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Master Thesis

"Rediscovering Lean Paradigm to Derive Innovation in the Engineering Services Sector"

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Abstract

Background - Lean paradigm has been successfully employed in the manufacturing sector in past decades, however in the engineering services sector its application has unfortunately not received the same attention both from academia and industry.

Problem Discussion – The negligence of Lean in the engineering services sector rendered this sector deprived from Lean's proven benefits in the manufacturing sector. The reason for this negligence can be traced back to the fact that Lean's implementation is not a straightforward task and additionally its direct translation from the manufacturing sector into the engineering services sector may impede innovative capabilities of the engineering services sector that are crucial for its sustainable growth.

Problem Formulation - In addressing the aforementioned issues, this thesis investigates the following key research question: "Whether and how Lean Innovation can be implemented in the engineering services sector?"

Purpose - This work explores and employs different modern theoretical concepts from literature to promote Lean Innovation in the engineering services sector by first developing a theoretical framework in terms of nine propositions and then examining them through a qualitative empirical research.

Methodology - The qualitative empirical research is conducted by first gathering empirical data through expert interviews and then analysing it employing the directed content analysis technique in order to examine the nine propositions promoting Lean Innovation.

Findings - This study concludes that Lean Innovation in the engineering services sector is achievable by employing modern theoretical concepts like open innovation, the systems approach to problem solving and transformational leadership in a thoughtful and planned manner.

Limitations - The lack of depth of the theoretical as well as empirical research focus in terms of the sample size and quality stemming from the challenge of finding enough experts with versatile knowledge in the thesis' timeframe can be considered as limitations on the quality of this research.

Keywords - Lean paradigm, engineering services sector, Lean Innovation, open innovation, systems approach, transformational leadership.

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List of Abbreviations

AH	Airbus Helicopters
BOM	Bills Of Material
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAM	Computer Aided Manufacturing
GPS	Global Positioning System
IP	Intellectual Property
LIFE	Lean Innovation Framework for Engineering
MITI	Ministry of International Trade and Industry
ODM	Original Design Manufacturer
OEM	Original Equipment Manufacturer
PPD	Product and Process Development
PR	Personal Relations
R&D	Research and Development
TPS	Toyota Production System
TQM	Total Quality Management
2D	Two Dimensional
3D	Three Dimensional

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1 Introduction

1.1 Background

Innovation drives economic growth and the theoretical relationship between them has been envisaged since at least as early as Adam Smith (2001). In order to survive and grow in today's highly competitive and dynamic business landscape companies need to incorporate innovation management into their organisational policies (Andriopoulos and Lewis 2010). This is especially true for the technological companies that can gain and sustain competitive advantage by transforming market opportunities through their new product development process to fulfil customer needs and wants (Krishnan and Ulrich 2001). New product development process primarily starts in the Research and Development (R&D) department of an engineering organisation, where ideas are generated (brainstorming), screened (qualitative funnelling), developed (design and analysis) and tested (prototype or mock-up) to exploit potential market opportunities. Having the working design of the product at hand, the next step involves the industrialisation (manufacturing) and commercialisation (product launch) of the product. The manufacturing domain of product development was revolutionised through the emergence of the Lean paradigm in management sciences at the end of the 20th century, which led to the notable increase in this sector's productivity (Womack *et al.* 1991, Womack and Jones 1996). However, the application of Lean philosophy in the first phase of the product development process, namely product design development in the engineering services sector[1], could not catch up to its manufacturing counterpart, thereby remaining deprived from Lean's proven benefits in the manufacturing sector (Murman 2012).

A possible reason for this being that the direct application of the Lean principles from the manufacturing sector (Womack *et al.* 1991) to the engineering services sector may hamper its innovative capabilities. This is due to the fundamental differences between the nature of input and output as well as the factors that influence them in the two sectors (Chen and Taylor 2009, Browning and Sanders 2012). In the manufacturing sector more emphasis of the Lean philosophy is put on the absolute elimination of waste compared to value creation aspect in order to reduce costs and enhance product quality. However, this Lean mindset in the engineering services sector is counterproductive because in this sector the value of a complex process differs from the sum of the values provided by its constituent activities and therefore the absolute waste elimination aim does not guarantee cost reduction and greater value (Browning and Sanders 2012). In order to apply Lean practices in the engineering services sector, without compromising its innovative capabilities, the notion of value and waste in the Lean paradigm needs to be re-examined in a critical manner, which authors consider as the "rediscovery" of the classical Lean notion, and that also justifies the thesis title selection.

[1] Throughout this thesis the terms engineering services sector and engineering organisation are used interchangeably because the engineering services sector is assumed to be comprised of either a pure engineering services organisation or an R&D unit of a hybrid engineering organisation (with both product development and manufacturing capabilities) providing engineering services to internal or external customers.

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1.2 Problem Discussion

Since the birth of Lean ideology at the Toyota Production System (TPS) it has mainly been applied in the manufacturing sector, especially in vehicle manufacturing (Gao and Low 2014). However, Lean's prospect of increased efficiency and thus greater profitability has appealed to other sectors, including the services sector that accounts for roughly two-thirds of global output (Best 2009), albeit with limited success (Ahlstrom 2004, Seddon and O'Donovan 2010). What is the reason of Lean's limited success in the (engineering) services sector? Many Lean scholars (e.g. Grönroos (1990) and Ahlstrom (2004)) have criticised the treatment of services as manufacturing and emphasised to retranslate the Lean concepts before their meaningful application to service organisations. However, none of these studies describes the adaptations that are necessary for adapting Lean paradigm to the services sector (Seddon and O'Donovan 2010). Lean's negligence in the engineering services sector, which forms a significant segment within the overall services sector, is even more acute (Murman 2012) that renders it unable to reap the benefits of Lean that have been enjoyed by the manufacturing sector. Unfortunately, the situation is not very different in academia, where Suarez-Barraza *et al.* (2012) report 172 publications in total until 2012 on Lean's application in the services sector, and the number does not even reach double digits in the engineering services sector. This justifies and motivates the need of this thesis that, in its limited capacity, attempts to fill this research gap.

What makes Lean's application in the engineering services sector a challenge that has hindered its widespread use in this sector? In order to understand this issue, a deeper insight into the engineering services sector is required. As a matter of fact, this sector can be considered the birthplace of a product and hence heavily relies on its innovative capabilities (Murman 2012). To cut a long story short, Peter Drucker stated, for some scholars an enterprise's fundamental choice can be reduced to "innovate or die" (Schulze and Störmer 2011). The role of innovation, especially within this sector, is hence indisputable for its sustainable growth. An engineering organisation achieving technological breakthroughs by promoting innovation, especially radical innovation, and then legally protecting them, can gain huge long-term competitive advantage over its competitors (Grant 2012). This justifies this thesis' prime focus on radical innovation instead of incremental innovation. For this reason, unless explicitly stated otherwise, innovation is meant radical innovation throughout this thesis. However, there is an ongoing debate in literature whether Lean philosophy is compatible with innovation, namely "can innovation be Lean?" (Browning and Sanders 2012), which explains the major reason behind the aforementioned challenge of Lean's application in the engineering services sector. In order to tackle this challenge, this thesis critically reviews the application of Lean manufacturing practices in the engineering services sector and attempts to resolve this challenge.

Is there any mechanism that can significantly enhance an engineering organisation's innovative capabilities with the given resources? One such mechanism proposed by Chesbrough (2003a, 2003b) is the "open innovation" approach, where contrary to the conventional approach of generating, developing and commercialising innovative ideas in a closed and self-reliant manner, organisations can leverage their innovative capacity outside their in-house R&D operations by harnessing innovative ideas from all possible external sources of knowledge. Can open innovation and Lean coexist? Open innovation in terms of a joint innovation venture among an organisation and its external partners demonstrates great similarities with the Lean's supplier development approach, which opens new possibilities of exploiting synergy benefits through the integration of these two notions (Weber 2014). This motivates this research to investigate the possibility of a Lean environment with open innovation in the engineering services sector.

What are the challenges of a Lean environment with open innovation and how can they be effectively handled? The implementation of Lean practices in engineering organisations is a complex problem (Murman 2012) that is even further complicated by the pursuit of open innovation, whose complex and unpredictable outcome further compounds the problem (Chen and Taylor 2009). In order to tackle this complexity and unpredictability, the systems approach to problem solving (Dreborg 1996, Robert *et al.* 2010) could provide an appropriate framework for the systematic transfer of Lean principles into the innovation management policies of an engineering organisation, also referred to as Lean Innovation (Krumm and Schittny 2013). The systematic implementation of Lean Innovation needs a major transformation to overcome organisational inertia and hence the role leadership becomes crucial in guiding an engineering organisation through such a complex and unpredictable transformation due to its strong decision making abilities (Anderson and Ackerman 2010), with certain leadership attributes and styles that combine to form a so-called "Lean Leader" (Toussaint and Berry 2013). A combination of these leadership traits forms specific leadership styles (DuBrin 2010), and some styles are more effective in implementing major organisational changes (Bossink 2007, Kotter 2013), such as the transformation towards Lean Innovation. This justifies this thesis' pursuit of a Lean environment with open innovation in engineering organisations in a systematic, customised and thoughtful manner to overcome the challenges of organisational inertia, complexity and unpredictability.

It is important to note that the Lean Innovation principles in the engineering services sector are similarly overarching across various engineering sectors as it is the case with the five well-known Lean manufacturing principles (Womack *et al.* 1991) that have proven their effectiveness in increasing productivity across different manufacturing sectors over the last decades (Suarez-Barraza *et al.* 2012). The reason being that the Lean Innovation principles primarily find their application at process and administrative levels rather than at product and technology levels.

1.3 Problem Formulation

From the discussion in previous sections, the following key research question is formulated and is investigated throughout this thesis.

Whether and how Lean Innovation can be implemented in the engineering services sector?

In investigating the "whether" part of this question, the literature on the compatibility issue of Lean paradigm and innovation is analysed in detail (e.g. Melnyk 2007, Chen and Taylor 2009, Browning and Sanders 2012). In exploring the "how" part of this question, the possibility of the employment of different theoretical concepts from literature is examined, e.g. open innovation (Chesbrough 2003a, Chesbrough 2003b), systems approach to problem solving (Dreborg 1996, Robert *et al.* 2010) and effective leadership (Pullin 2005, DuBrin 2010).

1.4 Thesis Purpose

The purpose of this thesis is to investigate whether Lean paradigm and innovation can co-exist and how Lean can in fact promote innovation, which is a major and complicated change process, if implemented through a systems approach and an appropriate leadership style. This investigation culminates in the development of a theoretical framework in terms of nine propositions for the systematic implementation of Lean Innovation in the engineering services sector with the aid of adequate leadership. In order to formulate these propositions, firstly the ideas and information from each of the theory sections have been funnelled into the final deductions at the end of each of these sections addressing the key research question investigated in this thesis. Secondly, by connecting the relevant deductions from each of these sections the propositions have been formulated to achieve Lean Innovation in the engineering services sector. Having this theoretical framework at hand, a qualitative empirical research is conducted to examine it by conducting interviews of experts with industrial background in Lean, innovation, systems approaches to problem solving and leadership in engineering organisations and finally drawing conclusions.

1.5 Delimitations

This thesis has been conducted in an industrial context and has possible limitations in terms of its suitability for the public and not-for-profit sectors because these sectors do not have the pursuit of long-term market competitiveness through (radical) innovation as their primary objective. Additionally, findings of this research are strongly linked to an engineering organisation's prime objective of achieving competitiveness through Lean Innovation, however, for engineering organisations seeking different business objectives, e.g. stability and reliability in their solutions, the findings of this thesis might not be very effective and could even be counterproductive, and hence need to be carefully considered.

1.6 Thesis Structure

This thesis is structured as follows. Chapter 2 contains the relevant theory corresponding to the four core key concepts investigated in this thesis, namely Lean paradigm, innovation, the systems approach and leadership. Section 2.5 synthesises the different theoretical aspects covered in the theory chapter and develops a theoretical framework in terms of nine propositions to promote Lean Innovation in the engineering services sector. Chapter 3 explains the methods, in terms of method choice, technique, data collection, analysis methodology and validity, reliability and trustworthiness issues, which have been employed to conduct the empirical research. Chapter 4 presents the empirical data collected through interviews with expert. In Chapter 5, the empirical data is analysed in terms of evaluating the experts' statements and reconciling them with theory. Finally, in Chapter 6 conclusions are drawn and complemented by their implications and future research is proposed.

2 Theory

This chapter explicates the main concepts corresponding to Lean paradigm, innovation, systems approach and leadership, which form the theoretical backbone of the present work and address the key research question raised in Section 1.3.

2.1 Lean Paradigm

The Lean paradigm emerged as one of the most influential ideas of management sciences in the twentieth century after the disclosure of the "Japanese Wonder" at the Toyota Production System (TPS) by Womack *et al.* (1991). However, the application of the Lean paradigm in the services sector, which accounts for approximately two-thirds of the global output (Best 2009), did not receive the full attention it deserves both in the academic and industrial domains to exploit the potential of Lean practices in this sector to the same extent as was done in the manufacturing sector. A general discussion on the mystery behind Lean, its historical overview and its application in the services sector is presented in Appendix A for interested readers.

2.1.1 Lean in Engineering Services Sector

Engineers are responsible for the design, analysis and prototyping of products and therefore their decisions mainly drive the product lifecycle costs. The engineering services sector can be perceived as the birth place of a product, however most engineers often feel that Lean thinking does not apply to what they do (Murman 2012) because they cannot fully realise the benefits of Lean in their work. A probable indicator of the negligence of Lean thinking in the engineering services sector is the scarcity of literature on this topic and there appears to be a significant research gap to fill in this domain. The use of Lean philosophy in engineering services is generally referred to as Lean Engineering (Garcia and Drogosz 2007). Traditionally, the Lean Engineering notion simply adopted the Lean Manufacturing principles into the engineering services sector. However, the direct use of Lean Manufacturing principles in an engineering environment does not prove to be very successful as Lean Manufacturing increases efficiency through inventory control and production process improvements and engineering doesn't have inventory and in most cases is not a "production" environment (D3 Technologies 2010). In order to achieve Lean Engineering, one can use Lean Manufacturing concepts where they make sense and modify or add new concepts that make sense within an engineering environment. In the following section, various Lean concepts, like customer, input, output, waste and Lean principles, are discussed in the engineering context.

Customer of Engineering Services

Among other stakeholders for an engineering-related undertaking, e.g. end user, program management, other engineers, production, operators, regulators (Murman 2012), customer is the most important stakeholder in terms of defining the value of a product or service. In Lean Manufacturing, value is defined based on the customer's perspective; therefore defining customer in engineering services is important in order to determine the value of engineering tasks performed and deliverables created. For an engineering organisation, a customer can be either external or internal. An external customer is someone who uses an organisation's engineering services but is not a part of it, e.g. a specialised design company supplying product designs to an engineering organisation can consider the engineering organisation as its external customer. On the other hand, an internal customer is any member or department of an organisation who relies on its internal engineering services, e.g. testing department conducting tests for the design department in the same organisation can consider the design department its internal customer.

Engineering Input

Engineering input can be divided into three major categories, namely people/engineers, tools/technology and existing engineering intelligence (D3 Technologies 2010). Engineers are an organisation’s most valuable asset as their innovative capabilities are irreplaceable (Murman 2012). A significant customer value enhancement is directly related to the productivity and efficiency of human capital of an engineering company. Tools and technology is everything an engineer needs to do her work and it can include anything from software to hardware to network infrastructure. Due to the rapid increase in their capacity and scope, this part of the engineering input can significantly influence output levels for a constant human capital. Finally, the existing engineering intelligence or know-how is also an important part of the engineering input. No engineering firm starts a design from scratch and they often start from a base-line design, which is normally a previous working design or solution, and then modify or update this base-line design to get a new design with required features. This approach is often referred to as “same as except” design, where the efficient storage and retrieval methods are very important to improve output level (D3 Technologies 2010).

Engineering Output

An engineering output is obtained by spending resources (input) in a process over a certain amount of time, and can be shown as follows (D3 Technologies 2010):

$$\text{Resources} + \text{Processes} + \text{Time} = \text{Output}$$

It becomes clear from this relation that in order to increase engineering output there are three possibilities. As the time factor can only be increased up to a certain limit by deploying resources subjected to working overtime, this leaves one with two areas of improvement to increase engineering output, namely resources and processes. In general, Lean philosophy in an engineering organisation mainly focuses on the process optimisation, although it has also a significant impact on the resources area. Morgan and Liker (2006) have shown that the three elements, namely processes, skilled people and tools and technology, must be integrated to create a high-performance Lean Product & Process Development (PPD) System, as depicted in figure 2.1. According to Garcia and Drogosz (2007), in order to create a Lean Engineering system, one must first start by creating a Lean process and then implementing the correct Lean tools and technology to support the process and developing the skilled engineers needed to work in the process.

Engineering Waste

Seeing engineering waste is the first activity in deploying Lean in an engineering company. According to Garcia and Drogosz (2007), typical wastes found in the product development process include hand-offs, waiting, external quality enforcement, reinvention, non-value added transactions, lack of system discipline, arrival and process variation, system over-utilisation, large batches, redundant tasks, stop and go tasks and unsynchronised concurrent engineering, as shown in figure 2.4. Baujard *et al.* (2014) translate the seven manufacturing wastes into the corresponding seven engineering

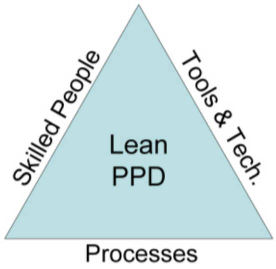

Figure 2.1 Lean product process development (Morgan and Liker 2006)

wastes, as shown in figure 2.2. In this translation, manufacturing wastes have been adjusted to fit their experiences in development (engineering) areas. For example, "inventory" in the manufacturing field becomes "partially done work" because a partially done task engages resources in investments (material and human) as storage does. From a Lean development standpoint "defects" are not considered as a recurrent impact and a bad yield (as in Lean Manufacturing) but are described as a risk introduced in the development processes, which means the later the detection the worse the impact. Finally, Liker (2004) defines an additional engineering waste, namely unused employee creativity that arises from not engaging engineers in process improvements for engineering.

7 wastes in Manufacturing	7 wastes in Development	Examples in Development
Inventory	Partially Done Work	Untested solutions/ unfinished documents
Overproduction	Extra Features	Unnecessary functions for customers
Extra Processing	Relearning	Re-invented solutions
Transportation	Handoffs	Complex validation process
Waiting	Delays	Waiting for decisions/ asynchronous tasks
Motion	Task Switching	"Stop & Go" tasks
Defects	Defects	Rework because of wrong requirements

Figure 2.2 Comparison of manufacturing and engineering wastes (source: Baujard *et al.* (2014))

Lean Engineering Targets and Principles

According to McManus (2005), Lean Engineering has the following three goals from a holistic perspective: (1) to make the right products; (2) effective integration between product lifecycle and enterprise; (3) Efficient engineering processes. Here, the first goal seeks the creation of products that increase the value for all stakeholders in an organisation, the second goal applies Lean Engineering to create value in product lifecycle and in the enterprise, and the third goal employs the Lean paradigm to eliminate waste, improve cycle time and quality in engineering. Additionally, in order to differentiate between the five Lean Manufacturing principles and their engineering counterparts, McManus (2005) made a comparison, as shown in table 2.1. As this table shows, the Lean Engineering principles deal mostly with intangible and abstract elements and processes while their manufacturing counterparts mostly deal with visible and physical elements and processes, which renders the Lean Engineering principles' outcome immeasurable and hence difficult to manage.

Lean Thinking Steps	Manufacturing	Engineering
Value	Visible at each step, defined goal	Harder to see, emergent goals
Value stream	Parts and materiel	Information and knowledge
Flow	Iterations are waste	Planned iterations must be efficient
Pull	Driven by "takt" time	Driven by need of enterprise
Perfection	Process repeatable without errors	Process enables enterprise improvement

Table 2.1 Comparison between manufacturing and engineering Lean principles (source: McManus (2005))

Traditional versus Lean Engineer

A "Lean Engineer" is different from a traditional engineer in a number of ways. As an engineer is the basic building block of an engineering organisation, these differences are also reflected in differences between a Lean engineering organisation and its traditional counterpart. According to Murman (2012), an engineer in a traditional engineering organisation might be primarily thinking about how to enhance the product from a purely technical perspective, while with a Lean mindset the same engineer would also be thinking about how to enhance the product to better meet customer needs and expectations. A Lean Engineer would seek to produce output just as the overall design/development cycle needs it and she would always question whether the work is adding value to the overall effort and try to continually find new ways to eliminate waste in the overall effort. However, on the contrary, a traditional engineer might be just focussed to increase her output without even knowing whether that output is adding any value from a customer's standpoint. Contrary to a traditional engineer, who leaves quality and scope concerns to others by simply focussing on his output boost (specialist approach), a Lean Engineer would always be designing to meet quality objectives, interpreting quality in the broadest possible sense and would remain flexible and adaptable, not only to the tasks undertaken, but also to their span of technical competencies. Finally, contrary to a traditional engineer who is waiting for management to make things better and likely be very cynical on management being so out of touch with the problems in field, a Lean Engineer is empowered, trained and rewarded by management to continually improve their contribution to the enterprise (Murman 2012).

Magnitude of Engineering Waste and its Elimination

At the core of a Lean system lies the identification of value-adding and non-value-adding activities (pure waste) and elimination of the later (Womack *et al.* 1991). In the Lean Engineering context, an activity taking time or other resources can be classified as pure waste if it does not meet the test of a value-adding activity. However, certain tasks, like weekly coordination meetings and technical trainings, fall into the necessary non-value-adding activities (necessary waste) category as without doing these tasks an engineer would likely be doing the wrong job and creating more pure waste (Murman 2012). Once pure waste is eliminated, Lean system seeks gradual minimisation of necessary waste.

Figure 2.3 shows quantitative estimates of value-adding, necessary non-value-adding and pure waste activities in the aerospace and automotive engineering sectors. The left pie chart depicts a remarkable comparison between value-adding and pure waste activities in the engineering sector, where pure waste activities (40%) overweigh value-adding activities (31%). The right pie chart depicts the estimated waste for an engineering job

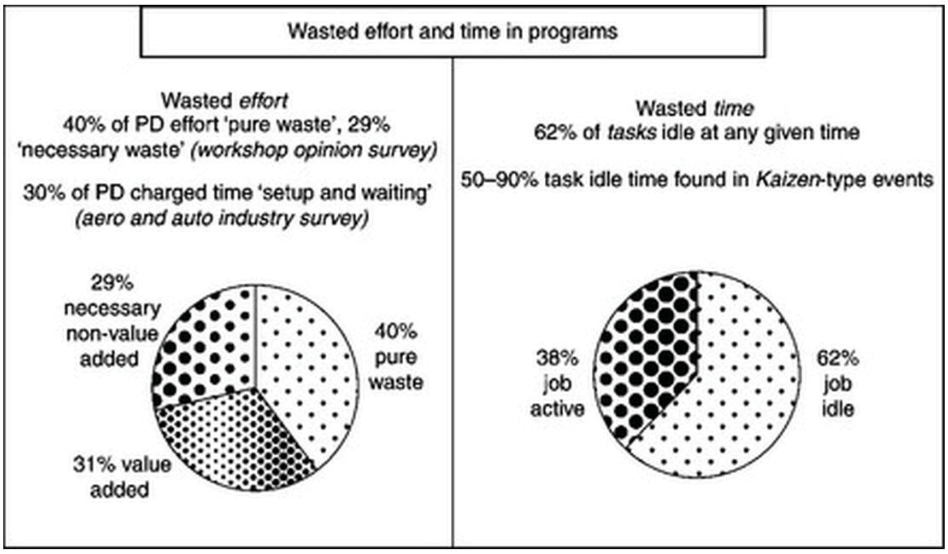

Figure 2.3 Estimated engineering waste (sources: McManus (2005) & Murman (2012))

package in the global system context, where no work is being done on a given engineering task about 62% of the time as this task is waiting for another task to be accomplished and someone to add value to it. However, when someone starts working on a task, only about 30% of their time adds value (left pie chart). This implies that only 11% (30% x 68%) of the total time spent on an engineering job package is value-adding activity (Murman 2012). Garcia and Drogosz (2007) provide a breakdown of the value-adding and non-value-adding activities in a product development process in an engineering organisation, as shown in figure 2.4. It can be seen from this figure that the cost saving measures in a traditional engineering organisation are solely focussed on a very small portion (≈11%) of the whole product development process, while Lean attacks the waste imbedded in the rest of non-value-adding activities (≈89%). This shows the magnitude of waste in traditional engineering organisations and at the same time a great opportunity to apply Lean practises to eliminate this significant amount of waste, thereby freeing up the engineering resources that can be redeployed to derive innovation.

