



APPLICATION OF LEAN PRODUCT DEVELOPMENT AT A MANUFACTURING ORGANISATION: A CASE STUDY

A C Dem^{1*}, J H C Pretorius^{2*} and D J Kruger³

¹Faculty of Engineering and the Built Environment
University of Johannesburg, South Africa
andile.dem@gmail.com

²Faculty of Engineering and the Built Environment
University of Johannesburg, South Africa
jhcpretorius@uj.ac.za

³Department of Mechanical and Industrial Engineering
University of South Africa, Florida, Johannesburg
dkruger@unisa.ac.za

ABSTRACT

The principles of lean were understood to be relevant to the operations of manufacturing enterprises meaning processes associated with material supply, component production and delivery of products and services to the customer. It was identified there was growing awareness that lean principles could be transferred readily to other functions and sectors. The purpose of the study was to investigate the application of lean principles to knowledge-based activities such as engineering design and product development. The organization under study was Olifant Manufacturing Company (OMC), a division of British Aerospace Systems, Land Systems South Africa. The problem statement was formulated as: "Would the researched Lean principles enable OMC to improve its traditional Product Development (PD) to Lean Product Development (LPD)?" The Life Cycle Management (LCM) framework was the mandated organizational framework that guided the execution of projects at BAE Systems. It would be sought to identify the relevant framework that would be tailored within the overarching framework to enable process improvements. The main findings were lean transformation is an organizational journey that would begin with a top down philosophy. Aspects of LPD were found to be integrated into a system framework that integrated the transformation of people, processes and tools and technologies.

* Corresponding Author

1 INTRODUCTION

The research is an investigative study on the application of lean thinking to what is a traditional product development (PD) organization with the intent of transformation to lean product development (LPD). The researched applications would be investigated for implementation at Olifant Manufacturing Company (OMC), a division of British Aerospace Systems, Land Systems South Africa a military original equipment manufacturer.

Lean is usually understood to be relevant to those operations of a manufacturing enterprise meaning processes associated with material supply, component production and delivery of products and services to the customer Baines, Lightfoot, Williams & Greenough, 2006 [1]. According to Baines et al. (2006) there was, however, growing awareness that lean principles could be transferred readily to other functions and sectors. The purpose of this study is to investigate the application of lean principles to knowledge-based activities such as engineering design and product development.

Haque and Moore (2004) [2] mentioned that certain techniques such as concurrent engineering have been implemented and have been successful in improving new product introduction (NPI). There was, however, a short fall according to Haque and Moore (2004) in the expected or desired improvements to NPI. This assertion was complimented by Raudberget (2010) [3], who asserted that set based concurrent engineering was seen as means for dramatic improvement in the product development processes. Raudberget (2010) mentioned that despite the popularity of principles of concurrent engineering in the literature the number of reported applications has so far been limited. Haque and Moore (2004) mentioned that these shortfalls could be bridged through the application of lean thinking to NPI.

In the journal, the words engineering design, product development (PD), lean product development (LPD) and new product introduction (NPI) would be used interchangeably to mean the process of transforming customer requirements to end products introduced for purchase into the market.

1.1 Company background and literature preview

BAE Systems, Land Systems OMC is South Africa's primary military vehicle manufacturing facility covering all disciplines of the military vehicle manufacturing including conceptualisation, design, development, manufacture, production, re-manufacture and in-service support, BAE Systems Website, (<http://www.baesystem.com/Businesses/LandArmaments/Divisions/LandSystems/Aboutus/>)

The justification for the research was due to and in response to current market trends, Edwards (2006) (an unpublished manuscript on current Global and South African markets, *the LS-OMC environmental analysis*). Market trends revealed the global recovery from the world recession remained tentative and the saturation of the light armoured vehicles (LAV) market was a reality. Further there were concerns over product liability, increased competition and a shrinking market. Developing markets would be looking for value for money and markets getting more sophisticated in their purchasing, wanting more than just a product for their money,

There would be the adoption of processes that would radically reduce the product development lead time, product introduction lead time to market, increase process efficiency and product quality and reduce development costs at OMC. Farris, Martinez and Leon (2011) [4] postulate that lean product development (LPD) is one of the leading approaches currently adopted by organizations attempting to maximize value, increase quality, shorten lead times, and lower cost for product development (PD) processes.

