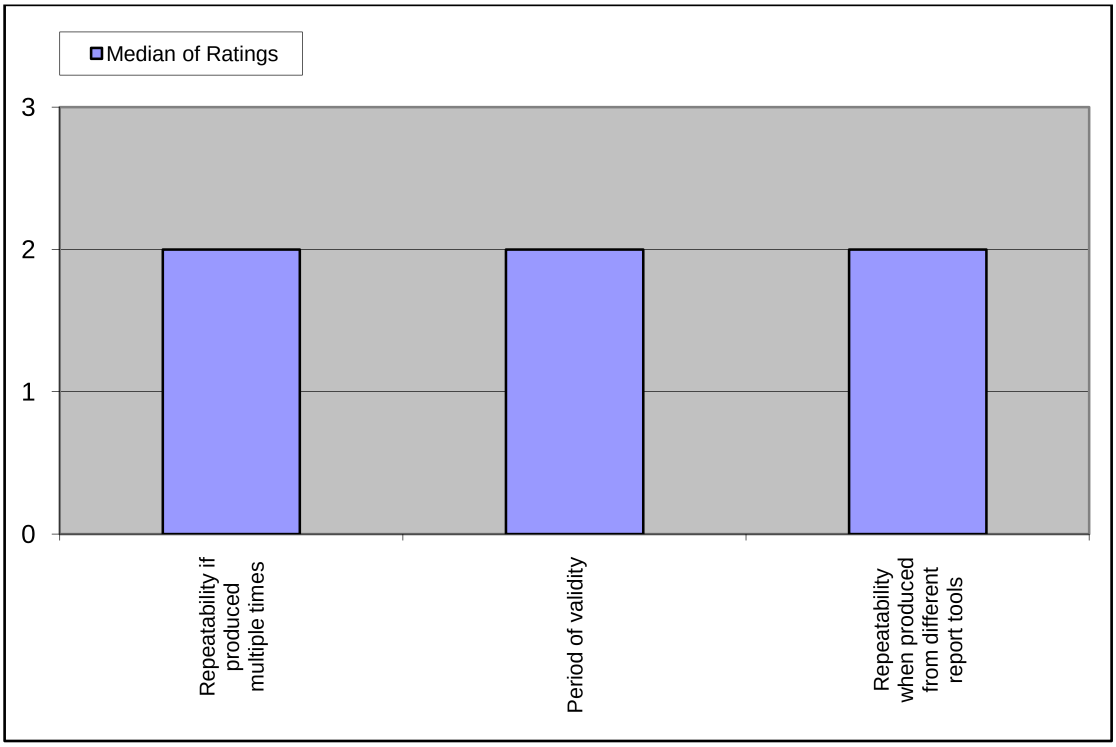
Appendix 2.9: Importance of variables of acceptability