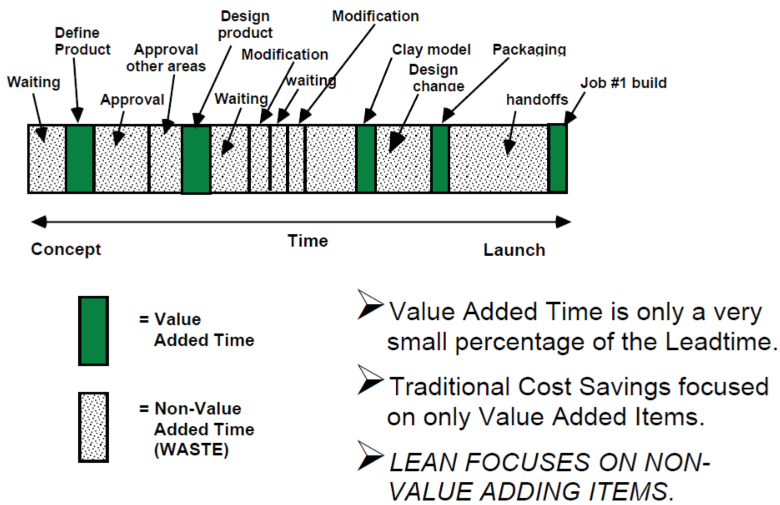

Figure 2.4 Product development process in a traditional engineering firm (source: Garcia and Drogosz (2007))

According to the five Lean principles, once waste has been specified and identified, the next important step is to make actions that create value *flow* and eliminate waste. In the context of an engineering organisation, this can be perceived as balancing workload among engineers, synchronising completion of task, co-locating teams and people, minimising handoffs between engineers, managing design iteration, and so forth (Murman 2012). By making actions that create value *flow*, it is possible to make only what is *pulled* by the customer, i.e. to initiate a design task so that the next step in the design process is ready to accept it. The final step is to strive for *perfection* by continually removing successive layers of waste as they are uncovered.

2.1.2 The Proposed Lean Engineering Approach

This section summarises different aspects that have been identified throughout this section that can help promote Lean Engineering as follows:

- Small, cross-functional and flexible teams composed of strong team players are helpful to promote Lean Engineering (Womack *et al.* 1991, Karlsson and Ahlström 1996, Womack and Jones 1996).
- People with strong leadership qualities and all relevant technical expertise as team leaders help to ingrain Lean culture in an engineering organisation (Womack *et al.* 1991, Womack and Jones 1996).
- It is beneficial to promote team spirit in a Lean engineering organisation by structuring career paths in such a manner that rewards go to strong team players rather than to those showing excellence in a single functional domain (Ohno 1978, Womack *et al.* 1991, Womack and Jones 1996).
- An early and regular customer engagement throughout the product development process enables an engineering organisation to focus mainly on enhancing the product value in line with its customer needs and expectations, instead of enhancing the product from a purely technical perspective (Womack and Jones 1996, Murman 2012).
- It is important to identify all stakeholders and work towards maximising their interests collectively (Womack and Jones 1996, Murman 2012).
- Creating a balance between waste elimination and value creation dimensions of the Lean paradigm can optimise customer value because absolute elimination of waste (too much Lean) can impede the value creation capability of a Lean engineering organisation (Womack and Jones 1996, Murman 2012).
- It is crucial to eliminate all types of engineering wastes including unused employee creativity that arises from not engaging engineers in process improvements.
- A smooth flow of information in terms of exchanging the right amount of information at the right time is crucial in implementing Lean in an engineering organisation (Womack and Jones 1996, Murman 2012).
- As a Lean engineering organisation functions as an integrated whole and not a collection of disconnected departments, coordination and communication are its essential constituents (Womack and Jones 1996, Murman 2012).
- The utilisation of integrated digital simulation tools (e.g. CAD, CAE, CAM) enables an integrated product development process, thereby reducing risk and guaranteeing the feasibility of product development output (Womack and Jones 1996, Murman 2012).

2.2 Innovation

This section discusses innovation's role in the engineering services sector and its compatibility with the Lean philosophy, which is a source of long-term competitive advantage and economic growth. However, there is no unique definition of innovation in literature and the interested reader is referred to Appendix B for a brief discussion on this topic. This works adopts a rather broad definition of innovation proposed by the department of business innovation and skills in the UK, namely "it (innovation) is a process by which new ideas are successfully exploited to create economic, social and environmental value" (Grant 2012).

Just like its definition, there is a big academic debate on different types of innovation that has led to ambiguity in the way different types of innovation are defined and discussed in research (Garcia and Calantone 2002). Due to its versatility and comprehensiveness, the present research employs the multiple dimensional model of innovation proposed by Cooper (1998) that classifies innovation in six dimensions, namely incremental, radical, administrative, technological, product and process. Incremental innovations "enhance and extend the underlying technology and thus reinforce the established technical order", while radical innovations represent advances so significant that revolutionary changes of the organisation and its support networks must occur to accommodate and implement change (Cooper 1998). Contrary to technological innovation that directly influences the basic output processes through the adoption of ideas, administrative innovation incorporates changes that affect organisational policies, resources allocation and other factors related to the social fabric of an organisation (ibid). The product innovation reflects change in the end product or service offered by a firm, while process innovation represents changes in the way an organisation produces end products or services (Utterback 1994). A more elaborate description of Cooper's model is presented in Appendix B for more curious readers.

2.2.1 Role of Innovation in Engineering Services Sector

In western management theory, it is assumed that a product is first innovated, then it grows and finally it matures (Vernon 1966). This implies that innovation is the first and crucial step in the product lifecycle that brings engineering at the epicentre of innovation. There is a huge amount of literary work available on the role and implications of innovation in the manufacturing sector, however innovation in (engineering) services sector remains a mysterious process (Ettlie *et al.* 2010). Perhaps this is so due to the dominance of the manufacturing sector compared to formal R&D (Tassey 2004, Ettlie *et al.* 2010). According to Beeson and Tannery (2004), as a result of the lack of innovation in the services sector, regional manufacturing sectors have declined in general and that has forced people to migrate to lower paying jobs in alternate sectors of the economy.

Engineering services sector has to deal with a constant stream of new problems that require effective, innovative, elegant and genesis solutions (Cropley 2014). Here, effectiveness ensures that solutions actually work, while innovation ensures that the widest possible range of ideas has been explored that maximises the probability of finding the best possible solution. Elegance ensures the completeness, aesthetical and sustainability issues of a problem, while genesis ensures that solutions look forward and open new ways of thinking about the problem. According to Ettlie (2010), the key difference between the innovation mechanism in the manufacturing and engineering services is that products are produced solely by manufacturers but services are always co-produced by the service provider and client, thereby rendering factors, like communication, mutual understanding, adaptivity and participation, very crucial in engineering services.

Incremental innovation is a general practice in engineering organisations as it is responsive to problems and opportunities/trends, it maintains/enhances competitive advantage, bears lower risk and is the most common form of innovation (Grant 2012). On the other hand, radical innovation challenges status quo paradigms and practices, poses higher risk, supports and promotes lateral and critical thinking, and goes beyond competitive thinking (ibid). Grant (2012) notes that long product lifecycles of large-scale manufacturing-intensive industries sanctioned a pragmatic focus upon incremental innovation during the 20th century, however, the apparent and ever-growing need for radical innovation in the 21st century is severely constrained by this historical legacy. The role of radical innovation cannot be underestimated as it leads to the discovery of new facts and the invention of new theories that mark a technological and paradigm shift in a historical context. Administrative innovation pursues a top-down approach where the management triggers such activities like Lean practices, while technological innovation follows a bottom-up strategy where lower organisation members are involved (Daft 1978, Gaertner *et al.* 1984, Weber 2014). However, both administrative and technological dimensions of innovation are closely related and even inter-related (Edquist *et al.* 2001). Product innovation is primarily market driven and it is introduced to meet customer need (Dubouloz 2012), while process innovation is defined as new elements introduced into an organisation's production or service operations and it has an internal focus and it aims to increase the efficiency and effectiveness of organisational processes (Utterback and Abernathy 1975).

2.2.2 Lean's Influence on Innovation

There is an ongoing literary debate on Lean's compatibility with innovation. One school of thought argues that Lean can impede innovation while the other argues that Lean can promote innovation.

According to Melnyk (2007), a Lean environment in its traditional form promotes narrowly bounded, well-defined, standardised, certain and short-term process improvements, where variance is considered an "evil". Browning and Sanders (2012) argue that a traditional Lean environment shapes its stable and routine processes, high-volume production, stable workforce, traditional learning curve and eliminated buffers. This environment is highly suitable for a firm seeking to reduce variance and waste as it is the case in applying Lean practices to manufacturing sector, and moderately suitable for achieving incremental innovation in an R&D environment (Melnyk 2007). On the contrary, however, radical innovation necessitates broader scope, longer implantation lead time, risk, variability, experimentation (slack), non-standardised procedures (ibid), and it involves dynamic and unfamiliar processes, low-volume production, workforce turnover, learning curve disruptions and purposeful buffers (Browning and Sanders 2012). For this reason, Lean serves poorly if the goal is to derive innovation (Wynett *et al.* 2002, Hale and Kubiak 2007, Browning and Heath 2009). Murman (2012) notes that as Lean practices are fundamentally focussed on the elimination of waste, the value enhancement through innovative solutions can be hampered by the application of Lean Manufacturing principles in an R&D setup that eliminate indispensable non-value added activities (necessary waste). Chen and Taylor (2009) and Van de Ven (1986) also argue in the same direction that standardised work processes and rigid work organisation through

Lean practices drive too much negative stress in employees that impede their innovative potential.

However, there are scholars who argue that Lean can promote innovation. This notion is sometimes referred to as "Lean Innovation" in literature. According to Krumm and Schittny (2013), the goal of Lean Innovation is to systematically transfer the principles of Lean thinking into innovation management. Lean can support innovation in many ways, e.g. by providing a suitable environment for innovation (Moore 2001, 2006, Schiele 2009), by turning an organisation into a learning organisation (Bhasin and Burcher 2006, Purhaghshenas and Esmatnia 2012), by turning employees to multi-skilled and multi-functional knowledge workers (Duguay *et al.* 1997, Ahlstrom 1998), by cultivating closer inter- and intra-team communication and knowledge-transfer (Drach-Zahavy and Somech 2001, Olivella *et al.* 2008), by decentralising and democratising innovation (Isa and Tsuru 2002) by downplaying hierarchical supremacy (Olivella *et al.* 2008) and empowering employees (Cross 2013), and by freeing resources (Chen and Taylor 2009) that can be further employed to drive innovation (Schiele 2009, Cross 2013). For Lean Innovation, Melnyk (2007) proposes the separation of the system responsible to derive innovation (R&D) from the system mainly responsible for physically manifesting the innovation outcome (manufacturing system), which would allow an engineering organisation to eliminate waste and variance as well as standardise products and processes in a Lean context.

2.2.3 Open Innovation - The Next Frontier for Innovation

The dynamics of innovation have been changing in the face of globalisation and digitisation of the business world over the last few decades. The innovation process is becoming more costly and risky due to the global competition, a short product cycle, technological progress, and as a consequence organisations start to share risk doing research with other organisations by exploiting the open innovation model (Koziol-Nadolna and Swiadek 2010). The notion of "open innovation" was first introduced by Dr. Henry Chesbrough in literature (Chesbrough 2003a). Chesbrough and Schwartz (2007) define open innovation as the "(…) use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively". Von Hippel (1988) identifies four external sources of knowledge in open innovation, namely suppliers and customers, universities, government and private laboratories, competitors and other nations. Contrary to the conventional so-called "closed innovation" approach, where ideas are generated, nurtured and commercialised in a closed and self-reliant manner within the R&D setup of an organisation, the so-called "open innovation" enables an organisation to leverage its innovative capabilities outside of its in-house R&D operations by harnessing innovative ideas from external sources of knowledge and information. More curious readers are referred to Appendix B for a detailed discussion on the background, challenges and future patterns of open innovation.

Lean Engineering and Open Innovation

Open innovation is important for this work as the idea behind open innovation i.e. joint innovation between an (engineering) organisation and its external partners, demonstrates great similarities with Lean's supplier development approach, as proposed by Weber (2014). According to Plenert (2006), Supply Chain Management (SCM) can achieve peak performance through Lean practices. Lean supply chain development takes into account the entire flow from raw materials to consumer and it has three specific features, namely cost transparency, mutual relationship assessment and no-blame-no-excuses culture (Plenert 2006). Similar to the open innovation practice, where an organisation opens and establishes external channels of knowledge and information (Chesbrough 2003a, Chesbrough 2003b), Lean organisations also actively develop links and work closely with their suppliers in order to reach mutual benefits (Bhasin and Burcher 2006). According to Krizner (2001), for a Lean transformation to succeed it is essential to bring together different sections that historically erected barriers between them. Baker (2002) argues that as well as going beyond the realm of enterprise, implementing Lean successfully also extends out into the supply chain, i.e. it is essential to get the suppliers on board. Bicheno (1999) reflects on how Lean supply chains could exploit the "partnership philosophy" that could benefit all parties. All these arguments point towards the fact that Lean's supplier development can be considered a step towards "opening" an organisation's doors to its external sources of knowledge, strictly speaking to its suppliers. Therefore, it can be inferred from the above discussion that a Lean (Engineering) environment provides a proper platform to incorporate and exploit the benefits of the open innovation approach. As a matter of fact, both open innovation and Lean organisations open their internal channels to communicate with external sources. The only difference is the degree of openness. In its classical form, Lean's supplier development approach limits its openness to its suppliers only; however the open innovation approach opens its doors to all possible external sources of knowledge. Therefore, one can argue that Lean's supplier development approach can gain extra leverage by opening its doors from its suppliers to all possible external sources of knowledge.

Similar to the Lean production approach to develop a supplier chain in order to guarantee a reliable components supply, the first step in developing Lean supplier chain in the engineering services sector involves the organisation of suppliers into functional tiers (Womack *et al.* 1991), such as suppliers specialised in Computer Aided Design (Liker 2004, Lean Academy MIT), Computer Aided Engineering (CAE), Computer Aided Manufacturing (Camison-Zornoza *et al.*), etc. Different R&D tasks in a project can be functionally segregated and assigned to firms in each tier. The encouragement of knowledge transfer among the suppliers and the organisation at different tiers both vertically and laterally can lead to an effective Lean supplier development. At this stage, opening channels of supplier firms in each tier to interact and collaborate laterally with external sources of innovation can incorporate all the aforementioned benefits of open innovation approach in the Lean supplier system. This transforms a "closed Lean supplier system" to an "open Lean supplier system" where ideas can flow vertically and laterally among supplier firms in different tiers as well as to their environment.

It is important to note that there is still lack of empirical evidence on the effectiveness of open innovation strategies (Knudsen 2007), especially in the context of Lean philosophy. Bigliardi *et al.* (2010) has reported some insights into open innovation practices in the food machinery supply chain and concluded that all the supply chain players (in food machinery sector) perceive innovation as a key factor to survive in today's competitive markets, and are all active in innovation and in open innovation in particular. Further theoretical as well as empirical research is necessary to understand the mechanism of open innovation and the pros and cons of integrating it within a Lean environment.

2.2.4 The Proposed Lean Innovation Approach

This section summarises the factors that have been identified in this section to drive Lean Innovation in engineering organisations.

- It is critical to link the wants and needs of the customer in terms of enhancing customer value to derive Lean Innovation (Ohno 1978, Womack *et al.* 1991, Womack and Jones 1996), which can be achieved through early and regular customer engagement throughout the product development process.
- In order for Lean and innovation to coexist in an engineering organisation, the separation of the system responsible for deriving innovation (R&D) from the system used to derive out waste and variance and to standardise products and processes (manufacturing) is necessary (Melnyk 2007).
- In order to remove pure waste during the new product development process, it is essential to take a holistic and system perspective by distinguishing pure waste from the necessary waste and by allowing a certain amount of necessary waste that is essential to generate innovative ideas in a Lean engineering organisation. In this context, factors like, a proper understanding of the complexity of the system, reconceptualisation of value and waste, functioning working processes and moderate use of Lean practices, can help to promote innovation in a Lean engineering organisation (Browning and Sanders 2012).
- Employment of smaller and adaptable teams facilitates a free interaction across different functional departments that helps generate innovative ideas (Utterback and Abernathy 1978, Maidique and Hayes 1984, Sahyouni 2013).
- In order to promote Lean Innovation, it is important to cultivate learning culture (Bhasin and Burcher 2006, Purhaghshenas and Esmatnia 2012) and turn employees to multi-skilled and multi-functional knowledge workers (Duguay *et al.* 1997, Ahlstrom 1998, Drach-Zahavy and Somech 2001).
- Closer inter- and intra-team communication and knowledge-transfer is the key in inspiring an innovative working environment in a Lean engineering organisation (Drach-Zahavy and Somech 2001, Bhasin and Burcher 2006, Olivella *et al.* 2008).
- Decentralisation and democratisation (Isa and Tsuru 2002) of a Lean engineering organisation's structure through the downplaying of hierarchical supremacy (Olivella *et al.* 2008) and the empowerment of employees (Cross 2013) encourage an innovative working culture.
- Contrary to the conventional closed innovation approach, the open innovation approach unlocks the doors of unlimited innovative ideas for a Lean engineering organisation by exploiting all possible external sources of knowledge and information (Chesbrough 2003a, Chesbrough 2003b).

2.3 The Systems Approach

This section adds on to the discussion of complexity and unpredictability arising from the implementation of Lean Innovation in engineering organisations and proposes a solution for this issue by exploiting the systems approach to problem solving that has been successfully employed in dealing with the most complex and unpredictable challenge of our time, namely sustainable development and the protection of our planet (Holmberg and Robert 2000). A system is generally comprised of a number of sub-systems that interact with each other in a specific manner (Robert *et al.* 2010). In the context of an engineering organisation the organisation can be considered as a system and its different organisational entities its sub-systems, such as engineering, manufacturing, finance, marketing, etc. The use of a systems approach is suitable because an engineering organisations seeking Lean Innovation conforms to the systems behaviour of emergence, complex interactions and thresholds of its sub-parts (Robert *et al.* 2010). First of all, changes in one part of an engineering organisation seeking Lean

Innovation may have an unpredictable innovation outcome on the overall system and therefore it can be inferred that such organisations conform to the system characteristic of *emergence* (ibid). Next, complex relationships between sub-systems are evident in a Lean engineering organisation where a change in one sub-system may cause a linear or non-linear change in other sub-systems, which conforms to the system characteristic of *complex relationships between system parts* (ibid). Finally, the implementation of Lean in engineering organisations often experiences resistance (Toussaint and Berry 2013) as Ohno (1978) argued that once this initial resistance to change is overcome progress increases in speed through the rest of the engineering organisation. A parallel can be drawn between this attribute of a Lean engineering organisation and the system characteristic of *thresholds* (Robert *et al.* 2010). For a more detailed discussion on the systems approach and its suitability to the implementation of Lean Innovation in engineering organisations, more inquisitive readers are referred to Appendix C.

There are various methods of systems approaches to problem solving, with two of the main ones being forecasting and backcasting (Robert *et al.* 2010) and clear understanding of the difference between these two approaches is essential to understand their suitability to the implementation of Lean Innovation in engineering services. The forecasting approach considers the planning of future events based on current knowledge only, and thus has limitations (ibid). The backcasting approach however creates a vision of success for the future and examines the actions required today in order to achieve this vision (ibid). Backcasting is able to deal with multiple facets or principles during implementation by incorporating changing technologies into its final vision and is thus considered as a technique in which Lean principles can be implemented in engineering services in the most sustainable, effective and efficient manner in order to promote innovation in the engineering organisation. Backcasting itself has two possible approaches to problem solving, namely backcasting from scenarios and backcasting from principles (Holmberg and Robert 2000, Robert *et al.* 2010). Backcasting from scenarios is a method whereby a particular scenario of the future is imagined which aligns with the aims of the problem solver (Roorda 2001). Backcasting from principles on the other hand defines the vision in terms of basic principles. The basic principle definition is that a certain condition needs to be met in order for the system to continue in its state (Robert *et al.* 2010). Interested readers are referred to Appendix C for a more detailed discussion on different systems approaches.

2.3.1 Application of Backcasting to Drive Lean Innovation

Backcasting has been chosen as the preferred method for the systematic implementation of Lean Innovation in engineering services due to its ability to handle complexity and unpredictability of this process. The following sections discuss the role and impact of the backcasting method on the concepts of Lean, innovation and leadership. The manner in which backcasting interacts with these three aspects is discussed in the next sections.

Backcasting to Implement Lean in Engineering Services

It is important to decide which backcasting approach, i.e. backcasting from scenarios or backcasting from principles, is suitable to implement Lean Innovation in engineering organisations.

The implementation of Lean in engineering organisations requires a major/radical initial change and a search for continuous improvement thereafter. The final outcome of the implementation is however unknown at the start as there are many interconnecting variables and interdependent sub-systems to consider. Each organisation is different and the approaches need to be adapted to their specific organisational situation (Abdi *et al.* 2006). If one were to use backcasting from scenarios, a definite scenario of the future would have to be made (Quist *et al.* 2011). When considering the implementation of backcasting from scenarios in complex systems over time, Quist and Vergragt (2006) propose the use of several goals. These include: creating normative options for the future and putting them high on the agenda, generating future scenarios, creating a follow up agenda designed to reach the scenarios and the stakeholders learning from the experiences of implementation, thereby creating a feedback loop (Quist and Vergragt 2006).

If one considers the problem through backcasting from principles, the approach would be different. In this case, a number of sub-systems would need to be identified (Holmberg and Robert 2000) by involving the stakeholders in the identification of principles that guide the implementation to the desired state, i.e. a successful implementation of Lean principles in engineering services (ibid). In the context of Lean, some of the backcasting principles could be: elimination of waste, effective communication, empowerment of employees, customer engagement, etc. One can see that these principles are more general in nature but they provide flexibility during the implementation phase of new technologies and for various solution approaches.

Based on this discussion backcasting from principles is proposed in this work to implement Lean in engineering services. The reason being that the implementation of Lean in engineering services is complicated and changes in one area of operations might have unforeseen repercussions in other areas. The rate of technological improvements is also high in the engineering services sector and the backcasting from scenarios is not ideally suited to this environment since it can exclude new technologies that do not conform to the initial scenario (Robert *et al.* 2010). If one follows the pre-defined Lean principles, it is highly probable that the result will be a transformation of a traditional engineering organisation into a Lean engineering organisation even without an exact layout through an evolutionary process in a dynamic environment guided by the pre-defined principles.

Backcasting and Innovation

In order to employ the backcasting systems approach to provide a framework for the promotion of innovation in an engineering organisation, it is essential to investigate the interaction of the two backcasting approaches with the innovation process. If a clear scenario of the innovation outcome can be established, the backcasting from scenarios approach can be more appropriate as it can be an agent to motivate the stakeholders towards the end scenario, focus the employees towards project objectives, attract project sponsors easily, etc. (Robert *et al.* 2010). If the system is complex and unpredictable, a clear scenario of the innovation outcome is difficult to perceive, and the backcasting from principles becomes suitable as in this approach the pre-defined principles set out lead to the completion of the vision. The main advantage of the backcasting from principles approach in this context is that it is able to incorporate new technological advancements and information as well as changing customer requirements that could occur during the innovation process, thereby achieving highly customer-focused and adaptable solutions (Robert *et al.* 2010). Hence, the backcasting from principles can be seen as a more adaptable approach than backcasting from scenarios. Finally, it can be concluded that both the backcasting methods can be employed to provide an appropriate framework for the innovation process, however the relative advantage of one over the other depends on the degree of complexity and unpredictability of the process.

Additionally, the use of the backcasting can also be helpful to facilitate open innovation in an engineering organisation in a systematic and structured manner. An organisation can understand its internal R&D capabilities well, however the same cannot be said for the external sources of information and knowledge that can be exploited in the framework of open innovation approach. From this it can be concluded that the outcome of open innovation is more unpredictable than the closed innovation approach (Chesbrough 2003b). Due to the relatively high unpredictable nature of the open innovation approach in terms of its outcome, it is unlikely that a specific scenario can be perceived. For this reason the backcasting from scenarios approach seems to be inappropriate for the implementation of open innovation approach in a Lean engineering organisation. As during the open innovation process a continuous exchange of technology, information and ideas occurs between the organisation's internal and external resources, it requires that a systems approach should be able to incorporate them throughout the innovation process. As the backcasting from principles has the capacity to absorb new knowledge, information and ideas throughout the innovation process, it is logical to infer that it has advantages over the backcasting from scenarios approach in implementing open innovation in a Lean engineering organisation.

In concluding this section it can be inferred that backcasting can enable, promote and drive (open) innovation by creating the best possible structure and planning methods for its implementation. The specific type of backcasting approach used depends on various factors, e.g. the detail to which the scenario or the principles can be established, technological advancement in areas related to the innovation projects, the openness to technology of the organisation, the willingness of organisational management to take risks, etc. The Lean engineering organisation needs to understand the innovation requirements and the advantages of each backcasting method and match the two accordingly as discussed above.

Backcasting and Leadership

The reconciliation of backcasting with leadership is an interesting one. Backcasting can provide a framework for the implementation of Lean Innovation in engineering services. Leadership is important in both the setting up of the framework and the execution of the backcasting principles or scenarios established, especially since leadership's primary concern is with future events and change (Romero 2010). In backcasting leaders need to establish the vision of the future and the strategic plan in order to reach the common vision. This is one of the most critical parts of the backcasting approach and one of the most challenging (Quist and Vergragt 2006, Robert *et al.* 2010, Holmberg 2014). However, it is sometimes difficult for people to reach a common vision and special leadership skills and styles are required to participate effectively in this process and show meaningful results (Robert *et al.* 2010, Romero 2010). In backcasting from principles it is also important that the leader is involved in the creation of principles. These principles will define the framework and constraints within which the solutions must be found. Choosing a leadership style appropriate to systems approaches to problem solving is crucial in order for the solution process to be effective. It has been concluded in Sections 2.4.3 and 2.5.4 that the transformational leadership style is most suited for this implementation, which is discussed in what follows.