Bohdan and Oppenheim (2004)[5] state that PD flow consists of a sequence of a large number of equal work periods called takt periods, each terminating in an integrative event.

Within each period, work is coordinated by the core team and executed by suitable concurrent and synchronised teams. Employees are dynamically allocated from their functional departments and assigned as needed to assure the timely completion of the work within the given period.

McManus (2005) [6] proposed that PD begins with value definition and detailed planning captured in a value stream map. The flow, which ends with the release of deliverables, proceeds at a steady rate as on a moving line.

Baines et al. (2006) compliments by postulating the product development process is normally complex and driven by too many stakeholders' functions to ensure optimisation of the current processes. According to Baines et al. (2006) it would make sense to focus on the identification of value and reduction of waste to achieve lean product development.

Similarly, efforts for identifying, defining and minimizing waste in PD processes have been developed by Farris et al. (2011). Several definitions of LPD waste were found in the literature however as confirmed by Farris et al. (2011) there does appear to be a lack of consensus on the agreed upon list of PD waste.

Complimentary to the identification of product development waste Hoppmann, Rebentisch, Dombrowski, and Zahn (2011) [7] conclude that product development needs to be understood as a system of highly interwoven components that only in their concurrency lead to high performance. The focus of the research would also be the identification of existing theories for lean product development that would combine to define a structured LPD framework.

Hoppmann et al. (2011) sought a coherent definition of an LPD system as consisting of the following components.

- Strong project manager
- Specialist career path
- Workload levelling
- Responsibility based planning and control
- Cross project knowledge transfer
- Simultaneous engineering
- Supplier integration
- Product variety management
- Rapid prototyping, simulation and testing
- Process standardization
- Set-based engineering

The main themes of the journal would be developed on the principles defined above. It would seek to identify the strategies for identification and elimination of product development waste and the identification of relevant frameworks that define Lean Product Development.

Farris et al. (2011) identified their findings as crucial for addressing the core problems that organization experience in successfully deploying LPD. According to Farris et al. (2011) the integration of Lean in current PD processes would be achievable through the exploration of the seven knowledge domains. These were the performance based domain, decisions based domain, process modelling domain, strategy domain, supplier partnership domain, and knowledge based network domain and lean manufacturing domain.

The performance based domain postulates that lean performance measurement relies on the assumption that desired behaviours would be promoted by measuring the correct factors.

Decisions based domain sought to identify which were the major categories of PD decisions, which decisions were most important and the way decisions should be made.

The Process modelling domain sought to use models as exploratory vehicles to describe, evaluate or predict performance of real life PD processes.

The strategy domain sought to study how companies could effectively manage a set of projects over time leading to LPD performance. Farris et al. (2011) stated that companies typically offered more than one product simultaneously and overall corporate performance would be the result of the aggregate effect of the products offered. Given the prominence of these business practices, product platform development (PPD) and multi-project management (MPM) have emerged as the two main prominent strategies.

Concerning supplier partnership, Liker and Morgan (2011) [8] noted the best performers of lean such as Toyota had much closer relationships with a close-knit network of systems suppliers. The suppliers were intimately involved in product development from the early concept stage. Further, Liker and Morgan (2011) noted that best lean performers tended to source complete systems from their largest supplier partners, so that the suppliers could work relatively independently.