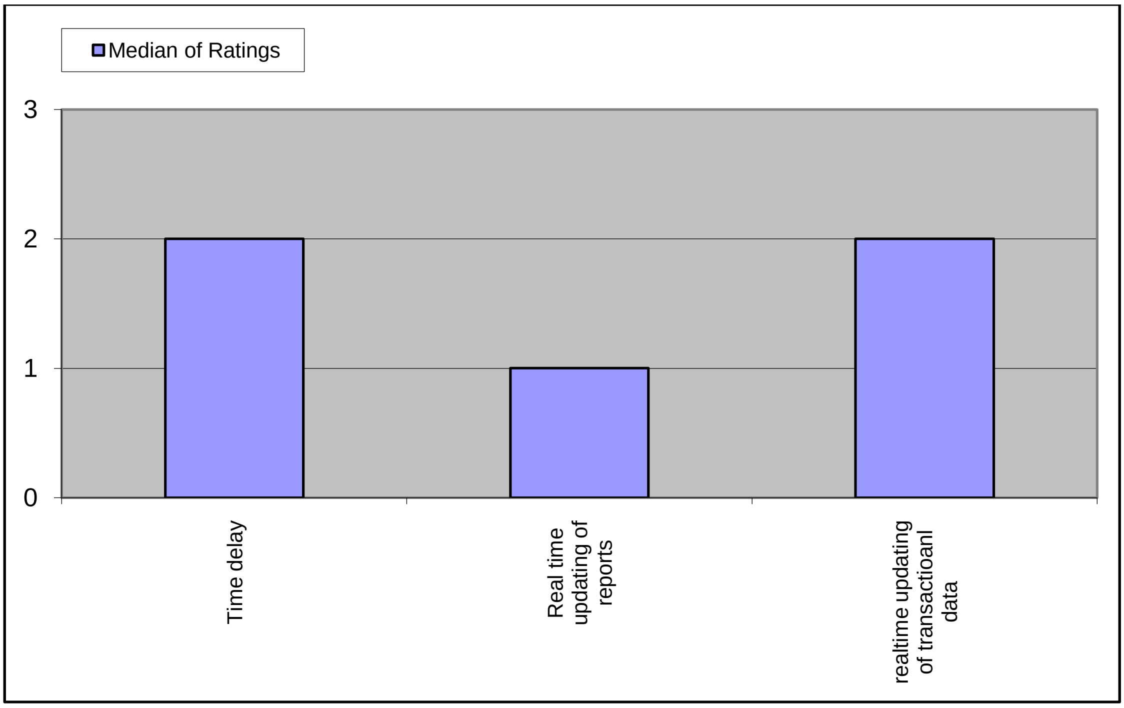
Appendix 2.10: Importance of variables of usefulness



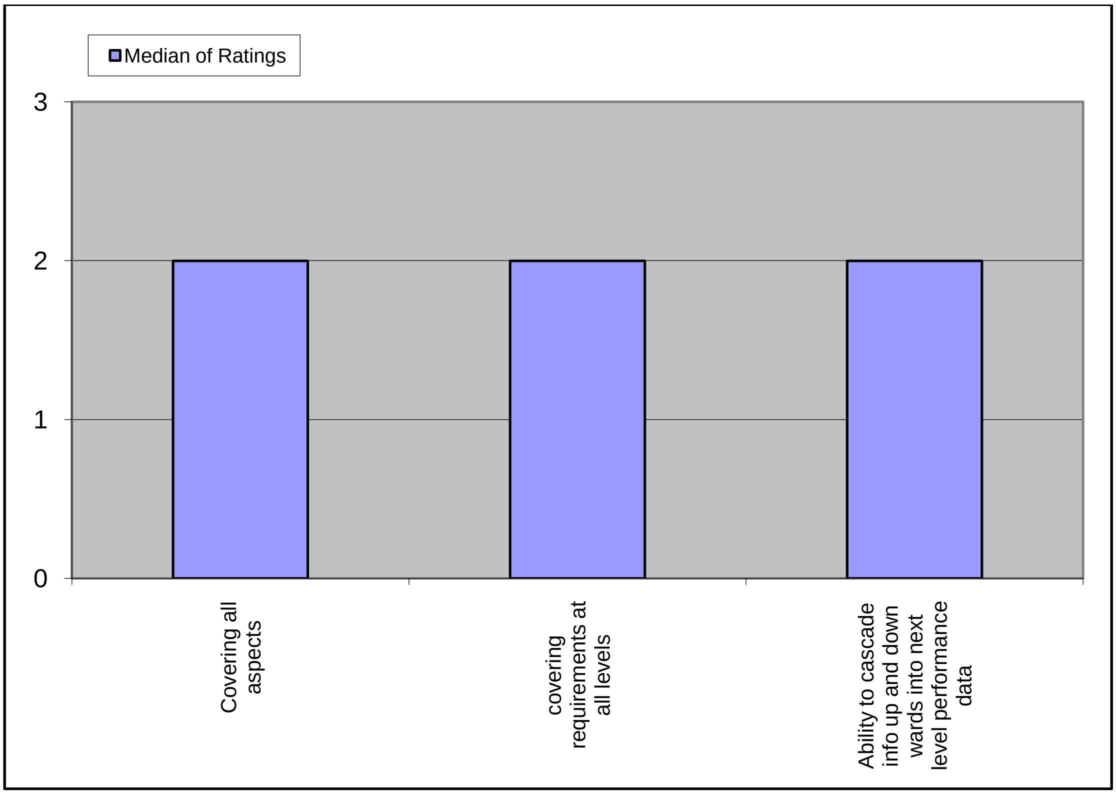
Appendix 2.11: Importance of variables of believability