The transformational leadership style is well suited to great change and to innovation (Hewitt *et al.* 2014). As previously mentioned the two backcasting approaches provide a framework for the application of innovation. The transformational leadership style therefore has to work together with the framework created by the backcasting approach in order to be most effective. In backcasting from scenarios a clear end scenario is created and the goal set. The leader thus has the task of focusing and motivating the team to achieve the scenario. The transformational leadership style has the ability to motivate others towards change and is enthusiastic about change (DuBrin 2010), a quality which translates to the team and can enable maximum efficiency of the implementation of a backcasting from scenarios approach. In the backcasting from principles approach the transformational leadership style (apart from its qualities in affecting effective change) has the quality of identifying areas requiring resources and allocating resources to the identified areas during the change process. The transformational leadership style is thus suited to the creation of principles and also to focus on the most important areas required for successful project implementation. In practical terms this would mean that the areas with the weakest resources would be identified and strengthened with additional resources to achieve the vision through pre-defined principles.

2.3.2 The Proposed Systems Approach

This section summarises the key findings on the systems approach to promote Lean Innovation in engineering services.

- The systems approach is suitable to drive Lean Innovation in engineering services due to the complexity of this process and its conformance to the systems behaviour of emergence, thresholds and complex interactions of sub-systems (Dreborg 1996).
- Among the two systems approaches, namely forecasting and backcasting, the backcasting systems approach is more appropriate for the implementation of Lean Innovation in engineering services, as the forecasting systems approach is not capable of dealing with the complex and unpredictable future outcome of a Lean Innovation process due to its utilisation of past and present data (Quist and Vergragt 2006).
- Due to its effectiveness in handling an unpredictable and complex process, backcasting from principles is more suitable for the implementation of Lean in engineering services than backcasting from scenarios, as well as the former's adaptability to incorporate any modifications necessary during the implementation process (Robert *et al.* 2010).
- Both backcasting from scenarios and principles are suitable to promote different types of innovation. The choice between the two backcasting approaches depends on a number of factors, e.g. the detail with which the scenarios or principles can be established, pace of technological advancement, organisation's openness to technology and top management's willingness to take risks in terms of pursuit of increment or radical innovation (Robert *et al.* 2010).
- When promoting innovation in engineering services the backcasting from scenarios approach can be employed if the client is able to provide a specific innovation scenario. Yet, a highly dynamic technological environment can threaten the effectiveness of this specific innovation scenario by rendering it technologically sub-optimal. Nevertheless, in this situation the backcasting from principles approach is more effective than the scenario approach due to the former's ability to incorporate (technological) changes during the innovation process (Robert *et al.* 2010).
- If the client is unable to present a clear scenario of the innovation outcome, however the vision of the innovation outcome can be perceived and the principles to achieve it

can be formulated, the backcasting from principles is appropriate for the promotion of innovation in engineering services (Holmberg and Robert 2000).

- Due to its capability to incorporate the unpredictability of the open innovation outcome and the continuous exchange of knowledge during the open innovation process, the exploitation of the open innovation approach facilitated by the framework created by backcasting from principles can leverage a Lean engineering organisation's internal R&D capabilities (Robert *et al.* 2010).
- Both the transformational and charismatic leadership styles can aid the systematic implementation of Lean Innovation in engineering services by employing backcasting from principles or scenarios due to the ability of these leadership styles to motivate stakeholders and effectively plan and implement great organisational changes (DuBrin 2010), e.g. Lean Innovation.

2.4 Leadership

Leadership has been credited with much success, especially collective success over the years, (Halling 2013). Halling (2013) also points out that management as compared to leadership is a much newer phenomenon. Leadership is important as it is needed to show the direction for great changes in organisations, e.g. promotion of Lean Innovation, and to guide the organisational processes whilst also instilling confidence throughout the organisation. The role of leadership is equally important in both the manufacturing and services sectors, however the situation in the services sector is far more fluid than in the manufacturing sector. The reason being that services are intangible and the leadership impact on enhancing their quality is more difficult to measure than on products, thereby making such a situation more difficult to manage (Carlborg *et al.* 2013). In the case of services, leaders in management positions have a difficult task of convincing workers that the changes implemented are taking effect (Chase and Garvin 1989), which requires leadership qualities of motivation and persuasion.

The situation becomes even more challenging for leadership when implementing Lean in (engineering) services due to the great organisational change that it brings, which requires strong leadership with motivational and persuasive qualities (Heath 1998, Halling 2013). Committed leadership is also said to be the key to kaizen, or continuous improvement of processes within companies and achievement of Lean transformation (Ohno 1978). An additional layer of unpredictability is introduced by promoting innovation in this scenario and therefore strong leadership becomes even more crucial as it can play a role in resolving this unpredictability (Anderson and Ackerman 2010). Supplementary material shedding more light on leadership and its role in Lean Services is provided in Appendix D for more curious readers.

2.4.1 Role of Leadership in Lean Engineering Services

The role of leaders in technically oriented companies, such as engineering service companies, has at times been undermined (DuBrin 2010). Leading, managing and implementing change is difficult in such companies. These companies tend to be rigid and the reaction to change, including innovation, is very slow (DuBrin 2010). In addition, the senior management and the specialists involved in operations are generally people with many years of experience (DuBrin 2010), but with limited management skills. They need this experience in order to have technical know-how and produce quality results (Pullin 2005). However, with this experience many of the bad habits, like the rigidness and resistance to change, have also been acquired over time, which are not what is required in the Lean paradigm (Ohno 1978). To change these habits and to influence such senior staff members requires respect, negotiation skills, guile and exceptional motivational ability (DuBrin 2010) (i.e. soft skills) that are lacked by mid line managers who are most critical to the successful implementation of Lean (Aucoin 1997, Pullin 2005). In addition, Bhandary (2011) has shown that some of the processes described in Lean, such as waste management and efficient process flows are similar across businesses and industries and are also crucial to mid line management.

As a response to the aforementioned issues there has been a trend in engineering organisations towards hiring managers without a technical background, however this is not very effective due to the specialised and technical nature of the work. Other factors detracting from this approach are that in order for highly qualified and skilled workers (such as the ones found in innovative engineering organisations) to follow a leader there needs to be an element of respect for this leader (Womack *et al.* 1991), which is difficult for a non-technical person to achieve. A leader in such organisations thus needs to be technically knowledgeable in order to demand the respect of followers, and also aware of the importance and advantages of Lean Innovation in order to influence others within the organisation. Ohno enhanced the capability levels of middle management in Toyota during his implementation of Lean principles. He decided to form teams with strong leaders that were capable of both production and industrial engineering (Womack *et al.* 1991). Ohno also structured the teams to have generalists instead of specialists. This enabled flexibility and redundancy during operations ensuring maximum efficiency, something that is key in Lean operations (Womack *et al.* 1991). This model is highly transferable into engineering services. Furthermore, it can be deduced that a team of multi-skilled staff and managers is able to adapt to changing situations of today's business world and of an organisation involved in innovation. The modern day manager in engineering services thus needs to be open to innovation and able to affect this innovation. She thus needs to be multi-skilled, i.e. a strong technical person as well as a strong leader in order to persuade others to join the Lean Innovation process (Ohno 1978, Womack *et al.* 1991).

2.4.2 Leadership Styles Suited to Lean, Innovation and Systems Approach

This section discusses the leadership styles best suited to Lean implementation, innovation and systems approach to problem solving within organisations, as recommended in literature. Leadership styles are comprised of a combination of specific leadership traits, as discussed in classical leadership literature such as DuBrin (2010). For interested readers a summary on the specific traits corresponding to different leadership styles has been presented in Appendix D.

Leadership Styles Suited to Lean

An important issue during the successful implementation of Lean is to use a leadership style of leading through participation (Flinchbaugh *et al.* 2008). Additionally, change management through an engaging/participative leadership style is shown to be highly effective according to Pritchard and Bloomfield (2013) as the workers within the organisation feel the desire to follow their leaders through the changes because they can engage with them emotionally and see the commitment of their leaders to the changes (Pritchard and Bloomfield 2013, Hills 2014).

Technical engineers who become managers in engineering services companies are usually very hands on and hence engaged in their work. It is safe to assume that this aspect of transformational leadership would not be difficult for engineering managers to master and adopt. The pursuit of Lean Innovation within an engineering organisation adds complexity to the situation and thus committed and involved leadership, which are traits of the transformational leadership style, are even more necessary.

Kempster and Parry (2013) found that the charismatic style of leadership also works very well during the change process. Interestingly they found that this type of leadership is associated with patriarchal tendencies. This means that the workers tend to feel safer through the change process when they identify a warm, caring nature in the leaders that they can relate to (Kempster and Parry 2013). Change is often difficult and it affects all parts of the organisation. Therefore the charismatic leadership style, which provides workers with the feeling of security, can be seen as a move towards Lean.

The styles of leadership thus identified from literature as being the most appropriate for effective change, i.e. implementation of Lean in engineering organisations, are:

- transformational
- charismatic
- participative

According to DuBrin (2010), some of the leadership traits associated with such styles are:

- courageous
- visionary
- great communication
- inspirational
- motivational

Leadership Styles Suited to Innovation

In their study of the Iranian car manufacturer Iran Khodro, Abdolmaleki *et al.* (2013) conclude that the correct leadership style can have a positive impact on an employee's innovation capabilities. Abdolmaleki *et al.* (2013) conclude that the transformational style of leadership proved to be the most effective for innovation implementation in an organisation. Another study in Taiwan found that the transformational leadership style is best suited for innovation taking place in an engineering organisation and it is the leadership style that is able to cultivate an innovative environment within an organisation (Lee and Liu 2008). Innovation thus needs to be cultivated in order to achieve long term, sustainable results within organisations. A study in Spain also found that a transformational leadership style is one that suited innovation best (Arragon-Correa *et al.* 2007). The extension of their study further indicates that organisational learning in combination with the transformational leadership style shows best results.

McCraw (1996) relates strong leadership with the promotion of innovation in engineering over the last few decades. He further goes on to state that leadership needs to evolve in order to allow this innovation to happen and that it needs to be entrepreneurial rather than technocratic and supportive and empowering rather than reactive. This view is supported by Gao and Low (2014) who conclude that in order to drive innovation in companies it is important that the process is aided by supportive and inspiring leadership. It can be inferred that these leadership traits point to the charismatic leadership style (DuBrin 2010). Another study based on empirical research in the

Netherlands and dealing with the impact of leadership styles on innovation in a sustainable building environment found that interactive leadership produces the best results (Bossink 2007).

In summary leadership styles suited to innovation are:

- transformational
- charismatic
- interactive

According to DuBrin (2010) and Bossink (2007), some of the leadership traits associated with such styles are:

- courageous
- visionary
- great communication
- emotional expressiveness
- inspirational

It should be noted that although strong leadership has successfully promoted Lean in engineering organisations seeking innovation (Ohno 1978), it does not necessarily need a hierarchal organisation structure, and can even be better achieved in flat organisational structures as bureaucracy is minimised and innovative thoughts and actions encouraged (Teece 1994).

Leadership Styles Suited to Systems Approach

In their research the Canadian Centre on Substance Abuse (2013) found that there has been a shift in the definition of leadership from a heroic individual to a person able to inspire a collective towards change. It also states that the best way to implement a systems approach is to be patient, have a well thought out plan, be encouraging and engaging, with effective communication abilities(Canadian Centre on Substance Abuse 2013). In one of the analysis of a backcasting approach van der Voorn (2010) states that an entrepreneurial leadership style is best suited to an implementation of backcasting. It has also been stated that transformative leadership can be used to implement backcasting effectively (Holmberg 2014), however its use is limited due to its inability to inspire and motivate (Weertman 2014).

Transformational leadership is often associated with backcasting however and it is even stated that backcasting can be used to enhance transformational leadership itself (Weertman 2014). Transformational leadership should in turn be used to implement backcasting as it is the best leadership style to follow processes, motivate and enhance the morale of the group (ibid). One can deduce that the transformational leadership style would be more suited to backcasting from principles in a Lean engineering organisation due to its focus on creating change processes and the ability to ensure that the followers follow these processes. Backcasting from scenarios creates a scenario of the future and then looks for implementation steps which will enable the realisation of this scenario (Quist and Vergragt 2006). For such an approach, leadership styles with the ability to implement change and motivate others are suitable, such as transformational and charismatic leadership styles.

In summary leadership styles suited to systematic change implementation are:

- entrepreneurial

- transformational
- charismatic

According to DuBrin (2010), some of the leadership traits associated with such styles are:
- courageous
- thoughtful
- great communication
- excellent planner

2.4.3 The Proposed Leadership Approach

This section summarises the main findings on leadership and leadership styles suitable for the promotion of Lean Innovation in engineering services.
- Leadership plays an important role in the implementation of Lean Innovation in engineering services as it is an important contributor to the implementation of great organisational changes (Kotter 2013).
- Multi-skilled team-leaders have a deep technological understanding of their industry and are thus able to perceive a realistic vision of innovation that can be achieved in an efficient manner (Ohno 1978), making them crucial to the implementation of Lean Innovation in engineering services.
- The transformational, charismatic and participative leadership styles are suitable for the implementation of Lean in engineering services, as they possess visionary traits with excellent communication skills, willingness to challenge the status-quo and ability to motivate and inspire followers towards great change (DuBrin 2010).
- Leadership styles suited to the promotion of innovation in engineering services are the transformational, charismatic and interactive ones due to their traits that enable them to inspire others towards innovation, portray energy, show courage in difficult situations during the innovation process and persuade the followers to pursue innovative ideas through open, honest and effective communication (Fidler and Johnson 1984, Arragon-Correa *et al.* 2007, Bossink 2007, Abdolmaleki *et al.* 2013).
- The transformational and entrepreneurial leadership styles are best suited to the systems approach because leaders with these styles systematically guide and support great organisational changes due to their ability to build structures towards a vision, show enthusiasm and make effective plans, follow processes and analyse complex systems (Canadian Centre on Substance Abuse 2013).
- The transformational leadership style is crucial to the concepts such as Lean, innovation and systems approach as this style possesses the traits that motivate and inspire followers towards the innovation outcome, instil trust in them and help them to systematically follow the processes. This leadership style is therefore very effective in implementing Lean Innovation in engineering services.

2.5 Lean Innovation Framework for Engineering (LIFE)

This section is aimed at synthesising different theoretical aspects covered in the previous sections to answer the key research question raised in Section 1.3. The first part of this question asks "whether Lean Innovation can be implemented in the engineering services sector?". In the light of the literature review conducted in the previous sections, it safe to deduce that this is possible. In answering the second part of the key research question that asks how Lean Innovation can be implemented, a theoretical framework, so-called "Lean Innovation Framework for Engineering (LIFE)", is proposed. It is acknowledged that there is no reason to believe that the proposed LIFE is unique. Other theoretical and empirical frameworks from different scholars, e.g. Lean engineering framework for the aerospace sector by Murman (2012), the framework for the Toyota product development system by Morgan and Liker (2006), the Lean framework for radical product innovation by Sahyouni (2013), value creation framework introduced by Murman (2002), etc., might also be equally valuable.

The following strategy has been employed to formulate the nine propositions of the LIFE. In the first step, the key findings from the previous (theory) sections, namely Lean paradigm, innovation, the systems approach and leadership, have been funnelled into the final deductions at the end of each of these sections, addressing the key research question formulated in Section 1.3. In the second step, propositions have been formulated by carefully comparing, extracting and synthesising the relevant deductions from each of these sections that can aid the promotion of Lean Innovation in engineering organisations in different ways. The following sections present the nine propositions of the LIFE and the detailed argument building behind their formulation.

2.5.1 Proposition 1 - Rediscovery of Lean Paradigm

According to Ballard *et al.* (2001), products (or services) only have value when they are used to fulfill purposes. A product is more valuable either if it allows greater fulfillment of purpose (which we call "value creation" from here onwards) or fulfills purposes at lower cost. Waste, on the other hand, can be considered anything that does not create value for the customer (Mossman 2009). As maximisation of customer value is the main objective of a Lean organisation (Womack *et al.* 1991, Womack and Jones 1996), it can be either achieved by enhancing value creation through innovation (differentiation approach) or eliminating waste (cost reduction approach) (Murman 2012). The product cost is what is exchanged for its use and it can be divided into cost to acquire and cost to use (Ballard *et al.* 2001).

The promotion of innovation in an engineering organisation is crucial for its survival in the present-day highly competitive global business environment (Grant 2012). On the other hand, the elimination of all types of engineering waste, including unused employee creativity, is essential for the successful implementation of Lean in an engineering organisation (Liker 2004). In order to reap the full benefits of Lean, both of its essential elements, i.e. waste elimination and value creation, need to be considered. However, in a conventional Lean Manufacturing environment the absolute elimination of waste (cutting costs) has been observed to be the prime objective (Browning and Sanders 2012), which according to Murman (2002) is insufficient and may not even lead to rise in revenues. On the other hand, he points out that solely focusing on the value creation aspect is also faulty as many improvement opportunities become visible only after eliminating waste.

However, Mossman (2009) notes that, in theory at least, there is no absolute definition of waste, and it is all relative (to customer value). As value can be different for each customer, the definition of waste will be different for each customer, or in other words what is waste for one customer can be value for another. This implies that aiming at eliminating waste from an organisation's processes is potentially wasteful if it is done in isolation from its value purpose (Mossman 2009). Additionally, according to Mossman (2009), primarily focusing on waste elimination (instead of value creation) diverts attention from the core purpose of any economic activity, which is creating value for customers. Furthermore, bringing waste elimination under primary focus leads to a so-called waste elimination cycle (Mossman 2009), where the amount of waste in a process increases and decreases in an oscillatory manner, depending on its organisational priority at a given time, and hence the waste elimination objective is likely to fail. Moreover, from a logical deduction, it can be inferred that waste elimination dimension of Lean paradigm is bounded (there is a limit on the amount of waste that can be eliminated) compared to its unbounded value creation dimension (further innovation is always possible) in terms of enhancing the product and service performance through innovation. Therefore an engineering organisation striving for unlimited market competitiveness through Lean Innovation should bring its prime focus on the value creation aspect of Lean paradigm compared to its waste elimination aspect. Nevertheless, as creativity is a prerequisite for innovation, one can argue that the value creation aspect in terms of innovation cannot be achieved without eliminating the waste corresponding to the untapped engineers' creativity (Liker 2004, Lean Academy MIT); however the authors think that the elimination of waste in terms of untapped creativity of engineers cannot be beneficial until exploited to create value through innovation. This implies that the final objective of the waste elimination target in terms of unlocking engineers' creativity is implicitly a value creation target. Therefore, the value creation aspect must be the prime focus of an engineering organisation promoting Lean Innovation.

On the contrary, in order to promote innovation a Lean engineering organisation should allow a certain amount of necessary non-value-adding activities (necessary waste) in terms of risk, variability, experimentation, non-standardised procedures, broader scope, etc., and the absolute waste elimination objective of a conventional Lean Manufacturing organisation can hamper its innovative capacity significantly, (Duguay *et al.* 1997, Ahlstrom 1998, Drach-Zahavy and Somech 2001). In summary, it can be inferred from the discussion above that by rediscovering the Lean paradigm, i.e. shifting Lean's focus from the waste elimination aspect to the value creation aspect, an engineering organisation can pursue long-term competitive advantage through innovation, which also explains the choice of thesis title and leads us to the following first proposition of the LIFE.

Proposition 1
Focusing on the value creation rather than the waste elimination aspect promotes Lean Innovation in an engineering organisation.

2.5.2 Proposition 2 - Separation of the Systems

There is an on-going debate in literature whether Lean philosophy and innovation can coexist (Melnyk 2007, Browning and Sanders 2012, Weber 2014). Melnyk (2007) argues that the attitudes, capabilities and culture that evolve in Lean organisations over time come into direct conflict with those required by innovation processes. Many scholars believe that Lean practices in their traditional form (Lean Manufacturing practices) can impede the innovation process (Melnyk 2007, Browning and Sanders 2012, Weber 2014) and therefore Lean paradigm needs certain modifications for its successful implementation in the R&D environment. A possible solution for promoting Lean Innovation in an engineering organisation is to separate the system meant to foster innovation (R&D system) from the system mainly responsible for physically manifesting the innovation outcome (manufacturing system) and to eliminate waste and variance as well as standardise processes in a Lean context, as proposed by Melnyk (2007). This separation of systems enables the required amount of necessary waste and risk taking behaviour needed to generate new innovative ideas in the R&D system, while aiming at eliminating waste absolutely from the manufacturing system in a conventional Lean approach (Browning and Sanders 2012). The separation of the system responsible for idea creation (R&D) and one for physically manifesting these ideas (manufacturing) facilitates effective Lean implementation in these systems with their different perception and tolerance of waste, which leads us to the following second proposition of the LIFE.

Proposition 2
Lean Innovation necessitates the separation of the R&D and manufacturing systems in an engineering organisation.

2.5.3 Proposition 3 - Holistic Perspective of Lean Innovation

A Lean engineering organisation is composed of many sub-systems that have intricate interactions among themselves, thereby having potential interactional frictions and compatibility issues (Browning and Sanders 2012). Additionally, in the Lean paradigm context, not every sub-system is suitable to Lean improvements, as there could be a conflict in the manner Lean interacts with the sub-systems, for example the Lean and innovation compatibility issue, as discussed by Browning and Saunders (2012). Furthermore, making one sub-system Lean may not necessarily make the entire system Lean, and can even reduce entire system efficiency as interactional frictions between sub-systems can create bottlenecks at the sub-system interface levels (Browning and Sanders 2012). This necessitates firstly the proper understanding of the entire system and its sub-systems as well as the complex interactions among these sub-systems, and secondly Lean's impact on these aspects taking a holistic perspective, which leads us to the following third proposition of the LIFE.

Proposition 3
Lean's interaction across different sub-systems within an engineering organisation needs a holistic perspective in promoting innovation.

2.5.4 Proposition 4 - Systems Approach to Lean Innovation

An engineering organisation seeking Lean Innovation is a very complex and unpredictable system, which includes a number of sub-systems with complicated interactions, where a minor change in one sub-system could lead to major changes in the other sub-systems or the entire system (Browning and Sanders 2012). The radical innovation process is inherently unpredictable in terms of innovation outcome (Grant 2012) and this unpredictability further adds to the overall system complexity for an engineering organisations pursuing Lean Innovation. Additionally innovation is a continuous and evolutionary process during which new information and technologies can emerge (ibid). If the innovation process is unable to incorporate this new information and technologies, its final outcome might be sub-optimal and out-dated (Robert *et al.* 2010). The backcasting from principles approach is able to handle complex, unpredictable and dynamic processes (Holmberg and Robert 2000), such as the pursuit of Lean Innovation in an engineering organisation, by initially formulating a future vision of the innovation outcome and then establishing a framework of principles that needs to be followed throughout the innovation process, thereby enabling the customisation of sub-systems and their interactions to reach this future vision (Robert *et al.* 2010). Additionally, backcasting from principles is able to incorporate new information and technologies that can emerge throughout the innovation process (ibid). In a conventional approach (e.g. forecasting) the complexity of the system is accepted (Holmberg and Robert 2000) and the extrapolation of the innovation outcome, based on the high system complexity and unpredictability of the innovation process runs the high risk of being erroneous. The pursuit of such innovation targets, without being able to include new information and technologies throughout the innovation process, can lead to waste of resources. The backcasting from principles is a major and continuous organisational process and it needs a support and guiding mechanism for its implementation in terms of an effective leadership style.

Due to their specific traits, the transformational and charismatic leadership styles are more suited to inspire and motivate others towards organisational goals (DuBrin 2010), and hence these styles can be helpful to manoeuvre a highly complex and unpredictable innovation process by entrenching the backcasting from principles approach into the organisational fabric. A transformational leader is able to bring in great change to an organisation and possesses the ability for analytical thinking therefore allowing her to understand organisational areas requiring change and prioritise resources towards the implementation of these changes (DuBrin 2010). Transformational leadership is additionally able to create an enthusiastic atmosphere towards innovation as it is able to inspire employees towards the innovation challenges (Lee and Liu 2008). However, Bossink (2007) argues that the charismatic leadership has an inherent shortcoming to follow a systematic approach to planning and problem solving in implementation of sustainable innovation. Due to this shortcoming the charismatic leadership style is less appropriate for the promotion of Lean Innovation through a systems approach. Hence, the transformational leadership style is suited to the concepts such as Lean paradigm (through transforming people, building trust and having a long term vision), innovation (through motivation and goal setting) and the systems approach (through creation of change processes, courage, effective communication, etc.) (DuBrin 2010), which leads us to the following fourth proposition of the LIFE:

Proposition 4
Complexity and unpredictability of a Lean Innovation process are effectively resolved by the backcasting from principles systems approach backed by transformational leadership.

2.5.5 Proposition 5 - Opening the Innovation Process

Similar to the open innovation idea, where an organisation opens and establishes external channels of knowledge and information (Chesbrough 2003a, Chesbrough 2003b), a Lean organisation also actively develops links with its suppliers and works closely with them in order to accomplish mutual benefits (Bhasin and Burcher 2006). This implies that the idea behind open innovation, i.e. joint innovation between an (engineering) organisation and its external partners, demonstrates great similarities with the Lean's supplier development approach (Weber 2014), and hence combining both these concepts has a high potential of creating a synergy effect within an engineering organisation with Lean Innovation. However, by opening the boundaries of the internal R&D department, an extra unpredictability is added into the Lean Innovation process, as e.g. the level of expertise of the external resources cannot be accurately evaluated (Chesbrough *et al.* 2006). Nevertheless, the backcasting from principles approach is capable of handling highly unpredictable processes (Holmberg and Robert 2000), through the use of principles that need to be conformed to at each innovation step, thereby resolving unpredictability (Robert *et al.* 2010). Furthermore, the transformational leadership style has been found to be effective for the successful implementation of the backcasting from principle approach, as established in proposition four. This implies that by systematically implementing a highly unpredictable open innovation process it is possible to boost Lean

Innovation in engineering organisations, which leads us to the following fifth proposition of the LIFE.