Studies in LPD knowledge base present organizational learning focused on the acquisition of knowledge to quickly develop good products. According to Farris et al. (2011) organizational knowledge creation is one of the distinctive characteristics that have helped Japanese companies with Toyota in particular to be more successful in product development than their Western counterparts. Farris et al. (2011) researched how companies could improve capability to create new knowledge and how learning networks are created. This would include structures and processes that allow for effective inter-organizational learning and how networks solving problems inherent in knowledge sharing should be. Liker and Morgan (2011) postulate the knowledge base component as originating from a strong customer-based culture that is deliberately developed by the most senior management. It would encourage cross-functional focus on the customer and organizational learning to leverage lessons learned anywhere in the company. A truly lean organization would drive its people to continuously improve toward increasingly challenging targets, stretching and testing the organization to establish a culture of excellence

On the lean manufacturing domain there seems to be consensus among LPD researchers that while there is abundant experience on the introduction of lean onto the manufacturing shop floor, concepts on how to employ lean in upstream or downstream processes and supporting functions like engineering remain to be investigated in nearly as much detail (Hoppmann et al. 2011). Nepal, Yadav and Solanki (2011) [9] agree that while application of lean manufacturing techniques offers significant potential for improvements in development cycle time and cost, in reality this transfer of techniques is complex. The complexity in transferring these techniques was based on fundamental differences. Unlike manufacturing, PD is a non-repetitive, non-sequential, unbounded activity that produces information. Cogent risk taking in product development could be value-adding and variability is inherently and necessarily higher than in manufacturing.

1.2 Problem statement

The problem statement was formulated as: "Would the researched Lean principles enable OMC to improve its traditional PD to LPD?"

A set of key guidelines were identified to guide the research work. The following research questions were pertinent for the development of the literature review and the development of the entire journal:

- What would be the relevant framework for OMC PD transformation?
- What are the process wastes that affect PD performance?
- How would lean principles be applied to traditional product development processes?
- What are the measures of performance for lean product development?

- What is the business case to OMC management for adoption of the principles of lean as defined in this report?

1.3 Proposed aim of this study

The aim of the study is to investigate the application of lean principles and theories to traditional engineering design or product development.

1.4 Proposed research methodology

Research methodology is defined as being either quantitative or qualitative. Qualitative research includes an array of interpretive techniques which seek to come to terms with the meaning and not the frequency of naturally occurring phenomena in the social world (Cooper & Schindler, 2008) [10].

Cooper and Schindler (2008) states that qualitative techniques could include focus groups, individual in-depth interviews, case studies, ethnography, grounded theory, action research and observations. Qualitative techniques exhibit insight needed to make the ever-more-expensive business decisions and are an appropriate methodology when aiming to propose a direction in thinking and methodology to be followed by an individual organization. Cooper and Schindler (2008) mention that in contrast quantitative methodologies attempt the precise measurement of something.

Due to the identified need to research the business PD process at BAE Systems for lean improvement and the need for qualitative outputs, the case study methodology would be the preferred research methodology for the dissertation. The research methodology would seek to propose changes in OMC's new product development (NPD) that would bring about predictable responses to customer requirements.

Research on available literature of lean product development (LPD) was undertaken to establish an understanding of the requirements for the transformation of product development (PD) processes to LPD. Literature on LPD was thus gathered through research on online engineering databases and engineering online journals.

Some of the researched databases are shown below:

- Google scholar
- Emerald engineering journals
- Engineering village 2
- Scirus
- ProQuest (for thesis and dissertation outlines)
- ScienceDirect
- EBSCO

In searching through databases, the goal was to identify peer-reviewed publications and research journals related to LPD. It was used as a limiting guide in establishing relevant material for inclusion into the literature review. The key words used in the literature search were a combination of the words "office+lean", "engineering+lean", "new product development." "lean+product+development", "Toyota product development" amongst others.

The search for relevant research material was also bounded by the fact that LPD was a relatively new field and one that is ever changing as new research is published. In order to access the most relevant and up to date material, the search criteria were limited by the years of publication. According to research guidelines, research material from the last five years of publication was considered. The initial research period was first limited to publication between the years 2005-2010, when the research started. The literature was further supplemented by literature including the year 2011. Relevant publications from 2004 were also found and are cited in the journal

2 MATERIALS AND METHODS

The literature review presents a critical analysis of the researched literature in the current state of knowledge in LPD. The major source of information has been peer reviewed journals.