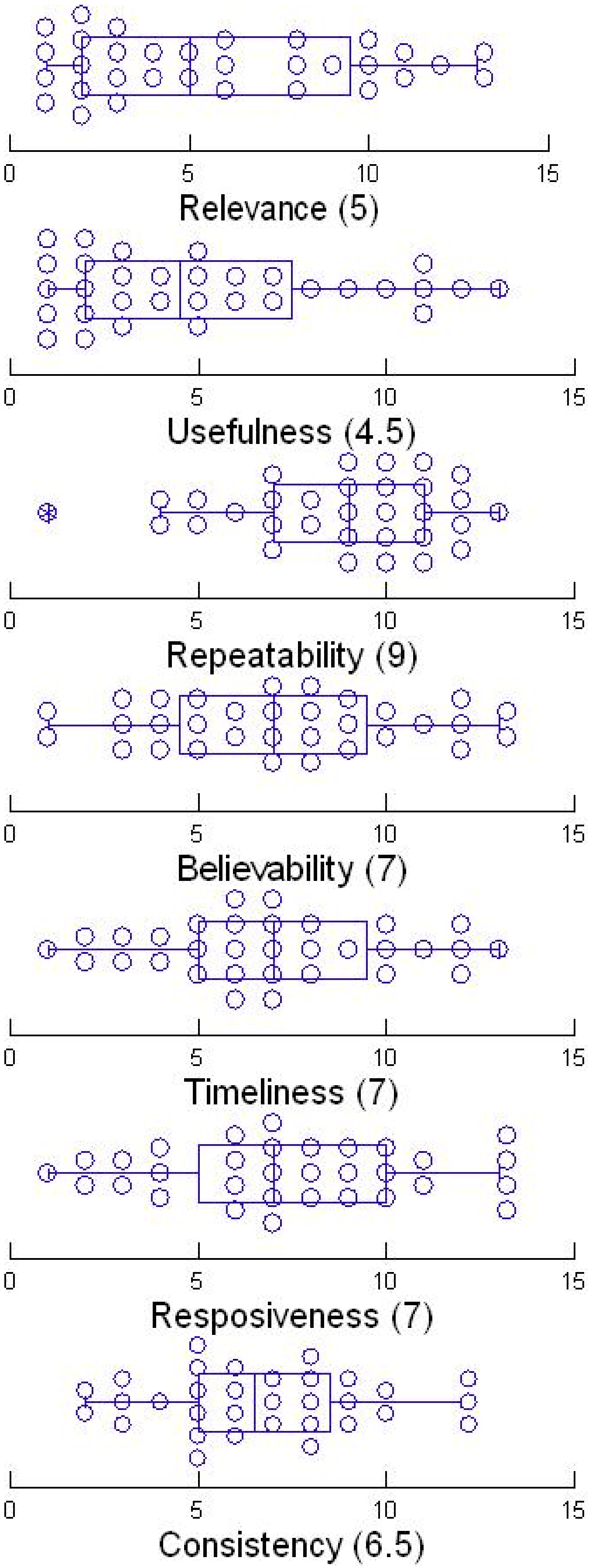
Appendix 2.12: Importance of variables of repeatability