Proposition 5
The systematic incorporation of open innovation in a Lean engineering organisation leverages its innovative capability.

2.5.6 Proposition 6 - Systematic Customer Engagement

Customers are at the focal point of a Lean system (Womack *et al.* 1991, Womack and Jones 1996) and their identification and value expectation is very important for a Lean Engineering organisation. On the other hand, the main purpose of innovation in an engineering organisation is the value maximisation of a given product or service (Van de Ven 1986). As value is defined by the customer, its creation and enhancement through innovation is directly linked to the customer (Srinivasan 2010) as is no use of innovation if it does not create or enhance value of a product or service from the customer's viewpoint. Therefore, innovation cannot be conducted in isolation from a business perspective and it should clearly target the value creation and enhancement from customer standpoint value (Ohno 1978, Womack *et al.* 1991, Womack and Jones 1996). This makes it necessary to involve the customer in the innovative process from the very beginning to avoid waste (innovation waste), which is also the key feature of a Lean system (Melnyk 2007).

This necessitates an early and regular customer engagement throughout the innovation process that can be guaranteed by employing the backcasting from principles approach to promote Lean Innovation in an engineering organisation. This can be achieved by incorporating customer wants and needs, in terms of involving her in the principle definition phase, thereby leading to the final outcome of the innovation process (vision of innovation) (Holmberg and Robert 2000). It also renders the active customer participation throughout the innovation process less critical, however still ensuring that the innovation outcome is aligned to her vision. This establishes the effectiveness of the backcasting from principles approach to ensure that the customer requirements are incorporated throughout the innovation process in a flexible and passive manner, thereby eradicating the possibility of innovative waste (Browning and Sanders 2012). This leads us to the following sixth proposition of the LIFE.

Proposition 6
Lean Innovation through an early and regular customer engagement is achievable with backcasting from principles in a passive and flexible manner.

2.5.7 Proposition 7 - Optimisation of Information Flow

An organisation with Lean Innovation functions as an integrated whole and not as a collection of disconnected departments, and to achieve this it needs to excel in coordination and communication (Womack *et al.* 1991, Womack and Jones 1996, Murman 2012). A strong correlation between performance and coordination has been reported by Gittel (2003). Additionally, the optimised flow of information in an engineering firm is very important to eliminate pure waste that occurs due to the over-processing of and waiting for information (Liker 2004, Lean Academy MIT). However the smooth flow of information and processes are interrelated, as argued by Murman (2012), and therefore the optimised flow of information and processes needs to be ensured to promote Lean Innovation in an engineering organisation. As the backcasting from principles can be employed to establish a framework that can accommodate an efficient flow of information and processes by defining suitable principles (Holmberg and Robert 2000), it can help to eliminate waste occurring from the bottlenecks present in the information and process flows, and hence can be identified as an appropriate method of promoting Lean Innovation in an engineering organisation. Additionally, the role of leadership plays a key role in optimising the flow of information and processes, as argued by DuBrin (2010). Therefore, it can be deduced that the transformational leadership style in conjunction with the backcasting from principles approach can facilitate an optimised flow of information and processes and thereby promote Lean Innovation in an engineering organisation, which finally leads us to the following seventh proposition of the LIFE.

Proposition 7
The optimised flow of information and processes through a backcasting from principles' framework drives Lean Innovation.

2.5.8 Proposition 8 - Team Composition and Environment

Cross-functional and flexible teams composed of strong team players are at the heart of a Lean Manufacturing system and also the Lean product development system (Womack *et al.* 1991, Karlsson and Ahlström 1996, Womack and Jones 1996). The effectiveness of such flexible teams enhances the ability of an engineering organisation to promote innovation by interactively bringing various ideas from different functional departments together in new ways (Tapscott and Williams 2006). Additionally, Lean can support innovation by decentralising and democratising it (Isa and Tsuru 2002) by downplaying hierarchical supremacy (Olivella *et al.* 2008) and empowering employees (Cross 2013). However, in order to provide a clear mission and vision to these cross-functional teams, it is important to have strong and effective leadership (Ohno 1978, Womack *et al.* 1991). On the other hand leaders with an in depth multi-functional technical background are more effective in engineering services organisations promoting Lean Innovation as they are able to understand the technical limitations and create a feasible and effective vision of the future (Pullin 2005). By logically connecting the team composition and administrative structure, impact of leadership on it and leadership characteristics in the context of the key research question an inference can be made which leads us to the eighth proposition of the LIFE.

Proposition 8
Cross-functional and empowered teams in a flat organisational structure led by multi-skilled and strong leaders drive Lean Innovation.

2.5.9 Proposition 9 - Risk Mitigation through Digital Tools

Risk reduction is very important to Lean Engineering (Murman 2012). On the other hand, Sahyouni (2013) argues that if a firm is to minimise risk, it is most likely to engage in incremental innovations and not its radical counterpart, as radical innovation involves high risk, due to a number of factors, like the unpredictable outcome of innovation, unpredictable market response to the product/service based on innovation, etc. (Grant 2012). However, radical innovation is the key in creating long-term competitive advantage through differentiated products that create new markets or maximise present market share of a Lean engineering organisation (Christensen 1997). This implies that in order to gain long-term competitive advantage through radical innovation a Lean engineering organisation is exposed to relatively high levels of risk. As Lean seeks to reduce risk, the promotion of radical innovation in a Lean environment comes into direct conflict with it (Melnyk 2007, Browning and Sanders 2012, Weber 2014). This issue can be mitigated by reducing the risk involved in the radical innovation process. In the context of an engineering organisation this can be achieved by employing the integrated digital simulation tools, e.g. CAD, CAE, CAM, etc. (Murman 2012). The use of these tools can enable an engineer to check different design concepts in a relatively short time by generating and testing virtual prototypes in a digital environment instead of making and testing physical prototypes in real time (ibid). Additionally, the use of integrated design tools in the context of open innovation, where a large number of ideas can be collected from external sources in a short time, can enable a Lean engineering organisation to efficiently evaluate and commercialise the promising design concepts. Therefore the conflict mitigation between radical innovation and Lean paradigm in terms of risk is feasible through the employment of integrated digital simulation tools, which leads to the following ninth proposition of the LIFE.

Proposition 9
The utilisation of integrated digital simulation tools helps mitigate risk faced by a Lean engineering organisation seeking innovation.

2.6 The Research Model

A research model visualises the key concepts and their relationships with each other (Lopetcharat *et al.* 2012). In the present research, four key concepts can be identified that have been employed to address the key research question formulated in Section 1.3, namely Lean paradigm, open innovation, backcasting from principles and transformational leadership. Figure 2.5 depicts the research model that visually represents the interactions of these four key concepts and their interfaces with and impact on a so-called "conventional" engineering organisation (not pursuing Lean Innovation) in terms of the nine propositions thereby transforming it into an engineering organisation with Lean Innovation. An arrow in this research model represents the direction of positive impact.

It can be seen in this research model that Lean paradigm and open innovation directly interact with a conventional engineering organisation, thereby promoting Lean Innovation in it. On the other hand, backcasting from principles and transformational leadership interact indirectly with a conventional engineering organisation as they interact directly with the Lean paradigm and open innovation in terms of providing a framework of principles for their implementation in an engineering organisation and hence indirectly promoting Lean Innovation in it. However, the interaction of Lean and open innovation with a conventional engineering organisation results in a high degree of complexity and unpredictability in organisational processes that can be effectively resolved through the employment of nine propositions by addressing organisational issues such as customer involvement, team and organisational structure, information and process flow and risk management. It should be noted that few propositions in this research model appear more than once as they relate more than two key concepts.

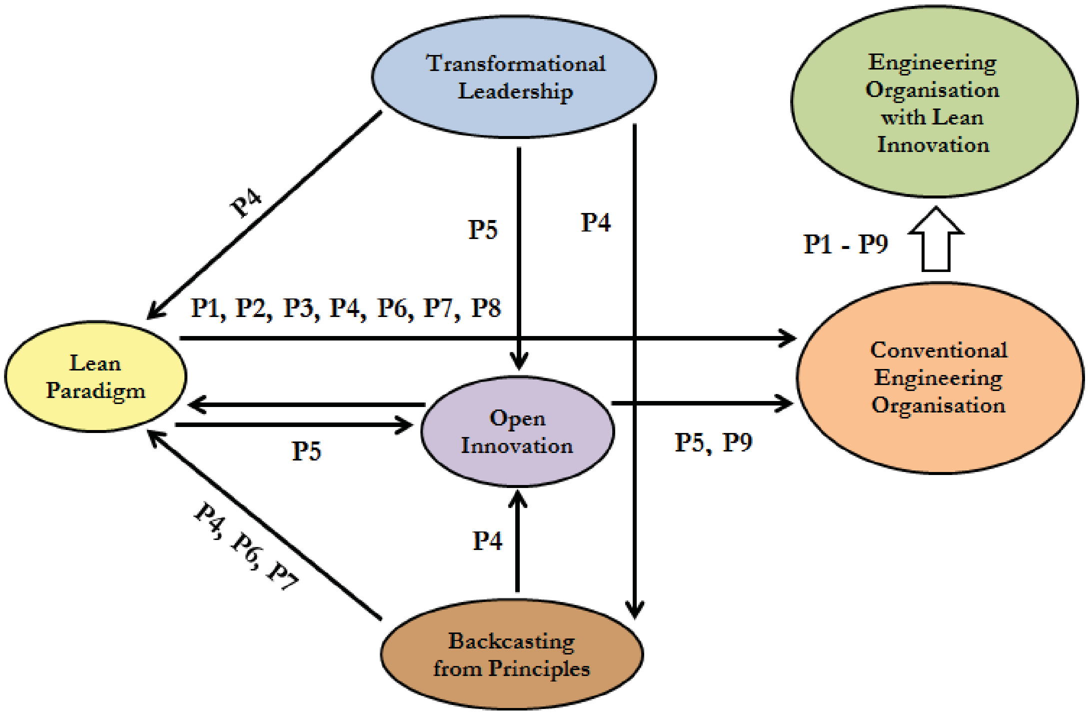

Figure 2.5 Graphical representation of the research model

3 Methods

This chapter discusses the theory behind the methodology used to conduct the empirical research in order to evaluate the theoretical framework developed in Section 2.5.

3.1 Research Design, Data Collection, Sampling and Selection Strategy

3.1.1 Research Method and Design

The first step in engaging research is to make a research method and design plan, which clearly states how to conduct the research process.

There are two distinct types of research methods employed to conduct academic empirical research, namely quantitative and qualitative research. Quantitative research involves mainly analysis of numerical data and qualitative research involves primarily analysis of data such as words and talks (e.g. interviews, questionnaires, etc.), pictures (e.g. images, videos, diagrams), or objects (e.g. artefacts) (Kothari 2004). In general, quantitative research aims to show you "what" is happening, while qualitative research on the other hand sets out to tell you "how" and "why" it is happening (Ahsan 2011). Both these research types have their merits and demerits and find their application depending on the nature of research. Since the present research mainly deals with "how" and "why" questions, qualitative research is found to be appropriate for it. Additionally, qualitative research is largely led with discussion around certain concepts or ideas (Business and IP Centre 2014) and it is highly descriptive in nature (Denzin and Lincoln 1994). Therefore qualitative research is found suitable to conduct the present empirical research.

According to Yin (2014), there are primarily five types of methods employed to conduct a research, namely experiments, surveys, archival analysis, history, and case study. Among them, surveys mainly focus on "who, what, where, how many, how much" questions, require no control of behavioural events, concentrate on contemporary events and provides researcher information about how people think and act. Considering the relative merits of surveys compared to other research methods based on the objectives of the present research, e.g. time and cost efficiency, flexibility, convenient data gathering, minor observer subjectivity, ease of design and analysis, etc., survey is adopted as the major research method for the present work.

3.1.2 Data Collection

Having selected the research method, the next important step is to select a judicious data collection technique. Interviews and questionnaires are two popular data collection techniques in the survey research method (Saunders *et al.* 2008). The selection of judicious data collection technique primarily depends on factors like, nature, scope and object of enquiry, availability of funds, time factor, precision required, etc. (Kothari 2004). As the main objective of the present empirical research is to examine the theoretical framework developed in Section 2.5, the (expert) interview data collection technique has been chosen for it as, in contrast to the questionnaire data collection technique, it facilitates the discussion in an interactive manner that allows the researcher to gather in-depth expert reflection on the subject matter, which can in turn be used to revise and/or extend the initial hypotheses (propositions). According to Kothari (2004), an interview can be either structured on unstructured. A structured interview employs a highly rigid interview process in terms of a pre-determined order and form of questions. An unstructured interview is flexible in its questioning method and the interviewer can even ask follow-up questions on the subject matter during the interview (ibid). In this context, a semi-structured interview procedure has been employed, where the discussion has been initiated by asking the interviewees' opinion on the propositions in a structured manner and then steering the interview in a flexible and unstructured manner by asking follow-up questions to deepen the understanding on the subject matter. The interview method of collecting data involves presentation of oral-verbal stimuli and reply in terms of oral-verbal responses, and it can be conducted through personal face-to-face interviews or through telephone/internet interviews (Cannell and Kahn 1968, Infinite Ideas 2012). Based on the availability of research relevant experts, both personal and telephone/internet interviews are conducted. There are four instruments to conduct a successful interview, namely a short questionnaire, interview guideline, audio recording of the discussion and a postscript (Arthur and Nazroo 2003).

The first interview instrument, the short questionnaire provides an insight to the social characteristics (age, gender, hierarchical position within the firm, etc.) of the interviewee without being obstructed by question that follow such simple question answer scheme. The second interview instrument is an interview guideline that can be seen as a mechanism for initiating and steering the discussion in an interview, thereby ensuring that the relevant topics and issues have been covered systematically with a maximum flexibility corresponding to a specific interviewee (Rubin and Babbie 2010). For example, the interviewer may adjust the order and wording of the questions. Additionally, when more than one interviewer is involved in the data collection, as it is the case in the present work, an interview guideline makes sure that different interviewers will cover the same prescribed topics while remaining conversational and free to check for unexpected responses and topics that appear during the interview (Rubin and Babbie 2010). According to Rubin and Babbie (2010), an interview guideline has to be as open and flexible as possible and as structured as necessary for the research interest. The interview guideline used in the present work comprises of the nine propositions developed in Section 2.5 and is presented in Appendix E. In the context of directed content analysis employed for the analysis of empirical data, the use of the propositions as interview questions is justified (Hsieh and Shannon 2005), as discussed in Section 3.4.1 in detail. Audio recording, the third instrument, is useful so that the complete interview can be recalled at later stages and all of its contents can be analysed in more depth and details. Additionally, the interviewer needs not to actively note down the complete interview and she can pay more attention to keep the flow of interview and pay more attention to the non-verbal aspects of the interview (Saunders *et al.* 2008). Finally, the fourth interview instrument, the postscript, is written directly after the interview by the interviewer to record the remarks related to the situational and non-verbal aspects observed during the interview.

3.1.3 Sampling and Selection Strategy

Sampling and selection strategies are important as in most cases it is not useful or even practically possible to interview the entire population (Kothari 2004). For this reason, sampling and selection techniques enable a researcher to reduce the amount of data she needs to collect by considering only data from a sub-group (sample) rather than the whole population (Saunders *et al.* 2008). Due to the highly versatile nature of the present research in terms of integrating different theoretical concepts corresponding to Lean, innovation, systems approaches and leadership, which makes it challenging to find interviewees with such expertise, a relatively small but a cross-industrial and cross-national data sample has been employed in the present empirical research.

There are three basic approaches available in literature on selecting a sample for qualitative research, namely convenience sample, judgment sample and theoretical sample (Weber 2014). The convenience sample involves the selection of the most reachable and eager to participate subjects. This sampling strategy is very cost efficient, however it may lead to empirical data lacking quality and intellectual credibility (Marshall 1996). Judgement sample is the most common sampling technique where a researcher selects the sample on the basis of her judgement to find the answer of the research question (Marshall 1996). Marshall (1996) identifies different variants of judgement sample technique. Among them, the maximum variation sample variant is useful to investigate a broad range of subject, the critical case sample variant for subjects who have specific experiences, the key informant sample variant for special expertise and snowball sample variant for subjects who may be able to recommend other useful candidates to study. Since the qualitative study design involves the iterative process, samples are usually theory driven to a greater or lesser extent (Glaser 1978). Theoretical sampling technique seeks building interpretative theories from the emerging data and selecting a new sample to examine and elaborate on this theory. Since the present research has a strong exploratory character and a limited timeframe for its accomplishment, it has been found appropriate to employ the judgment sampling strategy in combination with the key informant (special expertise) technique (Marshall 1996).

According to Schutz (1979), an expert (key informant) is a scientist who can reveal and communicate specific and explicit knowledge at any time. In order to explain Schutz's notion of the expert, Bogner and Menz (2009) describe expert knowledge as "special knowledge". Additionally, Schutz and Sprondel argue that the expert's special knowledge is immediately accessible while everyday knowledge is scattered and is not immediately accessible (Bogner and Menz 2009). According to Bogner and Menz (2009) there are three basic dimensions of expert's special knowledge, namely technical knowledge process knowledge and interpretative knowledge. Technical knowledge of an expert refers to information, i.e. about operations and control processes, field related application routines, bureaucratic competences, and provides a specific advantage through a difference between expert knowledge and everyday knowledge due to its systematisation and content specificity. Process knowledge consists of information about sequences of actions, routines, interactions, organisational constellations and past or current events and the expert gains it either through direct practical activities in her field or by observing activities in her immediate environment. Interpretative knowledge is gained through the expert's subjective orientations, points of view, rules and interpretations, i.e. it constitutes of ideas, ideologies, inconsistent configurations of meaning, and patterns of explanation (ibid.). An important issue in collecting data through expert interviews is access barriers in terms of gaining access to selected experts in high level organisational hierarchy and time restrictions as scientific research is unfortunately not always a top priority (Burke and Miller 2001). This work recognises an expert as someone who has specific and in-depth knowledge on the four core issues addressed in this work (Lean paradigm, innovation, backcasting systems approach and leadership). An ideal expert would possess knowledge in all the theoretical concepts investigated in this work; however the present sample does not fully comply with this optimal scenario as these theoretical concepts have not yet found mainstream utilisation in industry and are more of academic nature presently.

3.2 Sample Description

The underlying sample of the present empirical research consists of a total number of six experts, as summarised in table 3.1. Tomasz Krysinski is chosen as an expert due to his extensive experience in innovation processes in the R&D department and his organisational seniority status pointing to his leadership qualities. Elaine Daly is chosen as an expert due to her extensive knowledge of the systems approach to solving highly complex problems. Denver Dreyer is chosen as an expert due to his significant experience in managing engineering consulting teams and his expertise in business development where he gained knowledge in Lean management and leadership. Henry Jonker is chosen as an expert due to his expertise in leadership, his extensive experience in project implementation in engineering services and his good understanding of Lean principles gained through his work and Executive MBA studies. Norman Faull is chosen as an expert due to his expertise in Lean implementation and substantial experience in Lean Manufacturing as well as his leadership knowledge. Rogier van Beugen is chosen as an expert due to his profound experience in innovation and in particular in the optimisation of innovation processes as well as his seniority in a large multi-national organisation and hence his leadership knowledge and capabilities. A detailed profile description of these experts is provided in Appendix E.

#	Expert	Position	Company	Industry	Country
1	Tomasz Krysinski	Head of Research & Innovation	Airbus Helicopters	Aerospace	Germany
2	Elaine Daly	Programme Assistant	Blekinge Tekniska Högskola (BTH)	System Design Consultancy /Academia	Sweden
3	Denver Dreyer	Executive	Worley Parsons	Engineering Consultancy	South Africa
4	Henry Jonker	General Manager	Worley Parsons	Engineering Consultancy	South Africa
5	Norman Faull	Emeritus Professor of Business Administration	University of Cape Town – Graduate School of Business	Production & Operations Management /Academia	South Africa
6	Rogier van Beugen	Director Innovation	KLM Royal Dutch Airlines	Airline	Holland

Table 3.1 Overview of the interviewed experts

3.3 Implementation and Data Preparation

According to Kvale (1996), there are seven stages in designing and implementing an interview based empirical research, namely thematising, designing, interviewing, transcribing, analysing, verifying, and reporting. The previous sections have covered the first two stages in detail and this section is mainly devoted on the next two stages, i.e. interviewing and transcribing. Burke and Miller (2007) structure an interview in a pre-interview phase, during-the-interview phase and a post-interview phase. Similarly, Kvale (2007) refers to pre-interview and a post-interview phases. The pre-interview phase involves activities which need to be performed before conducting an interview, i.e. planning, pre-testing and organisational issues. A pre-test can be employed in terms of a pilot study, conducted on a few people from the targeted sample to verify the effectiveness of the interview guideline before actually collecting data in the field, thereby serving to find out the most logical sequence of the topics and question and to identify wording issues, which could have a negative impact on integrity of the data collected (Burke and Miller 2001). Additionally, a pre-test helps to determine the approximate interview duration that needs to be clarified in advance since this might be one of the first questions a researcher would be asked by the potential interviewee (Witzel 2000). Furthermore, ethical considerations should be made in all phases of the interview process since qualitative research may examine deeply into sensitive and confidential information (Brinkmann 2008). Therefore, confidentiality, informed consent and a consideration of the ramifications of participating in the research should be taken as ethical rules of thumb (Given and Saumure 2008).

In the present work, the first interview conducted is considered as the pre-test, however it is found that the information gathered in this pre-test interview is relevant; therefore this interview is employed in the data analysis. This further establishes that the interview questions are clear and relevant and they can be used for the collection of empirical data. All the interviews are recorded using a digital audio recorder, so that the data collected could be transcribed and analysed effectively at a later stage. In the next step, audio recordings are converted from audio data into textual data (transcription). Although software programs can be used to structure and code the audio data collected in the form of text (McLellan *et al.* 2003), due to the small sample size, lack of expertise in interviewing, interviews are transcribed fully but only on a basal level in the present work (transcription rules are not applied). As the principal interest of the present research lies in the thematic and content information, breaks, empty phrases, fillers and other non-content-related articulations, like tone of the voice, emphasis or laughter are not transcribed. Finally, from the ethical standpoint, informed consent is sought at the beginning of the interview and copyright of interviewees' words and (confidential) company information are taken into consideration.

3.4 Data Analysis

According to Kothari (2004), the process of data analysis and data collection are necessarily interactive. Data analysis allows a researcher to interact with her qualitative data in order to comprehend it, to integrate related data drawn from different transcripts and notes (interviews), to identify key themes and patterns from them for further exploration, to develop and/or test theories based on these apparent patterns or relationships and to draw and verify conclusions (Miles and Huberman 1994, Kvale 1996, Kothari 2004). According to Hsieh and Shannon (2005), qualitative data content analysis can be describes as a research method for the subjective interpretation of textual data by applying a systematic process of coding in order to identify themes or consistent patterns.

Hsieh and Shannon (2005) propose three basic approaches to interpret and analyse textual data, namely conventional content analysis, directed content analysis and summative content analysis. The major differences among these three techniques are based on the coding schemes, origin of codes, and their influence on the trustworthiness of the research (ibid.). In the conventional content analysis, the researcher derives coding categories directly for the data collected. In the directed content analysis, the starting point for the analysis is theory or relevant findings as a direction for initial codes. The summative content analysis is all about counting and comparisons, usually of keywords, followed by the interpretation of the underlying context (Hsieh and Shannon 2005). The directed content analysis technique, also referred to as deductive qualitative research (Gilgun 2011), has been used in the present work to analyse the empirical data collected through expert interviews.

3.4.1 Directed Content Analysis

The directed content analysis is chosen in this work as it is the preferred technique when the purpose is "to validate or extend conceptually a theoretical framework or theory" (Hsieh and Shannon 2005) and the analysis structure is "operationalised on the basis of previous knowledge" (Elo and Kyngäs 2008). As the theoretical framework in terms of nine propositions has already been developed in Section 2.5, it is the aim of the present empirical qualitative research to examine these propositions, and therefore the directed content data analysis technique is most suitable to fulfil this objective.

According to Hsieh and Shannon (2005), in the context of directed content analysis, targeted questions about the predetermined categories (propositions) can be employed to collect the empirical data through interviews. However, if necessary, targeted follow-up questions are employed during the interview to obtain better insight into the subject matter. It is important to note that the key issue that differentiates the directed content analysis from the conventional content analysis is that in the former technique the existing theory or research (propositions) is at the focal point of the research/interview question while in the latter several open-ended questions with an implicit focus on the researched issue are asked from the interviewees and this data is used to formulate a new theory or hypothesis (propositions) (Hsieh and Shannon 2005). While the directed content analysis can be considered as somewhat biased compared to the conventional content analysis, the latter can be plagued by its inability to develop a complete understanding of the context, thus failing to identify key categories and develop a hypothesis (ibid). The choice of which of these two techniques to employ in a qualitative empirical research depends on whether the aim is to validate an existing hypothesis or develop a new hypothesis.