According to Nepal et al. (2011) the generic product development utilized the stage gate review process developed and implemented in many US industries during the late 1980's and early 1990's. An illustration of a stage gate review process is illustrated in figure1.

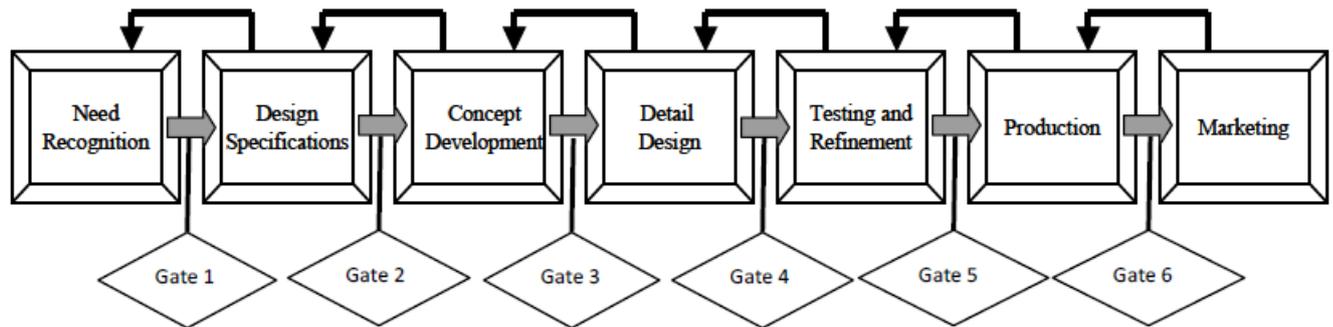


Figure 1: Typical Stage Gate Process Development Process

(Solanki, R., Yadav, O.P., & Nepal, B.P., (2011). Improving NPD Process by Applying Lean Principles: a Case Study, *Engineering Management Journal*, 23, (1): 52-68)

According to Nepal et al. (2011), a significant limitation to the efficiency of the stage gate would be the lack of time management and scheduling within each phase. The traditional stage gate product development process would require long design review cycle times and an excessive amount of documentation and would give less attention to early stages of PD, thereby, causing further reductions in design productivity.

The major goal of the stage gate process as defined by Nepal et al. (2011) would be to improve business performance and to develop higher quality products for enhanced revenue growth. The process provides a mechanism for controlling quality and reliability issues during the gate reviews.

Nepal et al. (2011) mentioned that in today's globalized competition where time to market would be a winning strategy, process efficiency would complement traditional factors such as quality and reliability. Issues that hinder process effectiveness were classified into three categories namely management, technical and relational issues.

Liker and Morgan (2011) agree that currently a challenge exists in the definition of an agreed transformation framework for lean product development. The challenge is posed by the fundamental difference between manufacturing and engineering design. Product Development is largely based on information flow and process waste is very difficult to see.

McManus, Haggerty and Murmur (2007) [11] explain most of the differences between factory lean and PD are driven by the fundamental uncertainty of product development processes. The exact content of the output is unknown at the beginning of the PD process, in stark contrast the ideal in factory operations is to produce a part precisely that same as the last one.

Despite the challenges identified Liker and Morgan (2011) presented a systems view of an integrated LPD. To apply lean improvement techniques to product development processes, the product development value stream mapping (PDVSM) method developed by McManus (2005) was proposed as a critical complimentary tool.

Farris et al. (2011) identified their findings as crucial for addressing the core problems that organization experience in successfully deploying LPD. The findings entailed seven aspects of lean product development. These would be used as guideline towards the desired LPD framework.