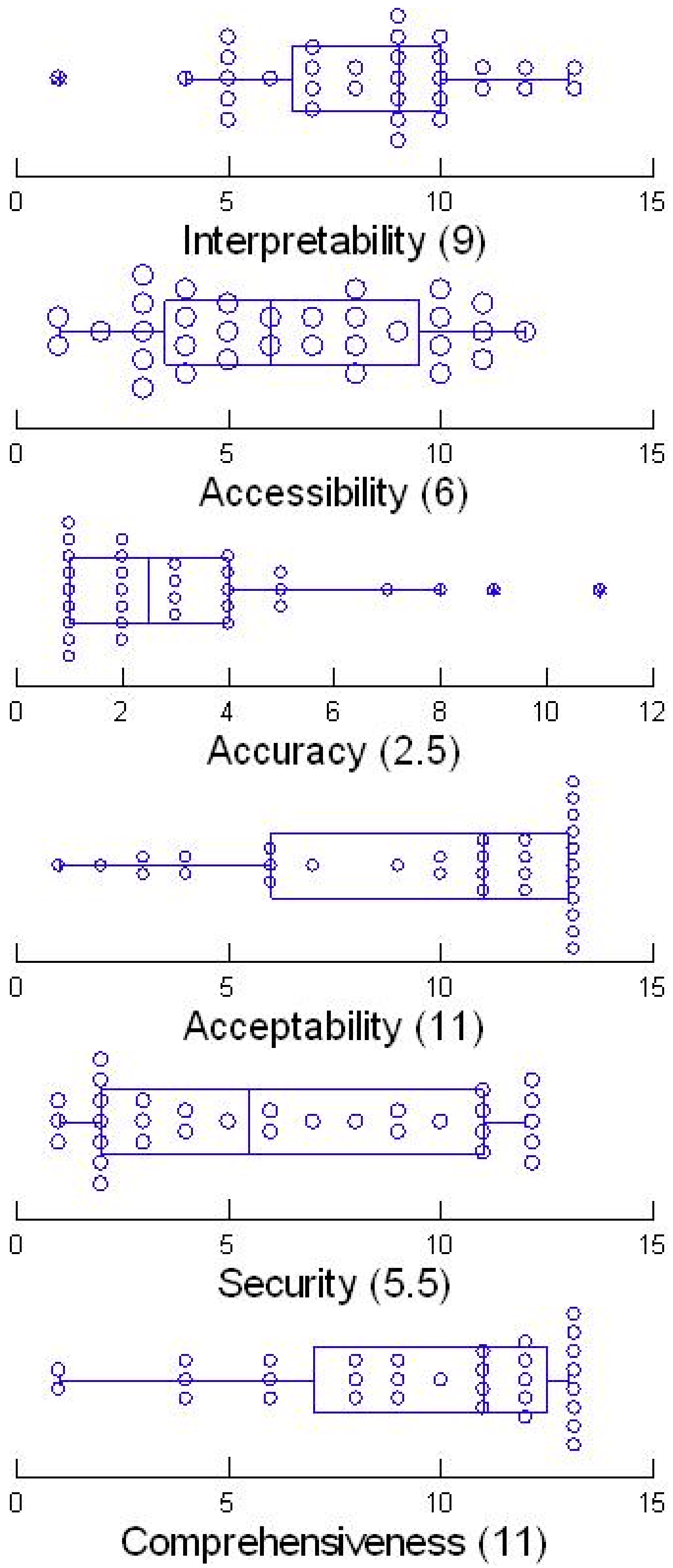


Appendix 2.13: Importance of variables of responsiveness

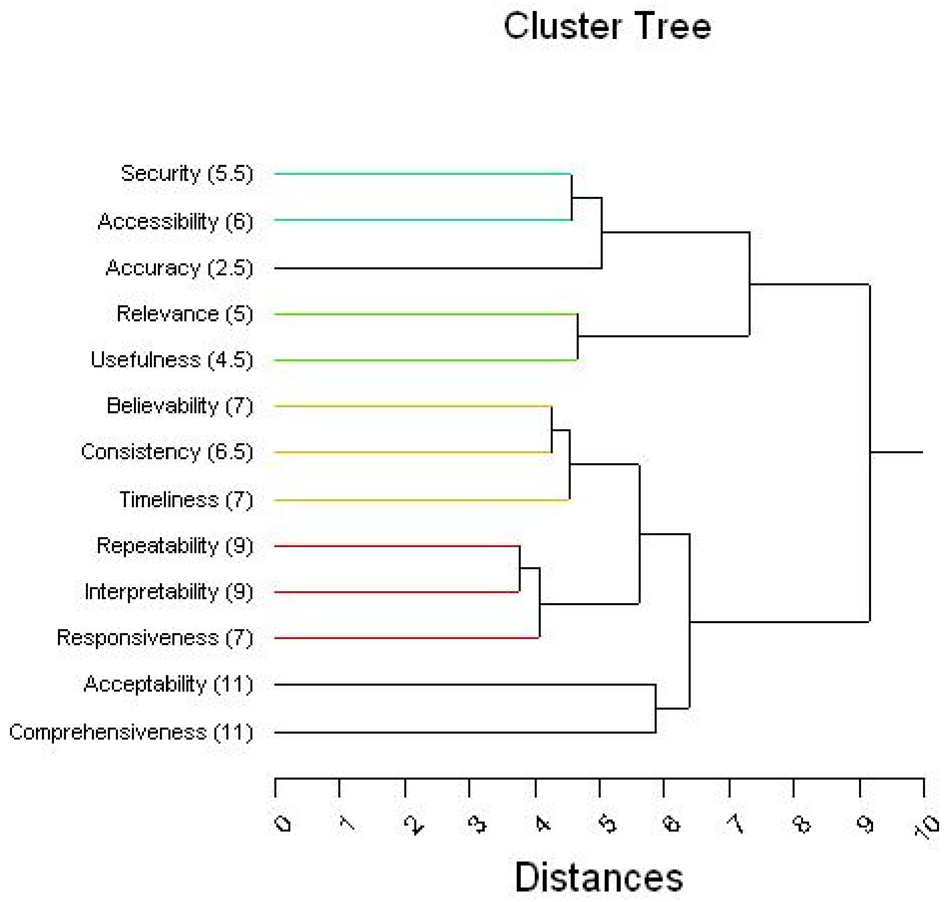


Appendix 2.14: Importance of variables of comprehensiveness

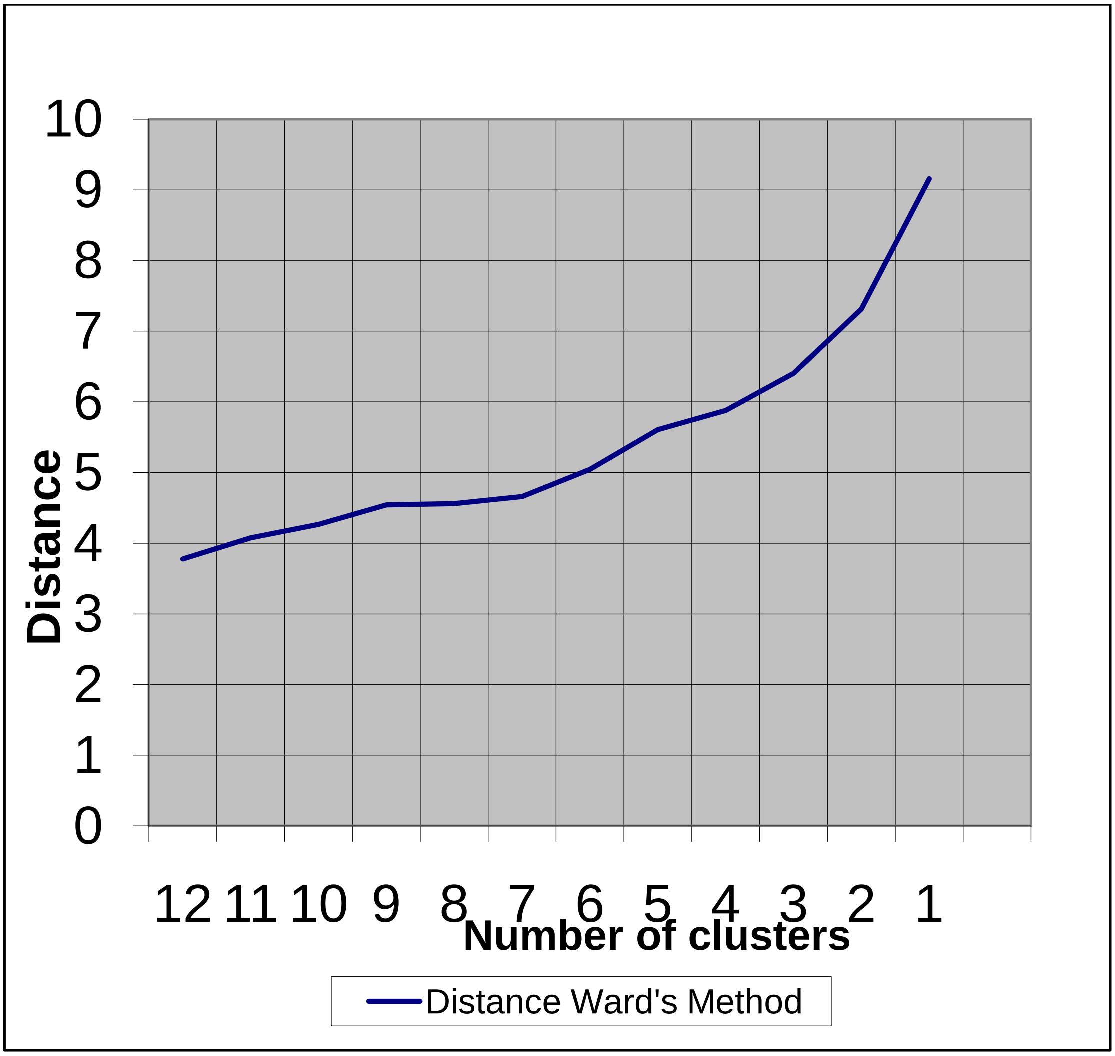

0 5 10 15
Relevance (5)
0 5 10 15
Usefulness (4.5)
0 5 10 15
Repeatability (9)
0 5 10 15
Believability (7)
0 5 10 15
Timeliness (7)
0 5 10 15
Resposiveness (7)
0 5 10 15
Consistency (6.5)



Appendix 2.16: Box plots of the characteristics of information and information transfer



Appendix 2.17: Cluster tree using Ward's method



Appendix 2.18: Scree-plot of the cluster distances of information characteristics

APPENDIX 3: INTERVIEW QUESTION GUIDE

Company:__________________________

Position:___________________________

Name:______________________________

Measure	Variable	Percentage	Unit
Accessibility	Access to information		%
	User friendly access screens		%
Consistency	Comparability		%
	Enterprise wide communication of changes		%
	Clearly defined process of information provision		%
Timeliness	Time taken to retrieve data (real-time)		%
	On-time provision of data		%
	Time difference between receipt and responding		min %
	Reporting of late or missing data		%
Relevance	Meeting needs of data presentation		%
	Ability to adjust for future needs		%
	Consideration of information priorities		%
Accuracy	Correctness		%
	Control of information consistency		%
	No of correction required		%
	Treatment of erroneous data		%
	Specified accuracy levels for information		%
Security	Protection from unauthorised access		%
	Protection from unauthorised change		%
	Regular backups		%
Usefulness	Usefulness to the user		%
	Usefulness of data to all users from strategic to operational level		%