In general, content analysis involves one or more of: editing (summarising) data; classifying (categorising) data; coding data using narrative to recognise relationships and tabulating data, and finally developing and testing propositions to produce well-grounded conclusions. Kothari (2004). The editing step is not necessary with the present empirical data as during the transcription of expert interviews the non-thematic and non-content related information has already been omitted, as indicated in Section 3.3. The empirical data is classified and coded in Chapter 4 on the basis of the nine propositions developed in the theoretical framework. This means the nine propositions become the codes (prior codes) themselves as it is the case in the deductive qualitative (directed content) analysis

(Gilgun 2011). Once the code is defined, open coding is employed (ibid), i.e. sweeping through the data and marking parts of the transcript that affirm the propositions (codes) to test the viability and usefulness of the codes. In the next step, the negative case analysis is performed by looking for parts of the transcripts that can add to, undermine, and even refute the codes by employing the open coding technique (ibid). This enhances the credibility of the empirical research. Finally, in order to examine the propositions, an analysis is performed on the coded data related to each proposition where the opinions of interviewed experts to the propositions are summarised, analysed and linked to literature in Chapter 5.

3.5 Validity, Reliability and Trustworthiness

Validity and reliability of the research is very important to qualitative researchers in terms of its trustworthiness as it provides them a set of tools by which they can demonstrate the worth of their research outside the boundaries of the often ill-fitting quantitative parameters (Given and Saumure 2008). In their seminal work on the trustworthiness of qualitative research, Lincoln and Guba (1985) argue that the trustworthiness is established through credibility, transferability, dependability, and confirmability.

The credibility criterion is comparable to internal validity in a traditional sense and it involves establishing that the results of qualitative research are credible or believable from the perspective of the research participant (Given and Saumure 2008). In order to establish the credibility of qualitative research, the researcher makes sure that the data is presented accurately (Lincoln and Guba 1985), which can be achieved through various strategies, e.g. by employing prolonged engagement in the field, the triangulation of different methods, researchers and data, or negative case analysis (William 2006). The transferability criterion is comparable to external validity in a traditional sense and it refers to the degree to which the results of qualitative research can be generalised or transferred to other contexts or settings (Given and Saumure 2008). According to Given and Saumure (Lincoln and Guba 1985), quality of research findings can be judged by how well others can determine to which alternative contexts these findings might be applicable, or in other words from the degree of transferability of qualitative research, which can be increased through a thick description (Weber 2014), i.e. by describing the studied phenomenon in-depth and in proper context so that other researchers can assess the extent to which the findings are transferable to other times, settings, and people (William 2006). The dependability criterion is comparable to reliability in a traditional sense and it is based on the assumption of repeatability, i.e. whether we would obtain the same results if we could observe the same thing twice (Lincoln and Guba 1985). According to Lincoln and Guba (1985), reliability is deemed to be a precondition for validity since measures that are unreliable cannot be valid. However, reliability can be hard to achieve for researchers in an ever changing social world, therefore dependability is a more accurate notion in the qualitative context, where the researcher provides as much transparency as possible regarding her procedure and research instruments in a manner such that others can attempt to collect data in a similar setting (William 2006). Finally, the confirmability criterion is comparable to objectivity in a traditional sense and it refers to the degree to which the qualitative research findings could be confirmed or corroborated by others.

In establishing the trustworthiness of this qualitative research, it can be said that the present research is transparent and it follows a sound methodology and hence it fulfils the criteria of credibility and transferability. Separate sections of the theory chapter have been devoted to discuss the notions of Lean, innovation, leadership and backcasting systems approach in detail and all these concepts have been subsequently condensed into a theoretical framework. Similarly, the methodology employed for the empirical research is described in detail in the present chapter. However, as techniques to increase the degree of credibility, e.g. by employing the prolonged engagement in the field, the triangulation of different methods, could not be utilised in the scope of this research, the authors' think that the degree of credibility of the present research lies in the medium range. Nevertheless, data triangulation and to certain degree negative case analysis have been employed in the present research. The data triangulation is achieved by collecting data from experts with very diverse backgrounds, which is a data triangulation type referred to as triangulation of sources, where sources with differing viewpoints on the subject matter are compared (Denzin 1978, Patton 1999). The negative case analysis has been incorporated to a certain extent by searching for and discussing elements of the data that do not support or appear to contradict patterns or explanations that are emerging from data analysis. This approach has increased the degree of transferability and dependability as the findings of the present qualitative research can be easily applied to other services industries where the Lean philosophy and innovation are sought to coexist. Finally, the present research is partly biased due to the use of directed content analysis to analyse the empirical findings in terms of employing these findings to evaluate the developed propositions, as discussed in detail in Section 3.4.1. Therefore, the confirmability of this study can be deduced of the medium degree.

4 Empirical Findings

This Chapter summarises the empirical findings in terms of the relevant excerpts/phrases extracted from the expert interview transcripts. The empirical findings collected through expert interviews are coded by sweeping through the transcripts and marking parts of each transcript that affirm, negate or supply additional thoughts on the nine propositions (codes) developed in Section 2.5. These findings are summarised in table 4.1 and presented in the following sections in terms of confirmations, negations and additional thoughts.

Proposition	Confirmation	Negation	Additional Thoughts
1 - Rediscovery of Lean Paradigm	Krysinski, Daly, Dreyer, Jonker, van Beugen	Faull	Krysinski
2 - Separation of the Systems	Krysinski, Daly, Dreyer, Jonker, Faull, van Beugen		
3 - Holistic Perspective of Lean Innovation	Krysinski, Dreyer, Jonker	Faull, van Beugen	Krysinski
4 - Systems Approach to Lean Innovation	Krysinski, Daly, Dreyer, Jonker, Faull, van Beugen		Daly, Dreyer
5 - Opening the Innovation Process	Krysinski, Daly, Dreyer, Jonker, Faull, van Beugen		Krysinski, Daly, Jonker
6 - Systematic Customer Engagement	Krysinski, Daly, Faull	Krysinski, Dreyer	Daly
7 - Optimisation of Information Flow	Krysinski, Daly, Dreyer, Jonker, Faull, van Beugen		
8 - Team Composition and Environment	Krysinski, Daly, Dreyer, Faull, van Beugen	Jonker	Daly
9 - Risk Mitigation through Digital Tools	Daly, Dreyer, Jonker, Faull	Krysinski	

Table 4.1 Summary of empirical findings

Proposition 1 - Rediscovery of Lean Paradigm

Focusing on the value creation rather than the waste elimination aspect promotes Lean Innovation in an engineering organisation.

Confirmations

When asked about their opinion on proposition one, different experts agreed in the following manner:

“Yes, this is right but when you really speak about innovation, value creation and not just incremental innovation. […] 95% (in innovation process) is (necessary) waste.” ~Krysinski

“I would say that value creation probably has a higher importance. If you only focus on waste elimination I think that you would miss out on new products that would come from value creation, or the new services that come from a mindset which has a strong focus on value creation. […] Definitely, I feel that value creation is more important within an innovative environment. […] Yes I think it (necessary waste) is definitely required (in innovation process).” ~Daly

“So I think you’re right. I actually think value (creation) is more important than waste elimination. […]. You need to allow guys (R&D) to be divergent in their thinking. I think you need to have a certain amount of (necessary) waste.” ~Dreyer

“I like this proposition, because if you focus on waste elimination you reach a limit […] when you focus on innovation, value creation, it is unlimited.” ~Jonker

“If I had to pick I would usually pick business case driven, and there is more to be gained than by waste elimination as you are maybe not extending your revenue pool.” ~ van Beugen

Negations

“Waste elimination and value creation are two sides of the same coin […] Unless you eliminate waste you can’t add value. […] You’ve got to hold those two concepts together in order to make progress.” ~Faull

Additional Thoughts

Krysinski highlights the significance of the waste elimination dimension of the Lean Innovation process as follows:

“So the Lean Innovation process is a process that allows you to kill bad ideas as quickly as possible, and a good Lean Innovation process is a process very high rate of mortality and allowing only good ideas to go through this process.”

Proposition 2 - Separation of the Systems

Lean Innovation necessitates the separation of the R&D and manufacturing systems in an engineering organisation.

Confirmations

“Yes, it is true. They should be separated and not under the same management. […] My experience is that whenever you have something really disruptive, you must validate it and push it outside the normal process, because value creation is very disruptive one.” ~Krysinski

“Separated as in their finances are separated and their management is separated then maybe yes. […] i.e. how they (the manufacturing and R&D systems) account for funding and how they have vigorous rules around waste should probably be different.” ~Daly

“If you had it separate you would have people (R&D) thinking about new ideas all the day.” ~Dreyer

“Look, when you separate them they would keep each other honest. […] so in your manufacturing your Lean is waste focussed and in the R&D your Lean is value creation focussed.” ~Jonker

"So the initial stage (of Lexus engine development) was disconnected from manufacturing but there was a clear understanding that they had to translate this thing into a manufacturable entity." ~Faull

"Sure I can see the value in that approach […] On the one hand we are very operationally focused […] but it needs to be balanced by sort of a time when you try new stuff which is a sandbox environment." ~ van Beugen

Proposition 3 - Holistic Perspective of Lean Innovation

Lean's interaction across different sub-systems within an engineering organisation needs a holistic perspective in promoting innovation.

Confirmations

"You know what you want to say is that the local optimum is not the same as the global optimum. Yes, of course it is true." ~Krysinski

"For me I think it is vital. […] So I feel that a systems perspective with a focus on the interconnections is required because I feel that is the bit that we have been missing for many years." ~Daly

"Absolutely. […] So I think it's critical that any good organisation wanting to optimise their processes and get value add has to do that." ~Dreyer

"That was quite an easy one (proposition) to relate to. At the end of the day we need a holistic solution, not just an individual solution." ~Jonker

Negations

"You simply can't do Lean across a whole organisation, at a situational level and a strategic level and a systemic level all at the same time. […] you have to actualise the problem […] And certainly in my own thinking you start at the situational level and you do, as you run into problems you understand if they are at a situational or at a system level and you respond accordingly." ~Faull

"I would say that it sounds very theoretical, meaning that I am not sure if this is a questions that will resonate in practice." ~van Beugen

Additional Thoughts

Krysinski also adds:

"It is better to change, you know, but you should in your study discuss about the virtuous circle of innovation."

Proposition 4 - Systems Approach to Lean Innovation

Complexity and unpredictability of a Lean Innovation process are effectively resolved by the backcasting from principles systems approach backed by transformational leadership.

Confirmations

"Setting and achieving the innovation vision by creating and following certain rules is very important as the innovation is a very complex and uncertain process. What is fundamental in such process is the mindset that you call transformational leadership, which is actually openness to the change." ~Krysinski.

"I think for me the backcasting systems approach is the overarching one. […] I would see systems thinking as a key trait (leadership) if you're going to use backcasting as an approach […] So I think a strong communication capacity, […] So having that collective vision of the future I think is also a very important trait." ~Daly

"I think it (backcasting from principles approach in innovative environments) would (work) because if the leader does not set, determine the environment and create an environment of innovativeness which allows innovative thinkers to flourish, to be retained in the organisation to be attracted to your organisation the organisation is doomed." ~Dreyer

"I can quite accept that as being quite acceptable with a prime focus on innovation. […] You know what I like about the proposition in this state with backcasting from principles is that you can only do it in conjunction with people that can have the ability to transform the organisation." ~Jonker

"One certainly needs a systematic style of leadership. Simply motivational or charismatic will not endure." ~Faull

"We would definitely be more on the principles side. […] I agree. Transformational leadership, if you really want to make an impact it is very important." ~van Beugen

Additional Thoughts

Daly proposes a hybrid systems approach in order to exploit the benefits of different systems approaches, as presented below:

"When I think there is a hybrid option between the two (backcasting and forecasting) where you take the best from both worlds. […] I think that backcasting from principles gives you a rigorous boundary condition. […] So you can use the scenarios as a motivational tool, or as an idea generator. […] With respect to forecasting I think you definitely need to look at past trends and I think you need to look at them in a really honest way and I think it's really necessary to view the flows that are currently going into the situation."

Dreyer indicates that in some engineering services sectors, e.g. nuclear power generation, petrochemical, etc., reliability of the design is more important to the client than additional design performance:

"We are actually quite a reactive organisation that follows tried and tested principles and our clients drive that. I can't relate to that."

Proposition 5 - Opening the Innovation Process

The systematic incorporation of open innovation in a Lean engineering organisation leverages its innovative capability.

Confirmations

"Yes, it's clearly the case as in a good innovation process idea can come from anywhere. […] Yes, you know ideas can go out. […] Somebody who thinks that he will close the office and do innovation in the office is wrong. He should be open minded, should listen, should share what can be shared, specially analyse what is going outside to have proper inputs." ~Krysinski

"I think it can. I think it needs to be designed with skill. […] Yes I believe that open innovation can offer huge advantages. I think it offers a completely different way of looking at value. […] So I think we are now actually looking at value as in sharing, not in holding things secret." ~Daly

"If you want to go forward you have to have fortitude to get that feedback, and I guess the openness to facilitate that type of session. Yes I think it's crucial." ~Dreyer

"So the openness really plays into our hands and we are quite comfortable with the open environment and open innovation." ~Jonker

"… it's a great idea but I can see companies large and small saying I am not sure that I can trust this other partner to play the game." ~Faull

"So we are doing it more and more, we are trying to run an open innovation culture where we ask outside partners to think with us […] I would agree with having a framework." ~van Beugen

Additional Thoughts

Krysinski highlights the following practical issue:

"The innovation must be guided by very strong result requirements."

Daly points out the need of new business models for successful exploitation of open innovation approach:

"So I think we need to shift that (the closed innovation approach) as well and look at different business models that can support open innovation."

Jonker emphasises on setting boundaries to the knowledge and information sharing in open innovation:

"Your openness must be bounded to a certain extent, it can't be completely unbounded."

Proposition 6 - Systematic Customer Engagement

Lean Innovation through an early and regular customer engagement is achievable with backcasting from principles in a passive and flexible manner.

Confirmations

"What your proposition says is perfectly true as any innovation is customer related. If there is no value creation it is no innovation, it is research." ~Krysinski

"I definitely think that having the customer's voice present early on in the design process is vital. […] I do think that if you align that with principles in backcasting from principles I think you need to look at, for me, I would look at the needs and desires of the customer […] I think those principles are the guiding constraints of your design." ~Daly

"As a general statement I would agree with that." ~Faull

Negations

When asked whether customer involvement in the innovation process should be active or passive, different interviewees respond as follows:

"Actively. You know in the commission the quality gate is some kind of process where you do what you do always with your ideas and you have the customer participating." ~Krysinski

"We wouldn't do that (passive involvement). We would involve them at the stage gates or the holding points." ~Dreyer

However, Krysinski continues on highlighting the issue of customer's rejection of innovation in its early phase as follows:

"Customers sometimes don't realize what the innovation can bring to them. They can kill it too quickly."

However, he agrees on the effectiveness of the backcasting from principles approach to mitigate this problem:

"Yes, I think your proposition can help to resolve the premature rejection of a good innovation by customer in its early stages."

Additional Thoughts

Daly highlights the importance of providing customers the right solution for their need that goes beyond their perception:

"You can actually better design a product or a service that will go beyond what the current customer is expecting. I think that's where real value comes in if you can really look at what the customer really needs and wants and design for that."

Proposition 7 - Optimisation of Information Flow

The optimised flow of information and processes through a backcasting from principles' framework drives Lean Innovation.

Confirmations

"This is true what this proposition is suggesting. […] Nothing can replace the real decision taking." ~Krysinski

"Definitely. Not only just of innovation but also (stimulation) of decision making authority. […] I think communication is often values based which may or may not be principles. […] Personally I would call them agreements, I wouldn't call them principles. […] I think agreements are softer and suit better the soft elements of communication." ~Daly

"So you need to have a process to bring people together, to allow that information to be interchanged and discussed. […] Both the use of the system and the provision of the system are absolutely essential." ~Dreyer

"But look at it, if you analyse it to take time to back it that makes sense. I don't have too much of a problem, the flow of information activities and processes in a Lean engineering organisation promoting innovation can be optimised." ~Jonker

"So I suppose that I am arguing that a structured way of communicating, where we agree when we are going to communicate (and) about what […] interruptions are a major source of quality errors in every industry. […] Stability is a hugely important principle. […] Variability causes resource and service inefficiency." ~Faull

"Correct. So availability should be structured so on intranet or forum and offered in a structured way but it should not be distributed that way." ~van Beugen

Proposition 8 - Team Composition and Environment

Cross-functional and empowered teams in a flat organisational structure led by multi-skilled and strong leaders drive Lean Innovation.

Confirmations

"I fully agree with it. […] This team must be empowered by the Exco's of the company. […] The Lean Innovation requires special management spirit, special management skills, which should be the mixture of the management background technical background, let's say open mindedness." ~Krysinski.

"I think that not only just within the engineering field but within most of our organisational structures that we are missing that cross-level communication […] I think it (flat organisational structure) is definitely more beneficial than a rigid hierarchical one. […] So I still see in certain circumstances that a hierarchy can be very important if I'm comparing it to the traditional hierarchical decision makers. […]
I think multi-skilled (team leader) is very important." ~Daly

"You'd be surprised what you get if you empower people. […] I think flat is better than complex hierarchies. […] I think if you want to stimulate innovation you need far more of a generalist (multi-skilled) than a specialist." ~Dreyer

"… in general I would say yes I agree with that proposition. […] in general I would say that flat is better that hierarchical but I am not a great fan or there is no boss and they all just muddle along together." ~Faull

"It is at least what we are trying now. […] So we have developed this strategy where we put important projects into small, transferable, cross-functional teams but I am not sure if our culture is ready for that. And so we will see how it works." ~van Beugen

Negations

"How do you keep them working to a common focus? […] So that one (proposition) didn't appeal for me so strongly." ~Jonker

Additional Thoughts

Daly differentiates between leaders with multiple skills (trans-disciplinary) and multiple academic degrees (multi-disciplinary):

"I think there is this notion of multi-disciplinary and there's also the notion of trans-disciplinary. […] but I still think there is another level above that of individuals (multi-disciplinary) who hold that full systems perspective (trans-disciplinary)."

Proposition 9 - Risk Mitigation through Digital Tools

The utilisation of integrated digital simulation tools helps mitigate risk faced by a Lean engineering organisation seeking innovation.

Confirmations

"I definitely think using software is definitely a benefit. […] I think not making use of them is actually going against the flow and probably damaging your organisation." ~Daly

"There's push and pull factors. We certainly want to push new technology and new advances but the clients don't always pull." ~Dreyer

"So if you look at what we do, we design in full 3D packages […] which give you that innovation and client interaction which, without having built it." ~Jonker

"… one has inevitably got to do that. Even if those technologies fail you can't wait until they have proven themselves to be not valuable, you have to experiment with the technology. […] but on the other hand what I see in Toyota is: how can we experiment in a simple common sense way, rather than building a realistic physical model or spending a lot of time building a simulation." ~Faull

Negations

"You should not limit it only just on the digital tools. It is not only this, very limited way and I do not fully approve it. […] Digital is ok, it is one part of the picture, you do not play digital games. So it's too limited the way you formulate it. It is engagement commitment of the people." ~Krysinski

5 Analysis

This chapter presents the theoretical analysis of the empirical findings presented in Chapter 4 in the light of various theory streams from literature.

5.1 Lean Innovation - A Shift in Lean Paradigm

Customer value maximisation is at the heart of a Lean organisation (Womack *et al.* 1991) and it can either be achieved by enhancing value creation through innovation or waste elimination (Murman 2012). However, both these aspects of Lean are equally essential, as noted by Murman (2002), who argues that focusing exclusively on one of these two dimensions can hinder in reaping the full benefits of a Lean system. Only eradicating waste is insufficient and may not even lead to revenue rise, while the complete focus on creating value is equally faulty as improvement opportunities usually become evident only after waste elimination. Faull (interviewee) endorses this notion by stating that the value creation and waste elimination aspects of Lean are two sides of the same coin and unless you eliminate waste you cannot add value and that you have got to hold those two concepts together in order to make progress, which is in agreement with classical Lean literature (e.g. Ohno 1978, Womack *et al.* 1991). This Lean philosophy is suited to the manufacturing sector, however it becomes too restrictive in an innovative environment as it can hamper innovative capacity significantly (Duguay *et al.* 1997, Ahlstrom 1998, Drach-Zahavy and Somech 2001). Additionally, innovation, especially radical innovation, as argued by Grant (2012) is the key for the growth of an engineering organisation in the cut-throat business world of today. Krysinski (interviewee) agrees with this notion by emphasising the point that radical and not incremental innovation is crucial for an engineering organisation to remain competitive.

According to Mossman (2009), there is no absolute definition of waste and waste is relative to customer value and hence what is waste for one customer can be value for another, which implies that eliminating waste from an organisation's processes is useless if it is performed in isolation from its value purpose (Mossman 2009). Furthermore, Mossman (2009) argues that focusing solely on waste elimination diverts from the main aim of any business that is value creation for customers. Interviewees Daly and van Beugen support these views by emphasising that a sole focus on waste elimination would cause an engineering organisation to fail to bring new services and products to the market by exploiting innovative ideas, thereby failing to grow their revenues. On the other hand, innovation, especially radical innovation (Grant 2012), is the key for an engineering organisation's growth and survival in the present-day cut-throat business world (Schulze and Störmer 2011). Krysinski (interviewee) agrees with this notion by emphasising the point that radical and not incremental innovation is crucial for an engineering organisation to remain competitive. Driving innovation further is always possible, however the same cannot be said for waste elimination (Murman 2002, Murman 2012). It is therefore judicious to deduce that Lean's waste elimination dimension is bounded compared to its unbounded value creation dimension and hence an engineering organisation must emphasise on the value creation aspect of Lean philosophy in order to secure long-term competitive advantage. In expressing his opinions on Lean's two dimensions, Jonker fully supports this deduction.

However, scholars are still divided on the issue whether Lean and innovation are compatible. Scholars such as Wynett *et al.* (2002), Hale and Kubiak (2007) and Browning and Heath (2009) argue that Lean (Manufacturing) practices also eradicate the necessary waste needed to derive innovation that results in hampering innovative capabilities of an organisation. In contrast, some scholars think that Lean can promote innovation, e.g. by turning employees to multi-skilled workers (Duguay *et al.* 1997, Ahlstrom 1998), by employing cross-functional and flexible teams (Womack *et al.* 1991, Tapscott and Williams 2006), by downplaying hierarchical supremacy (Olivella *et al.* 2008) and empowering employees (Cross 2013) and by freeing resources (Chen and Taylor 2009) to drive innovation (Schiele 2009, Cross 2013). The view that Lean can promote innovation has been backed by different experts in various ways, e.g. Dreyer (interviewee) prefers a generalist leader over a specialist and Krysinski emphasises the importance of leadership with both management and technical backgrounds, which is in line with Pullin's argument (2005) stating that the creation of an effective and reachable future vision (management skills) and understanding of technical limitations (technical skills) are two important attributes of effective leadership for engineering organisations seeking Lean Innovation. For democratised, flat and empowered teams, Jonker (interviewee) highlights the importance of strong leadership to guide them towards a common goal, as similarly argued by Ohno (1978). Furthermore, Daly (interviewee) prefers the trans-disciplinary team leader over a multi-disciplinary leader. Contrary to a multi-disciplinary leader who is a specialist in many discipline, a trans-disciplinary leader has relatively little experience from many disciplines and can view the system holistically, which can be identified as Ohno's (1978) chief engineer and is extended on by McGregor and Donnelly (2014) to formulate a term "transleader". Dreyer underlines the need to allow divergence of thinking in an innovative environment, which conforms to the argument of Bhasin and Burcher (2006) stating that Lean promotes innovation by turning an organisation into a learning organisation where there is no such thing as a bad idea to drive innovation (Wynett *et al.* 2002).

Divergence of thinking flourishes innovation as well as complexity in terms of motivating employees' towards a common goal (ibid). This complexity is further increased as an engineering organisation is comprised of various sub-systems (manufacturing, finance, marketing, etc.) that have intricate interactions among themselves, thereby also having potential compatibility issues (Browning and Sanders 2012). In a Lean context, some sub-systems of an engineering organisation seeking innovation are not suitable to Lean improvements because of a potential conflict among Lean and these sub-systems (ibid). In order to resolve these compatibility issues, Browning and Sanders (2012) suggest a thorough understanding of the entire system, its sub-systems and their interactions as well as Lean's influence on these aspects holistically. Krysinski backs Lean's holistic approach by comparing it with the mathematical concept of global optimum, i.e. making a sub-system Lean (local minima) does not necessarily make an entire system Lean (global minima). However, Faull disagrees with Lean's holistic approach based on the argument that one cannot apply Lean across the whole organisation by simultaneously addressing the situational, strategic and systemic issues and hence one should start implementing Lean at the situational level. However, in authors' opinion, the problem with Lean implementation at the situational level is that once the situation changes the solution dies and hence it is not sustainable.

In sharing his thoughts on Lean' holistic approach Krysinski also proposes the study of the idea of the virtuous circle of innovation in the present research context. Riley (2014) attributes virtuous circle with a complex series of events that reinforces itself through a feedback loop and produces positive outcomes, which implies that the parts/sub-systems of the circle create their own value and add to the value of the entire system. Therefore, the sum of the sub-systems becomes greater than the whole system, which is in line with Lean's proposed holistic approach. The virtuous circle of innovation has four steps, namely the idea source, idea focus, idea process and idea outcome (Riley 2014). Idea sources are comprised of people who create ideas, e.g. customers, suppliers, employees, etc. This step is closely linked to the open innovation approach (Chesbrough 2003a) where innovative ideas are collected from internal and external sources, as proposed in this thesis. The idea focus step is dedicated to provide a definitive direction that saves time and energy, hence reducing waste, which is the main objective of an engineering organisation seeking Lean Innovation (Murman 2012). The idea process step is one where the refinement of ideas occurs, i.e. separating the good ideas from bad ideas, which can be directly correlated to the backcasting from principles systems approach (Robert *et al.* 2010) where ideas have to conform to the principles that are aligned to organisational goals to achieve a future vision. Finally, in the idea outcome step the good idea is implemented and its value is measured. Following this, the idea is built upon by creating idea sources from those receiving the value of the original idea, thus completing the feedback loop. This feedback loop mechanism is an inherent quality of the backcasting from principles approach as its innovative outcome can be further built upon following the principles in the continuous innovation loops.