The findings by Farris et al. (2011) would be complemented by Liker and Morgan (2011) through their integrated LPD framework. Liker and Morgan (2011) asserted that the proposed LPD framework was the most comprehensive view of lean product development and was proven to have yielded results in practical applications. The proposed framework introduces a systems view of lean product development which integrates people, process and tools and technologies.

Under people, pivotal to LPD integration is the role of the chief engineer. The role of the chief engineer was identified by Liker and Morgan (2011) as the systems integrator from concept to production launch. The chief engineer together with the matrix organization that allows technical specialists to reside in functional units was the proposed LPD people's structure. A typical Matrix structure as proposed by Smit (2007) [12] is presented below:

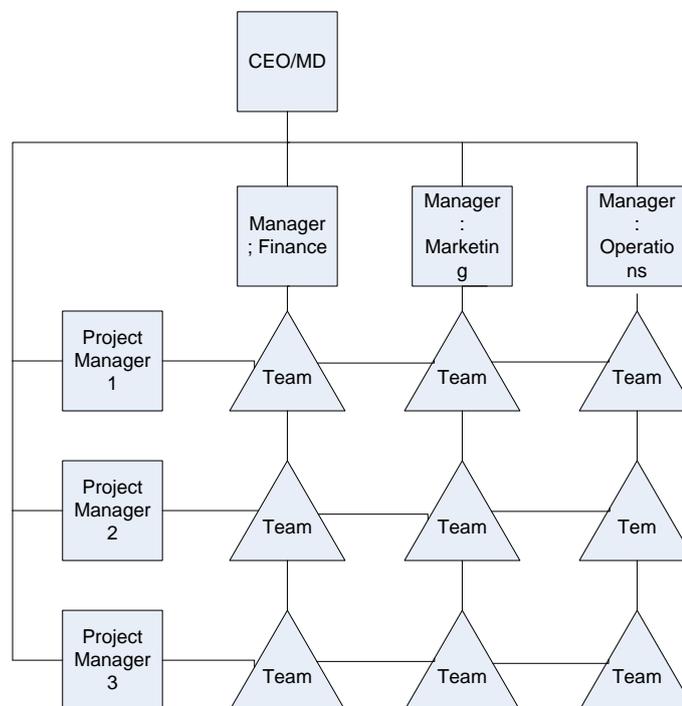


Figure 2: Matrix organisation structure

(Smit, P.J., (2007) Management Principles, Contemporary edition for Africa)

Liker and Morgan (2011) proposed to govern the peoples' transformation framework; the organization would develop a chief engineer system to integrate development from start to finish. Organise to balance functional expertise and cross-functional integration. It would develop towering technical competence in all engineers. Fully integrate suppliers into the product development system. The organization would build in learning and continuous improvement and build a culture to support excellence and the pursuit of relentless improvement.

During the transformation of processes the focus of LPD processes would be to establish product development flow and cross functional synchronization. It was in direct opposition to the traditional model of product development where each function works independently and a large batch of work was pushed onto the next operation in the process. Liker and Morgan (2011) argue that a better approach would be set-based, concurrent engineering in

which sets of ideas are developed co-operatively across functions and then flow through to downstream processes. With proper planning parts of the design could be released downstream early enough to allow simultaneous development of the product and processing to the point where tools are actually cut before the total design is complete.

Liker and Morgan (2011) proposed that the development teams would create process overview at the appropriate levels, process comparison maps of current state processes and ideal or future state maps. Gaps to reach ideals or future states would be developed for each major development step. At each of the state's strategic enablers to close the gap would be identified. The required strategic enablers would be grouped into the categories of people, process and technology.

During the transformation of tools and technology the usual product development tools such as computer-aided design (CAD) were used in most product development organizations. To govern the transformation of product development tools and technologies Liker and Morgan (2011) proposed to adapt technology to fit the organization people and processes. It was proposed to align the organization through simple and visual communication and to use tools for standardization and organizational learning.