With the aim of driving innovation in a Lean engineering organisation, Browning and Sanders (2012) and Chen and Taylor (2009) argue on the softening of the absolute waste elimination objective of a conventional Lean mindset by allowing a certain amount of necessary waste in terms of variability, experimentation, risk taking behaviour, slack, etc. Although necessary waste is required to promote Lean Innovation, its minimisation is yet an important objective of this process. Krysinski argues similarly by stating that a Lean Innovation process has the built-in ability to differentiate between ideas with low and high value creation potential and adjust the necessary waste tolerance threshold in such a manner that the bad ideas are terminated as early as possible. One effective mechanism proposed in literature to achieve the minimisation of necessary waste objective is proposed by Melnyk (2007), who emphasises on the need of the separation of the system designed to drive innovation from the system primarily responsible for physically producing the innovation result. This separation of systems facilitates to maintain the essential amount of necessary waste required to develop innovative ideas in the system responsible to drive innovation (Chen and Taylor 2009, Browning and Sanders 2012) and at the same time facilitating the complete elimination of waste from the system responsible for producing the innovation result (Melnyk 2007). Jonker supports the separation of systems while highlighting an interesting benefit in terms of mutual honesty of these separated systems, i.e. the two separated systems challenge each other's limitations and hence foster intra-organisational competition that results in improving overall organisational productivity, a strategy successfully implemented by Sloan in General Motors to improve the productivity of its different business units in the early twentieth century (Sloan 1964). Faull backs the separation of systems by reflecting on his experience in Toyota where the highly innovative Lexus engine prototype was first developed within an R&D project that was disconnected from the manufacturing department.

5.2 Implementational Issues of Lean Innovation

Due to the complicated interactions between its different sub-systems, a Lean engineering organisation seeking innovation represents a highly complex and unpredictable system (Browning and Sanders 2012, Grant 2012). A method that is able to tackle such complex and unpredictable processes is backcasting from principles (Holmberg and Robert 2000). Backcasting from principles handles the complexity and unpredictability by formulating a vision of success (innovation outcome) and subsequently developing a set of principles that guide the process towards the vision (Robert *et al.* 2010). The implementation of the backcasting from principles approach is a major and continuous organisational undertaking (Dreborg 1996, Quist and Vergragt 2006) that requires a supporting and guiding mechanism for its effective application. One such supporting and guiding mechanism can be transformational leadership (DuBrin 2010) as it is able to implement great organisational changes due to its ability to motivate and inspire others and analytically analyse complex situations (Lee and Liu 2008, DuBrin 2010). Dreyer endorses this finding by stating that a leader needs to create an environment conducive to innovation to be effective in a Lean engineering organisation seeking innovation. In addition Daly, Faull and van Beugen positively suggest that a systematic way of thinking will aid the leader to implement the innovation process effectively.

Instead of exclusively employing the backcasting from principles approach to resolve the complexity and unpredictability of a Lean Innovation process, Daly rather proposes a hybrid approach which employs of a combination of three different systems approaches, namely forecasting, backcasting from scenarios and backcasting from principles (Robert *et al.* 2010), to address the challenges of Lean Innovation. The combination of the forecasting and backcasting systems approaches is aimed at exploiting their individual benefits and customising the solution to suit a specific situation. The advantage of backcasting from principles is that the boundary conditions (principles) would enable the framework of implementation to be well defined and structured thus leading to a future vision of success, which is also stated by Roorda (2001). Additionally the backcasting from scenarios can be used to motivate staff towards a vision as discussed by Robert *et al.* (2010). Furthermore, Dreborg (1996) indicates that backcasting from scenarios is helpful in achieving the goals strategically and through the maximisation of current resources. Finally, the benefits of forecasting in terms of realistically looking at past trends and learning from them can be highly beneficial in this hybrid approach, as argued by Robert *et al.* (2010).

This systems approach to promote Lean Innovation connects various sub-systems of an (engineering) organisation (Dreborg 1996, Holmberg and Robert 2000) and therefore such an organisation functions as an integrated whole and not as a collection of disconnected departments (Womack *et al.* 1991, Murman 2012). This requires excellence in an organisation's process coordination and communication channels, which has proven to positively impact its performance (Gittell 2003), thereby gearing it towards the promotion of Lean Innovation. Furthermore, efficient information flow in engineering organisations aids the elimination of waste (Liker 2004, Lean Academy MIT). However, Murman (2012) argues that the smooth flow of information and processes are interrelated, therefore ones optimisation results in other's. The backcasting from principles aspect of the hybrid system approach can provide a framework based of pre-defined principles and supported by transformational leadership can facilitate this smooth flow of information and processes (Holmberg and Robert 2000, Kotter 2013).

Faull agrees that a structured approach to communication is crucial for the promotion of Lean Innovation as it reduces interruptions in activities and processes resulting from random communication that are a major source of quality errors, a view supported by Kaye (1995). Daly principally agrees with the structured approach to communication, however instead of using the framework of principles to optimise the flow of information she recommends the framework of "agreements" instead of "principles" as the use of the later is too strict in the softer elements of communication. This flexible framework for communication is also advocated by Van Beugen who proposes the structured availability of information but less structured distribution of information initiated by the information user in order to avoid disruptions (Murman 2002), thereby adhering to Lean's pursuit of stability (Ohno 1978, Womack *et al.* 1991).

A systems approach for the promotion of Lean Innovation in an engineering organisation through the optimisation of flow of information and processes provides an effective base to incorporate other compatible theoretical concepts into this structured and fertile environment and exploit their benefits. This thesis proposes one such theoretical concept, namely open innovation approach (Chesbrough 2003a) due to its great similarities with the Lean's supplier development approach (Weber 2014) and hence offering high potential for exploiting a synergy effect between these two concepts. In arguing for open innovation, Chesbrough (2003a) states that no firm can keep its best talents within its four walls, a view endorsed by Krysinski who explicates that no organisation can keep their innovative ideas secret by closing their office. Additionally, Chesbrough's (2003b) proposes that organisations should profit from selling their Intellectual Property (IP) and that they should purchase IP of other organisations when it supports their business model, a point reiterated by Daly who considers the value of selling the organisation's innovative ideas more beneficial than holding them secret and unutilised. Faull also agrees with the open innovation idea but reflects on the lack of mutual confidence among companies while sharing their ideas. This concern is based in the open innovation paradox identified by West and Gallagher (2006) who express their concerns for an organisation's R&D efforts when the outcome is available to rival firms. To this extent, Chesbrough (2006) argues that if an innovation cannot be commercialised within a company's business model, a company with open innovation mindset could still receive benefits by sharing/selling this idea to other companies.

By opening the internal R&D boundaries in an open innovation approach, an engineering organisation faces extra complexity and unpredictability in its organisational processes (Chesbrough and Garman 2009), which can be effectively handled by employing the hybrid systems approach in conjunction with transformational leadership (Holmberg 2014) through the utilisation of appropriate principles that resolve the complexity and unpredictability attributed to the open innovation outcome (Holmberg and Robert 2000). Van Beugen shared his experience by stating that his organisation (KLM) is increasing its use of open innovation and he would prefer a structured framework for its implementation, a view backed by Gassman *et al.* (2010). One of open innovation's challenges, as discussed by Cargill and Bolin (2004) is that organisations share knowledge with intentionally inbuilt flaws to sabotage organisations' innovation projects, an apprehension also shared by Jonker. West and Gallagher (2006) point out another challenge of open innovation, namely the need of a new way of capitalising on innovative ideas coming from external sources, which has also been figured out by Daly in terms of the urgency of the development of new business models compatible to open innovation.

For any effective business model, customer focus is the key of its success, which becomes even more crucial in an open innovation environment (Chen 2011) where the customer can become part of the innovation process (Von Hippel 1988). There is no use of an innovation if it does not add value to a product or service from the customer's viewpoint (Van de Ven 1986, Srinivasan 2010), a view also expressed by Krysinski by stating that any innovation disconnected from customer value is simply research and worthless in a business context. This is fully in line with the Lean mindset (Womack *et al.* 1991) that necessitates the early and regular customer involvement in the innovation process to avoid waste (Melnyk 2007). Such an undertaking can be achieved with backcasting from principles where customer wants and needs are incorporated in terms of pre-defined principle that guarantee the customer oriented innovation outcome (Holmberg and Robert 2000), thereby acting as the guiding constraints of the innovation process, as mentioned by Daly. Additionally, this helps to regulate active customer participation whilst incorporating customer requirements throughout the innovation process in a flexible and passive manner.

However, Krysinski prefers active customer participation during the innovation process, although simultaneously cautions over too much customer participation that can result in the premature rejection of the innovation outcome if not introduced to the customer at an appropriate time (when the innovation outcome is mature enough to be realised by the customer), an issue also discussed in detail by Borgqvist and Lindberg (2011). However, a further discussion on this matter brought a common understanding between the author and expert on the importance of a regulated active and passive customer involvement at different innovation stages, as also argued by Alam (2002). In this approach passive customer involvement is foreseen at the start of the innovation process where customer requirements are incorporated into the setting of the vision and principles and is thus incorporated throughout the innovation process. However, during the innovation process a regulated active customer involvement is foreseen by ensuring that the innovation outcome is mature enough to be introduced to the customer (ibid).

In the context of the systems approach (Robert *et al.* 2010), another effective strategy to resolve the complexity and unpredictability attributed to the open innovation (Chesbrough 2003a) is to define a principle for the utilisation of integrated digital simulation tools (CAD, CAE, CAM, etc.), which can help to mitigate the risk (Murman 2012) related to open innovation by filtering the large number of innovative ideas from external sources in alignment with the organisational business model (Gassmann *et al.* 2010), i.e. separating good innovative ideas from bad ones. The use of these tools can also mitigate the risks associated with radical innovation (Grant 2012) by enabling an engineer to check different design concepts in a relatively short time by developing and testing virtual prototypes in a digital environment instead of a real environment (ibid). In line with Murman's argument (2012), Daly states that an engineering organisation would actually get left behind its competitors if it does not embrace digital tools. Similarly, Faull states that one cannot abandon the use of digital tools even if they might be flawed as most of the companies (competitors) are using them nowadays and simply abandoning them means that you are not part of the game. Krysinski partially backs the utilisation of digital tools, however he cautions the sole use of digital tools by excluding the human factor. This view is in harmony with that of Murman's (2012) who acknowledges the supremacy of the human factor over the digital tools, however supports their use to guide human decision making, to accelerate the innovation process and to mitigate the risk involved in this process.

6 Conclusions

This thesis investigates the possibility and challenges of implementing Lean Innovation in the engineering services sector and develops a theoretical framework in terms of nine propositions to effectively tackle these challenges. However, as it is the case with all research, the present research is not the final word on this topic and suffers from a number of limitations. First of all, both the theoretical and empirical research has been conducted within the scope of a master thesis and hence its focus could not be deepened extensively. Nevertheless, the most restricting limitation could be seen as the quality of the empirical data employed to examine the developed theoretical framework that can be rooted back to finding experts with versatile industrial knowledge in all four key theoretical concepts employed in this thesis, namely Lean paradigm, (open) innovation, systems approach and leadership. Additionally, the authors acknowledge that the objectivity of the empirical data could have been lowered due to their lack of experience in conducting interviews and (unconscious) bias towards their developed propositions. Furthermore, the number of interviews could not be increased beyond six that renders the sample size relatively small and hence impairs the reliability of the present empirical research. Despite these limitations, the conclusions of this research are drawn in the following.

In investigating the possibility of driving Lean Innovation in the engineering services sector, this thesis first conducts a state-of-the-art literature review and develops a theoretical framework in terms of a set of propositions by associating and integrating the main principles and characteristics of Lean philosophy, innovation management, systems approach to problem solving and effective leadership. Next, a qualitative research is conducted to examine the developed theoretical propositions in the light of experts' opinions collected through interviews. This whole exercise helps to answer the key research question formulated in Section 1.3, namely: "Whether and how Lean Innovation can be implemented in the engineering services sector?"

In concluding the first part of the key research question (whether part), it is judicious to answer it in the affirmative in light of the findings of this research. Although many scholars disagree that Lean can drive innovation in an organisation (Gopalakrishnan and Damanpour 1997, Wynett *et al.* 2002, Melnyk 2007) because of Lean's possible conflicts with certain innovation essentials, such as risk (Hale and Kubiak 2007), variability (Browning and Heath 2009) and slack (Melnyk 2007), there are numerous researchers who back the notion of Lean Innovation (Duguay *et al.* 1997, Drach-Zahavy and Somech 2001, Moore 2001, Bhasin and Burcher 2006, Schiele 2009, Purhaghshenas and Esmatnia 2012), as discussed in detail by Weber (2014). The findings of this thesis are closer to the second school of thought; however two key mechanisms, namely the systems approach to problem solving and effective leadership, have been identified to help promote Lean Innovation in the engineering services sector.

In answering the second part of the key research question (how part), a theoretical framework in terms of nine propositions has been developed by comparing, extracting and synthesising relevant theory streams from literature, and these propositions have subsequently been examined through expert interviewees. The following conclusions are drawn in answering the second part of the key research question.

First and foremost, contrary to a purely Lean manufacturing organisation where primarily absolute waste elimination objective is pursued, a Lean engineering organisation seeking innovation needs a paradigm shift in its mindset in terms of its tolerance to (necessary) waste as a certain amount of waste in terms of risk, slack and variability is essential to promote innovation (Melnyk 2007, Chen and Taylor 2009). This paradigm shift would change an organisation's prime focus from the bounded waste elimination to the unbounded value creation aspect of Lean, thereby providing an organisation with long-term competitive advantage through innovation (Browning and Sanders 2012). However, waste elimination is still an important aspect of Lean, however it should follow the value creation activity in an engineering organisation, i.e. value should be first created through innovative solutions and subsequently waste should be eliminated from these solutions thereby making them Lean. An engineering organisation can achieve this objective by tolerating different amounts of waste in various departments, thereby structuring its departments based on different waste tolerance thresholds, e.g. separating R&D department from manufacturing department (Melnyk 2007).

The innovation process in a Lean engineering organisation should be aimed at enhancing customer value, and this can be achieved by customer engagement throughout this process (Ohno 1978, Womack *et al.* 1991). However, excessive customer involvement during the innovation process can also potentially hamper it as there is risk that customers can reject a good innovative idea in its early development phase due to their inability in realising the benefits of the innovation outcome (Borgqvist and Lindberg 2011). This issue can be resolved by adjusting the intensity of active and passive customer involvement during different stages of innovation (Alam 2002), for which this thesis proposes the employment of backcasting from principles approach. Additionally, by opening its R&D boundaries to utilise innovative ideas from all possible external sources of knowledge and information, an engineering organisation can significantly leverage its innovative capacities outside its in-house R&D operations, thereby embarking from a "closed" to an "open" innovation approach (Chesbrough 2003a). Therefore, this thesis proposes that an engineering organisation seeking Lean Innovation should embrace open innovation in line with its business model accordingly (Gassmann *et al.* 2010) and in a reasonable and regulated manner in order to avoid risks related to open innovation (Cargill and Bolin 2004). However, by employing open innovation, there is a need of an effective mechanism to filter the high influx of innovative ideas coming from external sources. One possible state-of-the-art solution of this issue could be the utilisation of integrated digital simulation tools to assist the human decision making process in evaluating and commercialising the promising innovative solutions in a cost and time efficient manner (Murman 2012).

An engineering organisation (system) is comprised of various sub-systems (e.g. engineering, manufacturing, marketing, etc.) with complicated interactions among them, and introducing Lean Innovation in its organisational processes adds a high level of complexity and unpredictability in them (Browning and Sanders 2012). Embracing open innovation brings an additional layer of complexity and unpredictability in this equation. In order to tackle high complexity and unpredictability of an engineering organisations seeking Lean Innovation, which conforms to the systems behaviour of emergence, thresholds and complex interactions of sub-parts (Dreborg 1996, Robert *et al.* 2010), a hybrid systems approach to problem solving incorporating benefits of the three variations of the systems approach, namely forecasting, backcasting from scenarios and backcasting from principles, has been concluded to be adequate as this hybrid approach can effectively resolve the complexity and unpredictability of such systems (Holmberg and Robert 2000). In order to enhance the performance of this highly complex and unpredictable system, it is essential to take a holistic view of the implementation of Lean Innovation by understanding the interaction of Lean with different sub-systems and their interfaces (Chen and Taylor 2009, Browning and Sanders 2012). The use of the systems approach, in terms of establishing a framework of principles (Robert *et al.* 2010), has been identified to allow customer involvement throughout the innovation process in a regulated manner (Alam 2002) that helps to avoid the premature customer rejection of the innovation outcome (Borgqvist and Lindberg 2011) and providing out-of-the-box innovative solutions (Walker 2015) in order to optimise the flow of information and processes to promote Lean Innovation in an engineering organisation (Gittell 2003, Murman 2012).

In implementing great changes in an engineering organisation, like Lean Innovation through the systems approach, the leadership role becomes crucial as it can provide an effective guiding and supporting mechanism to facilitate such substantial transformations (Kotter 2013). Due to the specific traits of transformational leadership, namely its enthusiasm about change (Nusar *et al.* 2012), its willingness to motivate and inspire others (e.g. to innovate and change), its ability to instil trust in the followers (DuBrin 2010, Nusar *et al.* 2012) and its capacity to follow planned processes (ibid), it has been identified to be highly suitable to the systematic implementation of Lean Innovation in an engineering organisation. DuBrin (2010) and Nusar *et al.* (2012) also attribute courage and open mindedness to this leadership style that are essential for the promotion of innovation, especially open innovation (Chesbrough and Garman 2009), in an engineering organisation. Additionally, in order to promote innovation, multi-skilled strong leaders (Pullin 2005) heading cross-functional (Ohno 1978, Womack *et al.* 1991) and empowered teams (Cross 2013) have been concluded to be helpful. Transformational leadership can also stimulate Lean Innovation by optimising the flow of information and processes and by being open to new technologies in terms of employing integrated digital simulation tools to assist the human decision making process (Murman 2012). Finally, the separation of the system responsible for deriving innovation (R&D) from the system designated for its physical manifestation (manufacturing) demands different leadership mind-sets in terms of tolerance to waste, variability, experimentation and risk (Chen and Taylor 2009, Browning and Sanders 2012).

6.1 Implications

The findings of this work have a number of implications for engineering organisations seeking long-term competitiveness through Lean Innovation. The results of this research suggest a need of focus shift from the waste elimination to the value creation aspect of Lean philosophy in order to promote innovation, thereby abandoning the absolute waste elimination objective of a typical Lean Manufacturing organisation. This implies that an engineering organisation seeking Lean Innovation should allow a certain amount of necessary waste in its R&D processes to provide its employees freedom of experimenting with new ideas that is the key of generating innovative ideas. However, an engineering organisation can still pursue the absolute waste elimination goal in other departments, e.g. manufacturing, by separating the system responsible for generating innovative ideas (R&D) from the system responsible for materialising these innovative ideas (manufacturing).

The results of this thesis establish that an engineering organisation undergoing Lean transformation, while seeking open innovation, can significantly leverage its internal

R&D capabilities, however at the cost of increased complexity and unpredictability in its organisational processes. This additional complexity and unpredictability can be tackled through the effective utilisation of the systems approach to problem solving, which could in turn be backed by a supporting and guiding mechanism in terms of transformational leadership. In this regard, the engineering organisation should encourage and foster leaders with traits such as courage, vision, motivation, open-mindedness and systematic thinking.

6.2 Future Research

It is clear from the findings so far that Lean's impact on engineering organisations seeking innovation is an underdeveloped research domain and the need to fill this research gap is greater than ever before. In this context, the following knowledge gaps have been identified and proposed for future research.

In future research expert interviews should be conducted with experts possessing versatile industrial knowledge in all four key theoretical concepts employed in this thesis in order to obtain their rounded opinion on the developed propositions. Additionally, for higher reliability of the empirical findings, sample size of the empirical research conducted through expert interviews should be increased. Furthermore, objectivity of the empirical research can be increased by employing the conventional content analysis technique where, rather than the use of preconceived (theoretical) propositions, open-ended questions are asked from the interviewees and their responses are then used to formulate the propositions (Hsieh and Shannon 2005) that in turn are reconciled with the theory. A quantitative research could also be performed in future that would enable the researcher to conduct a statistical analysis of the responses to the propositions, thereby improving the objectivity of the thesis (Kothari 2004).

A possible future research topic, as proposed by one of the interviewees (Krysinski), is to study the creation of the virtuous circle of innovation (Riley 2014) in a Lean engineering organisation. The development of new business models compatible with the open innovation approach could also be an interesting future research topic, as highlighted by two of the interviewees (Krysinski and Daly). Lean's impact on engineering organisations seeking reliability and stability in its solutions (instead of innovation), as mentioned by one of the interviewees (Dreyer), opens another interesting future research direction. Yet another interesting future research topic could be the study of customer active and passive involvement during the innovation process and its impact on the degree of novelty of the innovation outcome.

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Appendices

Appendix A - Supplementary Material on Lean Paradigm

Brief History and Introduction of Lean Paradigm

Since the publication of the groundbreaking book "The Machine that Changed the World" by Womack *et al.* (1991), disclosing the "Japanese Wonder" at the Toyota Production System (TPS), the "Lean" paradigm has emerged as one of the most influential ideas of management sciences in the twentieth century. To gain a better understanding of this mystery, let us look back in history around the Second World War, as explained by Womack *et al.* (1991).

Toyoda family founded the Toyota Motor Company in Japan in 1937. The family first established the textile machinery business successfully during the late nineteenth century. Despite of their ambition to build passenger cars, they started building trucks for military using craft methods on the coercive demand of Japanese government. After the war, Toyota started manufacturing cars and commercial trucks at full-scale, however their productivity was way below Ford's Rouge Plant in Detroit (world's largest and most efficient manufacturing facility at that time). Toyota was facing the following problems entering the automotive sector after the war:

- The domestic market was tiny and needed a wide range of vehicles (luxury cars, trucks, etc.).
- The native work force was not flexible. Post-war labour laws strengthened the workers' demands for more benefits and restricting management to lay off employees. There were no immigrants or minorities willing to work under substandard conditions for higher pay.
- The war-ravaged Japanese economy was lacking in capital and foreign exchange.
- Foreign manufacturers were keen to enter Japanese market and defend foreign markets.

In response to the last difficulty, government issued a prohibition on direct foreign investment in the Japanese motor industry to protect it domestically, which resulted in the entrance of many Japanese firms in the automotive sector. Later, the Japanese Ministry of International Trade and Industry (MITI) proposed a series of plans to merge Japan's small car companies into a Big Two or Big, aiming to specialise in different sizes of cars to prevent excessive domestic competition and to compete with Detroit's Big Three on price in export markets. Considering no long-term effectiveness in export markets of MITI's plan, which lacked new production techniques, Toyota, Nissan and other companies decided not to follow this plan and set out to become full-range car producers by focussing on the development of innovative production techniques. Many Toyoda family members, namely Kiichiro Toyoda in 1929 and Eiji Toyoda in 1950, visited Rouge Plant aiming to find out the efficient manufacturing methods used there. As a result of these efforts, the Toyota system eventually became the most efficient and successful method of car production and revolutionised the industry. Much of the credit for this goes to Toyota's chief engineer and father of TPS, Taiichi Ohno, who managed to implement his ingenious ideas in the TPS over the years to tackle above mentioned issues, which finally culminated in a so-called Lean (production) philosophy.

Lean philosophy is based on two key dimensions: eliminating waste (muda) and creating value. It is important to emphasise here that both are essential elements of a Lean system and just focusing exclusively on one of these two dimensions can hinder to reap the full benefits of a Lean system. Murman (2002) argues that only eliminating waste (cutting costs) is insufficient and may not even lead to rise in revenues, while focusing solely on creating value is also faulty as many improvement opportunities become visible only after eliminating waste. Therefore, both waste elimination and value creation are essential elements that Lean must incorporate. However, as noted by Mossman (2009), in theory at least, there is no absolute definition of waste, and it is all relative (to value). In general, waste can be considered anything that does not create value for the customer/client, which is defined in terms of value. As value can be different for each customer/client, therefore the definition of waste will be different for each.

In the context of waste, Lean classifies the following three types of activities: (1) *value-adding activities* that enhance the customer value of a product or service; (2) *Non-value-adding activities* that do not add the customer value to a product or service and are unnecessary (pure waste); (3) *Necessary non-value-adding activities* that do not enhance the customer value to product or service but are necessary unless present processes are not changed radically (necessary waste) (Hines and Taylor 2000). There are seven types of activities that are seen as non-value-adding activities, hence referred to as waste. The seven wastes in a Lean system are as follows: (1) defects; (2) overproduction; (3) unnecessary processing; (4) inventories; (5) unnecessary movement of people; (Inno 360) waiting; (7)unnecessary transport of goods (Pyzdek 2003). But even these wastes are not absolutes. Some overproduction has value, as when a process is not yet capable of switching between products virtually instantly and yet customers want instant delivery – overproduction creates a temporarily necessary buffer (Mossman 2009).