To leverage on the design tools, Liker and Morgan (2011) proposed to utilize the design studio where 3D design models were shown with high levels of details. Once approved, the concurrent departments like jig design engineers could use the data to finish the detailed component engineering and templates. Leverage of the Big Room or Obeya methodology was utilized to promote concurrent development and by making problems visible to the team so that real time problem solving would be achieved.

The Big Room methodology has been proposed to effect visual communication. Through visual tools individual engineers would work effectively in teams. Key performance indicators, to communicate readiness of designs to other departments the developed value stream maps could be developed and posted in the "Big Room" to align the organization through visual communication.

In identifying product development waste Farris et al. (2011) postulate that if companies were able to identify what types of wastes they experience it would be easier to identify ways to remove it by using lean tools and thus gaining a competitive advantage. Although several definitions of PD waste have been identified in LPD literature no single agreed upon list currently exists as identified by Farris et al. (2011). Farris et al. (2011) identified categories of PD waste as strategic, organizational and operational.

Other categories of identified waste identified by Farris et al. (2011) were:

- Hand-off waste
- Waiting
- Redundant and re-invented work
- Miscommunications and unsynchronized concurrent activities.
- Bad project architecture
- Unnecessary work expansion
- Inflexibility
- Inefficiency
- Linear processes
- Low re-use

Similar to manufacturing processes, the non-value adding PD activities were defined by Nepal et al. (2011) as follows:

- Overproduction; designs turning faster than testing capabilities of overdesign
- Defects; customer requirements misunderstood resulting into unacceptable specifications

- Transportation; many handoffs of information and too many required approvals
- Over processing; rework as a result of late problem discovery (undesired iterations)
- Inventory; queues of unprocessed information (poor sequencing of design tasks)
- Unnecessary movement; poor data organization
- Waiting; resource conflicts, late information, hardware, software poor sequencing
- Underutilization of staff knowledge and skills; problems not solved at the lowest levels, decisions taken without consulting local experts, customer and employee feedback ignored in new designs.

Lean principles that could be adapted to a PD environment were identified by Nepal et al. (2011) as the following:

- Specifying value from the customer's perspective
- Identifying the value stream
- Making the value creation activities flow
- Customer pulled value
- Pursuit for perfection

Common wisdom for process waste such as poor planning and leadership, bureaucracy and lack of leaning were identified. The most important PD waste was identified by Farris et al. (2011) as knowledge waste. The major commonalities among the different forms of waste were working with defective information, waiting, lack of knowledge and ineffective communications. Farris et al. (2011) notes that differences in waste identifications in LPD literature mostly differed on the relative emphasis placed on each waste and some waste category definitions.

Various authors have identified the need for decision mechanisms for selecting the appropriate tools for waste elimination in any value stream. Value stream mapping (VSM) in the PD context as identified by Farris et al. (2011) has received some focus from researchers. Farris et al. (2011) argues that a possible limitation on the effectiveness of VSM is the dependency on the level of experience of the mapping participants and the difficulty to define value in the target process. PD value has been identified as a function of the quality of interim deliverables and the activities that produce them. With this emphasis on interim deliverables being lean in product development would mean the selection of the best activities to maximise value rather than the elimination of waste.

3 RESULTS

Life Cycle Management (LCM) was found to be the structured approach utilized at OMC to manage the company's commitments to projects throughout their lifecycles. Product development was integrated in the overarching LCM framework. OMC was an audited and certified ISO 9001 organization. It was found the organization had documented standards for all departmental procedures. The research was focused on the engineering development processes and the departmental interfaces with other functions external to engineering.

OMC had adopted the Quality Management System (QMS) to direct and control engineering activities associated with quality. According to ISO central secretariat (2002) [13], QMS had been adopted by organizations seeking to improve customer satisfaction and business competitiveness. The business market and environment was constantly changing and would have changed since 2002. The researcher was of the opinion that organizations who seek competitive edges in their businesses should be aware of current competitive behaviours. Lean product development (LPD) was identified as one of the leading approaches adopted by organizations attempting to maximize value, increase quality, shorten lead times, and lower costs for PD processes Farris et al. (2011).