Lean employs five principles to eliminate waste that constitute its backbone. These five Leans principles reads as follows: (1) *specify* what does and does not create value for the customer; (2) *identify* all non-value adding wastes in the *whole value stream*; (3) make actions that create value *flow*; (4) make only what is *pulled* by the customer; (5) strive for *perfection* by continually removing successive layer of waste as they are uncovered (Hines and Taylor 2000). It is essential to recognise that Lean thinking is a "way of thinking" and not a final state or set of tools, or in other words "Lean is a journey, not a state" (Murman 2012).

Lean Services

As mentioned earlier, services sector accounts for roughly two-thirds of global output (Best 2009) and almost 80% of gross domestic product of USA, however the productivity level in this sector has been lower than that of the manufacturing area (Suarez-Barraza *et al.* 2012). According to Cavaness and Manoochehri (1993), productivity based on the average sales per employee (adjusted for inflation) among manufacturing companies jumped 27% between 1982 and 1990, however during the same period, this productivity measure fell 1% for services companies. This put the services sector under growing external pressure to look beyond their traditional techniques to increase their efficiency, effectiveness, productivity and flexibility and cut down costs and lead times (Cavaness and Manoochehri 1993), and to achieve this, techniques used in the manufacturing sector over the last few decades, like Lean and Six Sigma principles, are being examined and adopted. In discussing the inability of the services companies to keep up with their manufacturing counterparts to adopt methodologies like Lean to improve their efficiency and quality Cavaness and Manoochehri (1993) argue that the physical nature of products in manufacturing allow quality standards to be precisely defined, conformance to standards to be evaluated, defects to be accurately determined and methods of improvement to be explored. However, services on the other hand, cannot be defined and measured in such precise terms and their quality can really only be assessed by the recipient of the service making its measurement more subjective than exact. This implies that many concepts and techniques can be borrowed from the manufacturing sector; however their implementation in the services sector poses special challenges and demands careful treatment.

According to Parasuraman *et al.* (1985), services have three distinctive features, namely intangibility, heterogeneity and inseparability, which makes them much more difficult to improve than products. First of all, services are intangible, i.e. they are activities rather than physical objects and therefore cannot be measured tested or verified before they are consumed. Next, services are heterogeneous and their consistency can vary depending on the performer, the client and the environment. Furthermore, production and consumption of services generally occurs simultaneously, therefore making them inseparable. One of the major challenges in applying Lean paradigm to services is the lack of widely available reference implementations to allow people to observe how directly applying Lean Manufacturing tools and practices can work and have their impact on the system and processes, which makes it more difficult to build the level of belief considered to be necessary for Lean's strong implementation (Ahlstrom 2004, Suarez-Barraza *et al.* 2009, Suarez-Barraza *et al.* 2012). Januska and Stastna (2013) note that Lean Manufacturing techniques and tools need to be better "translated" into the service context to support the more significant and innovative approaches of implementation, which has not yet received the level of work or publicity that would give starting points for implementers.

Although rather scarce, existing research on the application of Lean philosophy in the services sector deals mainly with industries, like health-care, education, banks, airlines, hotels, public service and e-service (Suarez-Barraza *et al.* 2012). Lean principles have been successfully applied to call-centre services to improve live agent call handling (Carlborg *et al.* 2013, Wikipedia 2015). Hanna (2007) reports that Lean practices have also found application in software application development and maintenance and other areas of information technology. Some research does relate widely recognised examples of success in retail and even airlines industries to the underlying Lean principles in these businesses (Ruffa 2008). By conducting a systematic literature review on Lean Services, Suarez-Barreza *et al.* (2012) reports 172 publications in total (including publications from less-academic sources) on this topic until 2012 (number has not increased significantly to date) and systematically classified the published literature into preliminary categories. This classification of the published material on the Lean Services shows that the literature referring to Lean Services can vary widely from the exploration of the meaning of the concept, its applications (case studies), the setting up of theoretical models to the generation of new definitions.

Brief Literature Review on Lean Services

Suarez-Barraza *et al.* (2012) reviewed the significant research literature on Lean Services and systematically classified it into four main categories, while further identifying and sub-categorising within the category of applications, like transport, banks and financial institutions, education, health-care sector, airline industry, hotels, restaurants, etc. The classification scheme for this study emerged from the parallel and simultaneous exercise of categorising and sub-categorising the collected articles and texts on Lean Services. The four main categories of Lean Services literature read as follows: (1) exploration of Lean

Services; (2) creation of the theoretical framework of Lean Services (models); (3) specific application of Lean Services; (4) new trends and extensions of Lean Services. In order to help the reader follow the published work on Lean Services, the classified publications went through a further analysis by attributing sub-categories that were coded according to the sector of the service described, the year of publication and the subject of the article. A brief description of the classification and analysis of Lean Services publications by Suarez-Barraza *et al.* (2012) is provided in what follows.

The first category comprises the publications (four in total) that provide first reflections and foundations on Lean Services, exploring the applications of the Lean (Morgan and Liker) concepts in service companies. Therefore, these publications can be considered the pioneers in the field. Although the Lean concept is not mentioned explicitly in these works, the four pioneering papers by Skinner (1969), Levitt (1972), Levitt (1976) and Lawler III (1978) pointed out the backwardness and inefficiency of the services sector due to its bureaucratic model of operations that has been consolidated over years and where clients' needs and wishes were totally ignored, and therefore emphasised on taking measures to address these issues. Skinner (1969) observed that the manufacturing sector was way ahead from its services counterpart in terms of finding ways and mechanisms to improve the productivity of the organisation, like planning, control, flexibility and strategies to achieve low costs and improved quality. Levitt (1972, 1976) proposed to focus on mass production "assembly line" methods based on a technocratic, rather than bureaucratic, point of view to ensure better efficiency in its operations, lower costs and satisfy clients in more specific ways.

The second category of Lean Services literature (60 publications in total) starts from 1990 onwards when the manufacturing techniques for enhanced production and quality, like Total Quality Management (TQM) and Lean, were first introduced in the academic arena, which made many scholars curious to investigate how different service organisations went about trying to improve on or innovate the operational aspects of the services they provided. Here, prior to the direct influence of Lean practices on services sector, application of the TQM movement to the services sector can be identified from several publications, which marks a significant shift towards improving the services quality, customer orientation and searching out the best ways to satisfy their needs and requirements, as TQM preached (Parasuraman *et al.* 1988, Chase and Garvin 1989, Schlesinger and Heskett 1991, Dean and Bowen 1994). However, it was not until the end of the 1990s that theoretical models employing Lean concepts in the services sector started to emerge in the literature, which some authors called a "re-industrialisation of service" (Womack and Jones 1996, Suarez-Barraza *et al.* 2012). According to Radnor *et al* (2006), the term "Lean Service" was first coined by Bowen and Youndahl (1998) in literature, who suggested that Lean Service could be present when certain principles, like flexibility and responsiveness, focus on individual customers, value-chain integration and disaggregation, empowerment of employees and teams, knowledge management and networked organisation, could be discerned in a company. The three sub-categories, namely 2a, 2b and 2c, under the second category classify the significant publications chronologically from 1980 to 1989 (e.g. Schmenner 1986), from 1990 to 1999 (e.g. Reichheld and Sasser Jr. 1990, Bowen and Lawler III 1992, Cavaness and Manoochehri 1993, Ghobadian *et al.* 1994, Gallouj and Weinstein 1997, Harvey 1998), and from 2000 onwards (e.g. Hing Yee Tsang and Antony 2001, Allway and Corbett 2002, Swank 2003, Weekkody *et al.* 2003, Karmarkar 2004, Abdi *et al.* 2006, Prajogo 2006, Kumar *et al.* 2008, Piercy and Rich 2009, Snee and Hoerl 2009, Seddon and O'Donovan 2010, Dahlgaard *et* *al.* 2011, Li *et al.* 2011, Malmbrandt and Ahlstrom 2012, Bateman *et al.* 2013, Carlborg *et al.* 2013, Hadid and Afshin Mansouri 2013), respectively.

The third category consists of research work dedicated to specific applications of Lean Services in terms of academic and practitioner case studies. The possible extension of Lean thinking to health-care system and other sectors was indicated in the pioneering work on Lean by Womack and Jones (1991, 1996). The publications in this category (80 in total) are of direct use of managers of service organisations, like health-care, education, banks and finance, airlines, hotels, restaurants, etc., who are becoming increasingly interested in how Lean techniques can directly be applied to bring about improvements in their own companies. The five sub-categories, namely 3a, 3b, 3c, 3d and 3e, under the third category classify Lean Service literature by the type of service sector, i.e. health-care sector (e.g. Aherne 2007, Ben-Tovim *et al.* 2007), education sector (e.g. Andersen Rostgaard 1995, Lethbridge and Hines 2008), banks and financial services sector (e.g. Streeter 1990, Batiz-Lazo and Wood 2001), airlines sector (e.g. Greenwood *et al.* 2002, Hutchins 2006) and hotels and restaurants sector (e.g. Heskett 1987, Johnson and Martin 1993), respectively. It is to note that, despite the availability of numerous case studies and research by academics as well as practitioners that present success stories about the application of Lean thinking in aforementioned services sectors, authors were not able to find any significant work on the application of Lean paradigm in engineering services sector, which is the main focus of the present work.

Finally, the fourth category constitutes new trends and extensions in the Lean Services literature. Here, the sub-category 4a indicates new trends in the public service sector (Furterer and Elshennawy 2005, Krings *et al.* 2006, Bhatia and Drew 2007, Radnor and Boaden 2008, Suarez-Barraza *et al.* 2009), the sub-category 4b specifies the associated topics like e-service (Voss 2003), and the sub-category 4c marks peripheral or linked publications dealing with Total Service Quality, Service Excellence or Service Science (Sureshchandar *et al.* 2001, Den Hartog and Verburg 2002, Johnston 2004, Gupta *et al.* 2005).

Appendix B - Supplementary Material on Innovation

Definition of Innovation

There is no unique definition for innovation in literature (Weber 2014), as has been reported by Crossan and Apaydin in consolidating their study on the state of the academic research on innovation, which points out that the term innovation has been loosely employed in literature from creativity to change and everything in between. The first definition of innovation was coined in the seminal work on economic development by the Austrian economist and political scientist Joseph Schumpeter (1983) in the late 1920s (Hansen and Wakonen 1997) who emphasised the novelty aspect in the outcome of innovation outputs: a new good or a new quality of a good; a new method of production; a new market; a new source of supply; or a new organisational structure, which can be summarised as "doing things differently" (Crossan and Apaydin 2010). However, there is an intrinsic flaw in this definition, as judiciously pointed out by Hansen and Wakonen (1997), namely "it is practically impossible to do things identically", which makes any change an innovation by definition (Crossan and Apaydin 2010). Although Schumpeter clearly defined innovation within the context of an organisation and outlined its output as product, process and business model, there has been a continuous literary debates over various aspects of innovation (Crossan and Apaydin 2010), its necessity and sufficiency (Pittaway *et al.* 2004), its intentionality (Lansisalmi *et al.* 2006), its beneficial character (Camison-Zornoza *et al.* 2004), its effective implementation (Hobday 2005, Klein and Knight 2005) and its diffusion (Holland 1997). Based on their sample of approximately 1200 public organisations in the United States, Damanpour and Schneider (2006) note that innovation has been defined in different disciplines from different perspectives.

Without going into much detail of the ongoing academic debate on what innovation actually means, we adopt a rather broad definition of innovation proposed by the department of business innovation and skills in UK, namely "it (innovation) is a process by which new ideas are successfully exploited to create economic, social and environmental value" (Grant 2012). In the context of innovation in the engineering services sector, its scope encompasses: (1) changes in services that an engineering organisation offers (services innovation); (2) changes in the way engineering services are created and delivered (process innovation); (3) changes in the context in which engineering services are introduced (position innovation); changes in the underlying thought processes, models and technology that frame organisation activities. This definition and scope of innovation fits very well within engineering services organisational context.

Finally, the terms innovation and invention should be differentiated because they are sometimes used interchangeably by people. In general, "invention can be defined as the creation of a product or introduction of a process for the first time. Innovation, on the other hand, occurs if someone *improves on* or *makes a significant contribution to* an existing product, process or service" (Grasty 2012). It should be noted that not all inventions can be realised into useful, marketable products, services or methods and therefore not all of them become innovation. In the present research' context, the term innovation includes both invention and innovation. This means that an engineering organisation seeking innovation can either make a significant contribution to existing ideas (innovation) or generate new ideas (invention) and nurture them further to be realised into useful, marketable products, services or methods (innovation), thereby generating necessary waste (Browning and Sanders 2012) in terms of inventions that cannot be realised into innovation.

Discrete versus Process Perspective of Innovation

Scholars are divided into two schools of thoughts on the issue whether innovation is a process or discrete event (Cooper 1998). One school of thought argues that innovation is a process, while the other considers it a discrete event (ibid). Proponents of innovation as a process focus on the various stages, namely identifying problems, evaluating alternatives, arriving at a decision and putting innovation into use, which an organisation goes through over the time while undertaking an innovation effort (Rogers 1983). According to Burgelman and Sayles (1986), roles and specific tasks of organisational participants in this approach are not fixed and they change as the process of innovation unfolds in an organisation. On the other hand, proponents of innovation as a discrete event give more importance to the implementation of innovation that occurs when there is real acceptance of risk and the commitment of resources, however they do not necessarily disregard the process (Cooper 1998). This leads to a perspective, differentiating between innovators and non-innovators in the context of an organisation, thereby leading to take a more macro approach towards innovation. Principal focus of this type of innovation is on the organisational characteristics, such as firm size or age, and conditions of the industry that promote or impede innovation, such as market concentration or the maturity of the industry (Cooper 1998).

Innovation as a process has been presented in literature using different models. Due to their serious limitations and wide-spread literary criticism, early technology-push and market pull linear models lacking interactions among various components of the innovation process, several nonlinear advanced multi-actor, network-based and highly integrated innovation process models have been proposed in the literature (Rothwell 1994, Tidd 2006). Rothwell (1994) provides a systematic and historical evolution of innovation process models in literature over last few decades by differentiating them in five generations. The first generation innovation process (1950s – mid 1960s) can be characterised by a technology push resulted from the advanced market economies enjoying unparalleled rates of economic growth largely through rapid industrial expansion after the Second World War. The technology push model assumes a direct linear relationship between innovation input (R&D), i.e. more R&D effort will lead to more successful products. The second generation innovation process (mid 1960s – early 1970s) can be characterised by comparatively simple sequential model that shifted main focus towards the demand side of the matter, resulting in the "market-pull" mechanism that recognises market as the source of ideas for directing R&D. The third generation innovation process (early 1970s – mid 1980s) looks at first and second generation models as two extremes and proposes a coupling model with generic process of interaction between technological capabilities (technology-push) and market needs (market-pull) by describing a logically sequential (not necessarily continuous) that that can be divided into a series of functionally distinct but interacting and interdependent stages. The fourth generation innovation process (early 1980s – early 1990s) is characterised by the superior competitive performance of Japanese firms in global markets through the exploitation of Lean-driven innovation based on the integration and parallel development, mainly characterised by the relationships with suppliers and efficient and quality-driven manufacturing procedures. The fifth generation innovation process is characterised by a focus shift towards systems integration and corporate strategic networking with various stakeholders, such as suppliers, risk-sharing partners, horizontal alliances and lead-customers (Rothwell 1994).

This debate is important in the context of the present research as we intend to employ the notion of the backcasting systems approach. Backcasting can either be from scenarios or from principles. The notion of backcasting from scenarios or from principles has common grounds to the consideration of innovation as discrete event or a process. Therefore, this work is intended to take into account both aspects of innovation, i.e. innovation as a discrete event as well as a process, and correlate them to the backcasting approach from scenarios and principles, respectively, in order to investigate its compatibility with the Lean methodology within the engineering services sector.

Multiple Dimensional Model of Innovation

The multiple dimensional model of innovation proposed by Cooper (1998) employs different dimensions of innovation as they exist in an organisational setup, such as product, process, incremental, radical, administrative and technological. This classification is conceptually similar to that of the Damanpour (1988) and has been employed by Weber (2014) to conduct an empirical qualitative study to investigate Lean's impact on innovation. In order to cover numerous dimensions of innovation presented and discussed in literature, Cooper (1998) classifies the most prominent innovation dimensions in three main dichotomies, namely incremental versus radical, technological versus administrative, product versus process.

Incremental changes "enhance and extend the underlying technology and thus reinforce the established technical order", while radical innovations represent advances so significant that revolutionary changes of the organisation and its support networks must occur to accommodate and implement change. It can be seen that this dimension is based on the degree of newness or novelty of the innovation outcome with respect to an appropriate referent (Crossan and Apaydin 2010). The adaptive response to changes in the business environment essentially leads to incremental change/innovation and it can be perceived as cost cutting, quality improvements and features addition measures in existing products or services. This is the most popular form of innovation within the R&D setup of organisations due to its low risk potential. Development of improved versions of Microsoft Windows over the time is a good example of incremental innovation. On the other hand, the creative response leads to radical change/innovation – which is often disruptive (Christensen 1997) as it in most cases replaces old ideas, technologies, and products (Grant 2012). In essence, one can conclude that incremental innovation improves, while radical innovation transforms (Grant 2012). In his book *The Innovator's Dilemma* (Christensen 1997), Professor Clayton Christensen of the Harvard Business School investigated why some innovations that were radical in nature reinforced an incumbent's position in the disk drive industry, thereby contradicting well known innovation models in literature. Christensen found that the radical innovation creates a new market by applying a different set of values for customers, and in many cases it ultimately overtakes an existing market, therefore termed this kind of innovation as *disruptive innovation* (Christensen 1997).

Cooper (1998) differentiates between technological and administrative innovation based on the proximity of the change in relation to the organisation's operating core. Contrary to technological innovation that directly influences the basic output processes through the adoption of ideas, administrative innovation incorporates changes that affect organisational policies, resources allocation and other factors related to the social fabric of an organisation. This means that technological innovation involves the application of new technologies directly to products and processes to accomplish technological advancement. Microelectronics, nano-based products and development of better crops through genetic engineering are good examples of technological innovation. It is to note that technology is defined at several levels of abstraction (Weber 2014), however we employ its definition as a tool, technique, physical equipment, or a system by which the employees of an organisation extend their capabilities (Damanpour 1987). On the other hand, administrative innovation is more process-oriented and related to management and creation of a new organisation design which better supports the creation, production and delivery of services or products. Examples of administrative innovation include management by objectives, six-sigma processes, job rotation, staff incentive systems and telecommuting (Garcia 2010).

Finally, Cooper (1998) classifies innovation based on the subject that receives innovation. The subject of innovation can be either a product or a process. The product innovation reflects change in the end product or service offered by a firm, while process innovation represents changes in the way an organisation produce end products or services (Utterback 1994). However, it is worth mentioning that there is a strong interdependency between these two innovations (Weber 2014). According to Porter (1980), the type of innovation is very important in laying down an organisation's business strategy. While process innovation is very effective in pursuing a cost-leadership business objective, product innovation is the key to carve out a business strategy to attain product differentiation (Weber 2014).

Open Innovation - A Step Beyond Closed Innovation

Although roots of open innovation can be traced back to the open source methodologies for software development in the late 20th century, nevertheless these two notions have different focal points. Similar to the open source methodologies for software development, open innovation not only exploits the external channels of information to create value, but it also explicitly incorporates the business model as the source of both value creation and value capture that enables an organisation to sustain its competitive position in the industry value chain over time (Chesbrough *et al.* 2006). Another example of open innovation can be found in the late 90s by the Proctor & Gamble (P&G) that started to take a different approach to achieve innovation in its business (Inno 360 2014). Considering the fact that there is decreasing probability that employees will stay at a single company for the duration of their careers in modern times, P&G realised that secrecy of innovative ideas generated within an in-house R&D setup (closed innovation) can no longer be maintained (Gawarzynska 2010). This leads to a widespread proliferation of confidential business information across any given industry. Acknowledging the fact that no firm can keep its brilliant minds within its four walls, P&G decided to collaborate openly with outside entities to find out new business ideas at reduced R&D costs and accelerated time to market. The "Connect & Develop Program" at P&G was a manifestation of this paradigm shift, whose prime objective was to source 50% of new product development projects from outside the company for three years, which became such a success story that it has been continued and expanded upon for the past decade (Inno 360 2014).

Several factors have contributed to the popularity of the open innovation paradigm. Jelinek (2010) reports the popularity of open innovation in the context of three specific factors: financial pressures for efficiency, burgeoning globalisation, and increased technical complexity. Additionally factors like technological progress, globalisation of competition, increasing availability and mobility of skilled workers (knowledge diffusion), rapid and easy information and technology transfer, electronic data exchange, enhanced connectivity through internet and social media platforms, growth of entrepreneurship, availability of the ready-made new ideas, global market and a global consumer, increasing skills of external suppliers, etc. The popularity of the open innovation notion has attracted the attention of many scholars, producing a significant research work on this concept in the recent years.

There are numerous benefits to adopting open innovation. There are large sample studies that show that open innovation practices benefit and organisations that are more open to external sources or search channels are more likely to have a higher level of innovative performance (Laursen and Salter 2006). Gawarzynska (2010) correlates open innovation with business success and her research outcome suggests that by adopting open innovation a firm can double its innovation success rate and increase nearly 60 percent of its internal R&D productivity. A study conducted by European Industrial Research Management Association (ERIMA) to explore the market-related motives for corporate venturing (spin-in and spin-out) points out benefits, like meeting customer demands, collecting new ideas and knowledge, improving innovative performance and continuous growth (De Jong *et al.* 2008b). According to Chen (2011), open innovation strategy has practical significance in the hyper-competition and knowledge-based business ecology.

According to Gassmann *et al.* (2010), the era of open innovation has just begun and it has a very bright future. The industry penetration of this notion is on its way from pioneers (software, electronics, telecom, pharma and biotech) to mainstream. In authors' opinion, the notion of open innovation has a huge potential to find its application in engineering services sector where it is vital to sustain innovation while remaining cost efficient. By adopting open innovation practices in a Lean environment, highly innovative engineering services can be delivered at low costs, as discussed in the following sections.

Challenges and Patterns of Open Innovation

The open innovation is still a new and evolving paradigm. Practicing open innovation involves benefits as well as risks and challenges. West and Gallagher (2006) identify three principal challenges for organisations in exploiting the concept of open innovation, namely finding creative ways to exploit internal innovation, incorporating external innovation into internal development, and motivating outsiders to supply an ongoing stream of external innovations, where latter challenge represents a paradox over concerns that an organisation would spend its R&D efforts and the outcome would be available to rival firms. Another key problem is that organisations combining internal and external recourses for innovation can face higher coordination costs and risks than if all activities were internalised. Another challenge for managers here is related to the IP issues of accepting donations from a wider global community of unknown contributors. The concern is that a user can inadvertently contribute proprietary IP to a project based on open innovation (West and Gallagher 2006). Cargill and Bolin (2004) point out that proprietary "stealth" IP could be deliberately donated to open-source projects to sabotage those projects. Jelinek (2010) points out to a challenge of firms developing sustainable competitive advantages employing open innovation when products and processes are much easier to copy than methods of organising work and innovation (Kogut 2000).

In order to tackle some of these challenges, West and Gallagher (2006) propose the following four patterns and practices of combining internal and external innovation in order to achieve open innovation: (1) pooled R&D; (2) spinouts; (3) selling complements; and (4) donated complements. Pooled R&D refers to build consortia with other organisations on product development of mutual interests to gain leverage by combining R&D resources and knowledge of all participant organisations. Here, an open organisational culture is the key to overcome the managerial cultural syndrome such as "not invented here" and build trust between participant organisations (Nakamura *et al.* 1997, Santoro and Chakrabarti 2001, Chesbrough 2003b, Gawarzynska 2010). Spinouts help large organisations with powerful bureaucracies to unlock and commercialise technologies locked in their laboratories by financially and technically supporting spinout companies. In selling complements, organisations focus on developing and selling differentiated complementary products using commodity components from external resources. For example, Linux distributors (such as Red Hat) that take freely available software and providing installation, training and support services would be selling complements to a free core product. In donated complements, organisations profit from the core innovation or general purpose technologies sold to technically proficient buyers, who are capable of generating their own modifications and improvements, but they seek donated labour for valuable complements by motivating them (external innovators) through recognition and other non-monetary rewards. The PC game developers have exploited this model widely by providing the core technology and some "customer facing" complements to users, while encouraging them to develop their own complements, known as game modifications (West and Gallagher 2006).