It was found the cycle time for new product developments at OMC typically spanned a period of two years. Customization design activities of existing vehicle platforms spanned a period of about six months. The introduction of Lean Product Development at OMC would be introduced as continuous improvement to the mandated approach for Program and Project Execution. The introduction of the proposed framework and themes is identified in figure 3.

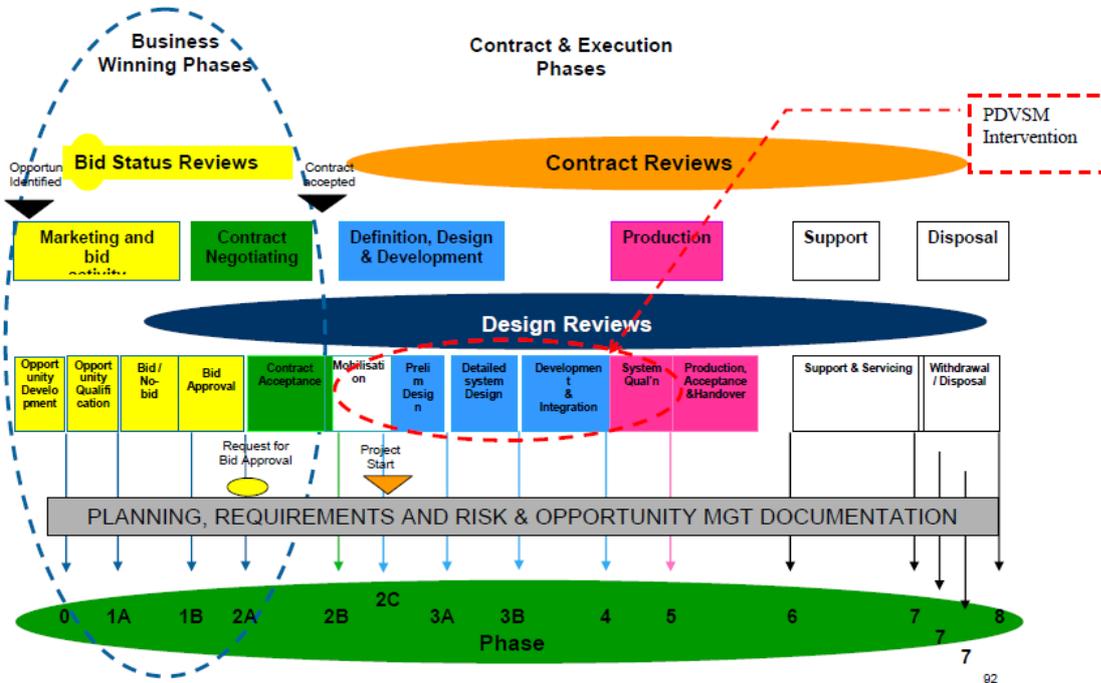


Figure 3: Life Cycle Management Framework

([OMC's Engineering Life Cycle (Adopted form BAE Land Systems OMC, Life Cycle Management Handbook, (2010)]. Unpublished Raw Data)

Given the identified LPD aspects and framework it was found that the role of the Chief Design Engineer was utilized at OMC. The Chief Design Engineer was the systems integrator and the use of a project matrix as suggested by Liker and Morgan (2011) was evident during project execution.

The development of deep technical skills to solve complex problems during product development was proposed as indispensable by Hoppmann et al. (2011). Through the people's development policy, OMC ensures its commitment to the development of its staff. Suitable training courses, both internal and external, were made available and the company offered study funds to further employee education in line with business strategies.

The career discussions between employee and managers at OMC were found to be subjective. Documented competency criteria by which to assess employee competency were not available. Development of a standard development pathway for OMC engineers would help to standardise the learning of engineers joining the organization. The role of the chief design engineer and design engineers was found to be important during the OMC PD process. Standard learning developments to achieve the competency would have to be developed.

The time based iterative aware visual process architecture and structure captured in a product development value stream map was found to be a gap in the current OMC development process. High level Gantt charts would be used for project execution and tracking. There was an opportunity for greater process efficiencies through the identification of process waste. It would be achieved through lower levels of mapping the value stream.

The use of current engineering design tools like Cad and engineering simulation tools were found to be in use during engineering product development. The efficiency of interdepartmental communication for approved 3D models could be improved. Liker and Morgan (2011) suggested the use of the "Big Room" to visually communicate design readiness to other departments.

To affect the required behaviours across the product development value stream, key performance indicators would have to be identified. Key performance indicators that would enable to communicate the efficiency of the product development value stream.

Liker and Morgan (2011) suggested the use of approved 3D in the Big Room to communicate readiness to other departments. OMC shared its complete 3D models with upstream processes. The efficiency of these communications for just in time flow would have to be further monitored for improvement. It was found the "Big Room" methodology was not in use nor fully appreciated at OMC. There would be great opportunity to effect visual communication and to promote a culture of continuous improvement through the implementation and vigorous management of this tool.

To affect supplier partnering the pairing of Engineering and Purchasing department was identified as key to optimise supplier partnership. This was also an identified gap in the current state and processes. OMC would leverage on the partnering to ensure efficient purchasing and supplier involvement in the development process.

4 DISCUSSION AND CONCLUSIONS

From the above results and findings the following discussions could be made. It would form the conclusions and recommendations on the research.

According to the researched problem statement a framework for transforming traditional product development processes had been achieved. The transformation framework entailed aspects of LPD principles and knowledge domains. An integrative transformation would be achieved through the systematic transformation of people, processes, tools and technologies.

The required outcome would be reductions in product development lead time, reduced development costs and increased product quality. Shorter lead times to market would complement the existing strategies of product reliability and quality through designs.

The main inhibitors for process efficiencies were identified. Waiting was identified as the most prominent information waste. Techniques for process improvements were identified. The product development value stream mapping was a visual tool proposed for process efficiency improvements. Other organization-wide, lean strategies like supplier integration were also identified through the presented aspects of LPD.

The proposed LPD principles would be proposed to be introduced within the overarching life cycle management (LCM) framework. It would be introduced as best practices proposed to be tailored within this framework. In order to affect the required behaviours, certain key performance indicators were identified where cost and delivery schedules were identified as the predominant measures. Input measures that separated lean process like the chief design engineer, process architects and planning were identified as existent at OMC. Proposals for improvement were identified.

The following business cases would be recommended for continuous improvement toward LDP at OMC.

- Establishment of a local LPD steering committee to drive the intervention of lean best practices
- Align the organization through visual value stream mapping techniques in department 'War Rooms' or 'Big Rooms' (Obeya)



- Rigorously chase process standardization where possible to increase process predictabilities
- Develop technical maturity matrices to develop learning pathways of engineering personnel and young engineers
- Develop a mentoring system to assist in the above of the learning pathways
- Visually communicate all key performance indicators, firstly, for the organization and for departments
- Cascade goals from the top down and serve to establish individual goals for employees
- Leverage the 3D modelling capability of the organization by communicating design readiness to upstream processes and thereby encourage development concurrency through the 'big room' methodology
- Revitalise the current LCM methodology by ensuring rigorous training and investigate forms of assessment in employees
- Establish an aligned culture that continuously seeks to improve by bringing problems to the surface so they can be solved
- Develop continuous learning and knowledge transfer by exploiting the development of check sheets wherever possible
- Establish engineering and procurement partnerships to ensure alignment of objectives between engineering and procurement and also facilitate in the selection and managing of OMC suppliers
- Interrogate the current development lead time to market for new product introduction (2+ years) and seek to improve this
- Leverage on visual communication and problem solving capabilities and engage engineers on opportunities for lead time reduction

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