Open Innovation – Sixth Generation Innovation Model

Earlier in this appendix we discussed a systematic and historical evolution of innovation process models over last few decades by differentiating them in five generations proposed by Rothwell (1994). According to Koziol-Nadolna and Swiadek , an open innovation model can be considered the "sixth generation" innovation model that provides an answer to the changes in the global business environment and its influence on enterprises at the end of 1990s and the first decade of 21st century by creating new knowledge, managing existing knowledge, storing up knowledge, transfer of knowledge or using it again. The maximisation of values coming from different sources, i.e. both firm's own ideas as well as the external ones, is the ultimate objective of sixth generation open innovation model. This innovation model renders the formal framework of an organisation symbolic and it allows the flow of knowledge between the organisation and its environment. This means, organisations develop ideas that are created by others and make their own ideas available to other organisations for their further development. Sometimes ideas are deliberately transferred to start-ups in order to let these ideas flourish in a young and more dynamic working environment in the absence of organisation's internal power influence (Koziol-Nadolna and Swiadek 2010)

Chesbrough *et al.* (2006) declare open innovation paradigm to be the antithesis to the traditional vertical integration model (closed innovation), where the inflows and outflows of knowledge are purposively exploited to accelerate the internal innovation and expand the markets for external use of innovation. In a closed innovation approach, organisations do create new ideas in their R&D setup, however they do not share their knowledge and ideas to other organisations as they fear that the use of their ideas by other companies will lead to the loss of profits they could earn by solely exploiting these idea. Interestingly, in a closed innovation approach, most of the valuable ideas are not rejected by the market or consumers but by the firms' own employees who either find the ideas irrelevant or useless at some moment or oppose them due to internal power politics. This leads to the wastage of valuable ideas that are never used. However, on the contrary, the open innovation paradigm assumes that organisations are unable to take advantage of all their ideas by themselves, therefore they are willing to share them with other organisations that results in a higher number of innovative products (Koziol-Nadolna and Swiadek 2010). Chesbrough (2003b) argues that the open innovation paradigm can enable organisations achieve a greater return on their innovative activities and their Intellectual Property (IP) by loosening their control over both. This way, open innovation processes integrate external as well as internal innovative ideas into an organisation's architecture and systems to generate additional value, while defining internal mechanisms to claim some portion of that value. Open innovation fundamentally assumes that knowledge is spread over the globe and even the most capable R&D organisation must identify, connect to, and leverage external knowledge sources as a core process in innovation to remain competitive in the present day business arena.

Appendix C - Supplementary Material on Systems Approach

Background of the Systems Approach

A systems approach to problem solving is not a novel idea. It has been around for some time and has been a successful approach to complicated problems as indicated in Robert *et al.* (2010). The systems approach to problem solving and problem modelling allows the problem solver/user to simultaneously represent and consider multiple aspects of the problem and investigate the interconnection of these problem parts (Mendez 2010). Systems approaches to problem solving are therefore most effective when dealing with highly complex problems which can be broken up into interacting systems (Robert *et al.* 2010). This allows the problem to be broken up into more manageable tasks and also makes the interaction of the systems simpler (Robert *et al.* 2010). This way of thinking comes from the basic systems theory, in which a system is defined as a set of interconnected parts where the behaviour of the parts is dependent on the interconnection between these parts (ibid).

The system is separated from its surroundings by a boundary. Inside the system boundary, a system is generally comprised of a number of sub-systems that interact with each other in a specific manner that characterises the overall system behaviour (Robert *et al.* 2010). An engineering organisation can be considered as a system and its different organisational entities, such as engineering, manufacturing, leadership, finance, marketing, etc., as its sub-systems. The organisation would also be considered as an open system as it interacts with the market and other organisations.

The characteristics of complex systems are described in Robert *et al.* (2010) as follows.

- *Emergence* means that the system behaviour cannot be predicted form the behaviour of its separate parts.
- *Complex relationships between system parts* means that the parts of the system are connected in many ways and there isn't a one to one connection from one sub-system to another sub-system only. A change in one part (sub-system), therefore, will cause a change in many other sub-systems. There is thus no linear reaction to any change.
- *Thresholds* means that a complex system undergoing change creates reactions which slow down the change process. When the system crosses a *threshold* in this change process, however, change tends to happen suddenly, quickly and forcefully.

Justification of the Systems Approach to Promote Lean Innovation

The use of a systems approach is suitable because an engineering organisations seeking Lean Innovation conforms to the systems behaviour of emergence, complex interactions and thresholds of sub-parts (Robert *et al.* 2010).

In the previous section characteristics of complex systems have been expressed from the work of Robert *et al.* (2010). One can relate these characteristics to an engineering organisation attempting to apply Lean principles and promote innovation. This shows that application of Lean in engineering services and the promotion of innovation is indeed a complex issue and is dealing with a complex system. It makes the systems approach to the implementation of Lean an appropriate method. There are so many sub-systems in an engineering organisation, such as the various business units, design, manufacturing, testing, marketing department, finance, etc., that it would be impossible to accurately predict the behaviour of one based on changes in another. One can therefore infer that changes in one part of a complex engineering organisation may have an unpredictable outcome on the overall system of the organisation. Engineering services promoting Lean Innovation therefore conform to the definition of *emergence*.

Complex relationships between sub-systems are easily seen for anyone who has worked in an engineering organisation of any mid to substantial size. For example Lean implementation in an engineering organisation affects the manner in which operations are handled, approach to innovation, the focus of leadership on certain aspects such as waste identification and eradication, quality and efficiency. Hence, the sub-systems are connected in many ways and there isn't a one to one connection from one sub-system to another sub-system, which further implies that a change in one sub-system causes a change in many other sub-systems and there is thus no linear reaction to any change. This therefore conforms to the abovementioned characteristics of *complex relationships between system parts* in an engineering organisation seeking Lean Innovation.

The resistance to change is probably best described in the context of the present research. The implementation of Lean in engineering services has often been met with resistance (Toussaint and Berry 2013). The resistance occurs due to the long time that a company has been operating in a certain way and the complexity of the changes required. In these instances employees often see a problem so complex that any change is resisted (Swank 2003). Sometimes change is also resisted due to organisational politics and willingness to maintain a "comfortable" status quo. Strong leadership can however be used to overcome these barriers to change, and drive the change process and innovation forward. Breaking habits is another problem in a change process. It has however often been found that once there is a break in these bad habits and once people can see the results of Lean implementation the principles spread and catch on very quickly (Ohno 1978). For this very reason Ohno (1978) decided to implement the Lean changes in one department only at first and then use that as a pilot project to show the organisation that this change can work and bring better results. Lean implementation in engineering organisations therefore needs time to happen, especially in the initial stages. Ohno (1978) showed that once this initial resistance to change is overcome the progress increases in speed through the rest of the engineering organisation. This discussion thus shows a link of the implementation of Lean in engineering services to the complex system characteristic of *thresholds*.

Two Different Systems Approaches to Problem Solving

The systems approach to problem solving and planning of complex problems can be performed in two different and distinct ways (Robert *et al.* 2010). The text below outlines each method in more detail and differentiate between the methods, showing why one of these methods is more suitable to the complex problem of the implementation of Lean Innovation in engineering services.

Forecasting

The forecasting method of systems problem solving is also the traditional approach (Robert *et al.* 2010). It is in essence a technique which is used as a foundation for the planning of the implementation of the solution to the problem faced. Forecasting is a technique used to plan based on the current and past events (Holmberg and Robert 2000). The current and past events, experiences and situations are used to predict future events and situations (Robert *et al.* 2010). This method can be highly effective and has been used by traditional engineering services organisations for many years to predict future events, especially when the aim is to predict a future in order to be able to react to it. It is thus useful for predicting and project possible outcomes and then finding ways to avoid the unlikely ones (Robert *et al.* 2010). For example a budget is a good form of forecasting known to most. Companies consider sales and costs from previous years, historical growth and possible future growth or decline, based on current knowledge and speculation, and consequently make predictions for the following financial year. The limitations of the method are that the planners can only consider what is current, known and realistic today.

The rise and exponential improvements in technology and engineering services mean that the limitations are highly valid and constraining in the engineering services sector. An example of such a problem is innovation. A company using forecasting is only able to innovate based on current knowledge and current principles which limit the innovation process and outcome greatly. The forecasting method therefore cannot consider technology which has not yet been established or thought of, or any future ideas which evolve during the innovation process. The uncertainty of the outcome during the innovation process means that using only the existing knowledge and innovating from it limits the process and the end product, and creates only small incremental improvements or incremental innovation. The conventional engineering organisation in this instance would not be able to make big innovation jumps which are related to radical innovation. If it only considers known technology it would not be able to be a market leader in innovation and gain that competitive advantage that comes from having a unique product, which it could use to capture market share and maintain it for long periods of time. It should thus be clear that innovation is where the forecasting method falls short of what is required for an engineering organisation to be a market leader through radical innovation. For highly complex problems where the future outcome based on current knowledge and events is not easily predictable, another systems approach to problem solving, namely backcasting, can be suitable.

Backcasting

Backcasting is one of the high level methods of approaching a problem in the systems environment. The term backcasting was first used by Robinson in 1958 (2003), and it was used to describe an approach of future studies using normative scenarios. It has been very effective for highly complex problems and ones which look set to revolutionise the manner of operations on a grand scale. One example of this is sustainable development (Dreborg 1996). Backcasting has also been extremely useful in tackling problems with uncertain and unpredictable outcomes and with many variables (Holmberg and Robert 2000). The way that backcasting operates is that planners would start by building a "vision of success" for the future. Following this an inquiry would be set up regarding what needs to be done today so that the vision can be fulfilled in the future (Robert *et al.* 2010). From this it follows that backcasting, when simplified, is actually a method of decision making. Through backcasting a future state can be envisaged and principles or methods put into place to reach this vision (Roorda 2001). It must be noted that since backcasting is a relatively new technique not much information is available on its ultimate success or on the comparisons of backcasting to other possible techniques, such as transition management or strategic niche management (Quist and Vergragt 2006). Due to its nature however backcasting puts no constraints on the path to get to the vision as when new information and knowledge become available the methods can be easily adapted (Robert *et al.* 2010). What this means is that the vision is created with respect to a desired state in the future and is not based solely on past events and current technologies. This quality is ideally suited to innovation, as new information gathered through the innovation process can be implemented into the new solution efficiently.

Dreborg (1996) identified the most suitable times to use backcasting as a problem solving tool. These included:

- When the problem is complex
- When there is a need for a major change.
- When the dominant trends are actually a part of the problem
- When the major part of the problem are externalities (outside influences which cannot be controlled, such as a market collapse)
- When the time horison is long enough to allow scope for deliberate choice

One can relate the abovementioned issues to the implementation of Lean Innovation in engineering services. According to Dreborg (1996), if any one of these issues is agreed with then the problem faced can be solved with the use of backcasting. It has already been established in the key research question formulated in section 1.3 that implementation of Lean Innovation in engineering services is of a complex nature. The implementation of Lean in engineering services is also a major change (Ballé and Ballé 2005, Browning and Sanders 2012). The remaining three issues could also be agreed with although they could raise debate and are not as clear cut as the first two. As Lean Innovation implementation in engineering services is a complex problem and constitutes major organisational changes, backcasting can be used for the implementation of Lean Innovation in engineering services.

Deductions on the Suitability of Backcasting to Lean Innovation

From previous discussions it is clear now that forecasting has limitations, especially when pursuing innovation because innovation can produce a number of outcomes that are unknown at the start of the innovation process. Simply forecasting an innovation outcome from the extrapolation of known processes and data is therefore not effective to promote innovation (especially radical innovation), because innovation process is inherently uncertain and requires a flexible evolution process. In the 1970's when the issues of climate change and sustainability were coming to the fore in a bigger way a new approach and method of thinking towards forecasting and planning was developed. It is called backcasting (Quist and Vergragt 2006). The forecasting method was unable to assist problems where futures are unknown due to the complexity and novelty of the problem (Robert *et al.* 2010). One can easily extrapolate the complexity of the implementation of Lean into engineering services as a situation in which the future is difficult to predict from the current state due to the complexity of implementation and the unknown influences that Lean implementation will have on all areas of the engineering organisation (e.g. human capital, cost, marketing, etc.). One could also put a case forward that the future or implementation outcome is a desirable outcome the organisation would like to see rather than something they can predict from known information and experience within their organisation. They would of course be able to gather information on the experiences of other organisations which have undergone the same process but Lean implementation is best performed when it is custom made for a specific organisation (Seddon and O'Donovan 2010). Creating a vision of the organisation once Lean has been implemented will enable the company to customise Lean implementation to their required level and with the appropriate technology, rather than adapting an existing system from another organisation with different processes, resources and needs.

With the backcasting method one would be able to consider the present and also then aim to reach a desirable future (Robinson 2003). In backcasting one would consider the outcomes. One would look at either the scenario in the future that one wishes to achieve and from there develop methods to reach it or alternatively consider the principles that one needs to follow which would enable a change of state to the one desired in the future (Roorda 2001). Relating the forecasting and backcasting methods to the thesis purpose, the implementation of Lean Innovation in engineering services, one can think of forecasting implementation as firstly the identification of current waste. Forecasting would only be able to identify waste which exists and has been encountered before, such as staff absenteeism and its impact on revenue. Backcasting would however be able to create a vision where waste is eradicated in the future. This vision would go through iterations. At first the same waste is likely to be identified. In the future however more waste can be found through iterations and waste such as the effect that absenteeism has on the training and future ability to innovate of those specific workers can be identified.

Due to the aforementioned advantages of backcasting over forecasting, especially in dealing with complex problems where future results are unpredictable, backcasting has been deducted to be the preferred method to provide a framework to implement Lean Innovation in engineering organisations.

Backcasting from Scenarios and Principles

The backcasting systems approach has two techniques that can be utilised for solving complex problems. The following sections consider the two distinct backcasting methods proposed in literature, namely backcasting from scenarios and backcasting from principles (Holmberg and Robert 2000, Robert *et al.* 2010).

Backcasting from Scenarios

As aforementioned, backcasting is a method of planning in which a vision of the future needs to be defined. A way to do that is to define this successful future outcome through scenarios (Robert *et al.* 2010). By using this method simplified scenarios of the future are used and they are then utilised to guide the planning and implementation processes (Robert *et al.* 2010). It is also possible to develop more scenarios of the future which can be complementary or not (Quist and Vergragt 2006). Backcasting from scenarios has been successful when dealing with emotionally charged problems, such as political disagreements, environmental issues where participants have vested interests, etc. (Robert *et al.* 2010). The people responsible would then develop the tools to enable the scenario to change from its existing phase to a new, desired stage Roorda (2001). The whole time the process would be measured with milestones and against the envisaged scenario. At the end of the project the implementation would be deemed a failure or success based purely on the outcome versus the envisaged, preferred scenario (Holmberg and Robert 2000). This method can be useful in Lean implementation in engineering services as it is able to consider the future scenario and guide the engineering organisation towards it (Robinson 2003). With backcasting the engineering organisation would be able to create a scenario of Lean in the future and apply its principles to its own organisation in whichever way is best suited to individual organisational sub-systems. Therefore a situation such as Lean implementation in engineering services is complex and intricate enough that it lends itself more toward envisioning a state of the solution and creating frameworks and processes to reach it, then copying an existing solution and trying to adapt it to the organisation.

The method of backcasting from scenarios has been successfully implemented in financial institutions to deal with risk and also in problems consisting of complicated social situations (Robert *et al.* 2010). When implementing the backcasting from scenarios method, Roorda (2001) suggests that follow-up issues need to be monitored:

- The manner in which the scenarios can be realised.
- The magnitude of the investments.
- The control methodology of the process.

These issues would also be critical in Lean implementation. It has been noted that Lean implementation tends to overuse the company resources initially, especially if the implementation process is not well planned (Seddon and O'Donovan 2010). It is also important to define scenarios which are different from the current status and also different from the conventional status. If this were not the case and a different future was not needed there would be no need to perform the work and secondly if the scenarios were not different to the conventional and expected outcome then forecasting could be used successfully (Robinson 2003).

A number of disadvantages with the backcasting from scenarios have however also been discovered as indicated by Robert *et al.* (2010). These include:

- It is difficult for large groups to agree on the exact scenarios of the future.
- Technological changes can make the chosen scenario obsolete.
- Certain scenarios could prove unsustainable in the future as more knowledge becomes available.

Backcasting from Principles

Another approach to backcasting is backcasting from principles. With this approach the principles required to implement change are identified. Once the principles according to which the work will be performed are outlined and identified the method is to ensure that all of the work functions follow the set principles (Robert *et al.* 2010). The idea behind this approach is that if the principles are followed at each stage of the process the result will effectively take care of itself (Holmberg and Robert 2000). The difference in the two approaches is that backcasting does not pre-define only one successful outcome (Robert *et al.* 2010). This is useful to Lean implementation in engineering services due to the ability of backcasting from principles to cater for the unexpected events during implementation. These could, for example, be technological improvements which could aid the Lean implementation process. The only aspect that Lean implementation needs to adhere to is the conformance to the principles outlined as backcasting from principles does not define the final implementation outcome at the beginning of the process.

The principles chosen in this method need to be the basic principles of eventual success and they are often seen as the defined system constraints (Robert *et al.* 2010). The plan is thus only judged to be successful if it conforms to the principles laid out (Holmberg and Robert 2000). A nice metaphor to describe the process is used by Robert *et al.* (2010) which relates chess and the players who play the game based on the principles of a chess game in order to reach an outcome based on these principles. The players do not know at the start of the game where the chess pieces will end up during the game (Robert *et al.* 2010).

The advantages of backcasting from principles are that it is more flexible than the backcasting from scenarios approach and caters for possible technological innovations as it does not define a definite outcome (Robert *et al.* 2010). The outcome can therefore be successful in a variety of ways as long as the principles are followed (Holmberg and Robert 2000). It is stated by Robert *et al.* (2010) that the major advantage of backcasting from principles is that the pre-defined rules are aligned to success and are therefore in constant sight and focus during the problem solving process. This is very useful in the innovation process as in certain instances there are no accurate ways to establish the precise outcome of the innovation process at the start. In such a situation the following of the backcasting principles at each stage of solution implementation leads to a successful result.

Appendix D - Supplementary Material on Leadership

Leadership is a concept which has been around and discussed in humanity since ancient times. Some of the great generals of the past were all spoken of highly in terms of leadership by great thinkers such as Plato, San Tzu and others (Halling 2013). Much of the collective success of nations and people has been contributed to the role of leadership. Halling (2013) points out that management as compared to leadership is a much newer phenomenon. Additionally he mentions that leadership has traditionally been very difficult to define and that the definitions have often been as a result of personal qualities, examples and based on opinions rather than scientific research. DuBrin (2010) defines leadership as: "the ability to inspire confidence and support among the people who are needed to achieve organisational goals". Chemers (2000) further defines leadership as: "a process of social influence in which one person is able to enlist the aid and support of others in the accomplishment of a common task". It is thus clear from these definitions that leadership is referred to as a tool which can both inspire others and also be used to gain their support. In fact those two elements of leadership are most common in all definitions. One can therefore conclude that from these definitions that leadership comprises of two elements, namely inspiring or motivating others and then using that help towards a task or purpose.

The Difference between Leadership and Management

Leadership and management are often confused (DuBrin 2010). A leader thus does not necessarily need to be a manager but a manager is much more likely to succeed if they have leadership qualities (ibid). DuBrin (2010) goes on to indicate that the easiest way to realise the difference is to understand the various roles and functions that each performs. Leadership is said to deal with the interpersonal parts of a manager's job (DuBrin 2010). Management is related to a position within a company and deals with the daily tasks of directing, monitoring, fixing, etc. Leadership on the other hand is not necessarily related to a position within a company (DuBrin 2010). This means that anyone in the organisations can be a leader. A leader typically has the qualities and ability to inspire, persuade and motivate others in order for them to follow this leader towards tasks or methodologies. It is quite clear from these definitions therefore that leadership is crucial if one expects people to follow a person's ideas through change.

Furthermore an interesting explanation of the two originally coined by Peter Drucker and recited by Treiger (2014) interestingly notes the definition and distinction between leadership and management as: management is doing things right while leadership is doing the right things. This distinction offers insight into the role of management which is to ensure that processes which are already set up are followed. Leadership on the other hand deals with the creation of the correct and appropriate strategy and hence an action plan for the organisation to take. It is also said that for an organisation understanding the difference between leadership and management is crucial for success (Romero 2010). Again Romero (2010) explains the difference between the two in terms of the functions that each performs. In concluding Romero (2010) states that management mainly deals with the present and that leadership is primarily concerned with the future but most explicitly with change. The reoccurring theme seems to be that change is associated with leadership and that good or strong leadership is necessary, or at least advisable, when change is required. It is also stated that it is vital for an organisation that distributed leadership exists throughout the organisation although management may only reside with the management positions (Romero 2010). The importance of leadership can thus not be undermined, especially when it comes to change processes. It is stated by Ifechukwude *et* *al.* (2014) that whilst management is important leadership is essential. A change process such as the move towards Lean and incorporation of innovation, be it radical or incremental is therefore reliant on leadership.

Traditional Leadership Importance

Leadership has had different importance assigned to it throughout history and in particular throughout its history in a company or another type of financial organisation. DuBrin (2010) clearly identifies the two varying thoughts on the importance of leadership in organisations. The two opinions are that leadership does make a difference and the other that it does not make a difference to the way an organisation should be run. In the research conducted for the support of the importance of leadership to performance of organisations it is also interesting to note that leadership showed to be the most significant in transformational circumstances (DuBrin 2010). In the argument against leadership significance DuBrin (2010) points out that there are three circumstances when it is believed that leadership is not important. These are times when there are substitutes for leadership within certain organisations in terms of structure, support and incentives; leadership irrelevance such as external factors which influence the performance of the organisation rather than leaders with the example of a mobile phone boom which would have made most companies in that sector profitable; and finally complexity theory which states that companies are such complex entities that leaders can have little or no influence (DuBrin 2010). It is very interesting however that in the last point on complexity theory it is noted that the best way that managers and leaders can hope to make a difference is to keep innovating and adapting to the changes in the external world (DuBrin 2010).

Generally, however, most literature points to the importance of leadership in organisations. In his work, Auble (2001) points out that leadership is a strategic necessity in large and complex organisations and also goes on to list six major US companies which have invested heavily in top leadership and are reaping the rewards. This view is supported by Bird *et al.* (2004) who state that companies who learn to place their best leaders in the most important position historically do much better than the companies that don't. It is also recommended in Weiss (2003) that the most important tasks within organisations should be given to people identified as leaders or those with strong leadership skills and potential in order to maximise results and minimise resources. On the other hand leadership is said to be important not just in certain positions but in all positions within an organisation and a concept of self-leadership by employees is described as extremely meaningful for success (Marion and Uhl-Bien 2001). Due to the obvious challenges an organisation faces in a transition period the role of leadership gains in importance.

Leadership in Times of Change

In the previous discussions leadership and management have been identified and explained further in terms of the responsibilities and needs of an organisation. This section focuses on the requirements of leadership in times of change. In her review of studies on leading through change, Nolan (2013) relates a study by Pritchard and Bloomfield (2013) which indicates that an engaging style of leadership is the best way to manage change. The case study is based on a major transformation in a governmental department. Anderson and Ackerman (2010) discuss what they term as breakthrough change in their book. Breakthrough change is said to be radical change potentially yielding large changes in results and increases in performance. They state that leadership is what drives such change in organisations (Anderson and Ackerman 2010). Kotter (2013) goes further to state that ensuring effective change is one of the functions or traits of leadership and not only that leadership is helpful in such situations. In all of the situations mentioned above major organisational change is considered. This is similar to the move towards Lean in engineering services. A change towards Lean is thus a radical change and this has already been discussed from an innovation point of view where Lean is considered as radical innovation.

Leadership involvement in change is thus particularly true in complex situations and implementing Lean methodologies in the engineering services sector definitely qualifies as one such activity. A further novelty factor is the implementation of Lean through a systems approach. Although the implementation of Lean should be conducted through a systematic approach as mentioned earlier in this proposal the idea of systems approaches to problem solving is novel to most managers. Additionally, the idea of backcasting can be assumed to be fairly new to most outside of the sustainable development environment (having only been introduced in the 1980's), based on the lack of literature on the topic, and thus the leadership part of such a process is extremely important based on such a great change taking place through this process. The role of leadership in engineering organisations is primarily to explain, motivate and reason (DuBrin 2010). In order for people to accept the reduction of waste in Toyota, for example, a lot of time and effort was spent (Ohno 1978). There is an assumption that the transition was due to the Japanese "culture" and that this is why it was easier to implement than in the West (Ohno 1978). As stated in Ohno (1978) the process required not just telling the people what needed to be done but for them to accept the methodology and take it on themselves. The change had to come from within in all forms of work activities (Fujimoto 2013). This process took time. Ohno and Toyota often talk of creating a culture in which waste was reduced at all possible levels (Ohno 1978). This means that the workers and all members of the organisation would take it upon themselves not only to eradicate waste but to identify all forms of waste in their daily routines (Fujimoto 2013). One example of this was the 5 why's which Toyota advocated for its workers to use in their everyday activities. The 5 why's were a system whereby workers were encouraged to ask why of a process or task 5 times in order to fully understand it or to discover that it was perhaps unnecessary (Ohno 1978). The empowerment of workers in a Lean organisation, such as Toyota, can be related to the similar concept used in innovation. In technological innovation, the bottom-up approach is one where the workforce is encouraged to take ownership of the innovation process and drive it. This is very similar to the Toyota way of the workers owning Lean and implementing it from the bottom up. Although it must be said that Ohno (1978) also stated that Lean needs to be driven by both management and workers.

It also took leadership by example and perseverance as well as belief in the system to achieve this. Only once the workers realised that the changes would be beneficial and were correct and needed did they start following them. The workers thus became the champions of change themselves (Ohno 1978). In this process leadership was perhaps the most important factor in the implementation of Lean methodologies (Ohno 1978). It is important to stress once again here that it is leadership and not necessarily management which was the most important (Romero 2010). Implementing a change and monitoring/policing is something which is done by management on a daily basis. It is also usual for such policies and changes to not take off or for methods of work to go back to their previous state once the intense monitoring by management has subsided (Treiger 2014). The key is thus for the workers to take ownership of the changes and provide self-leadership (Weiss 2003). If this is the case in what is considered to be a simpler area for implementation of Lean methodologies one can immediately see that the need for strong and motivational leadership is what is required in the engineering services sector. It is stated by Womack *et al.* (1991) that there are many non-technical managers in engineering companies and this is detrimental due to their inability to identify areas worthy of innovation.

Lean Leadership and its Role in Services

Lean Leadership

Companies which were even more successful had managers with leadership qualities who instilled the desire in their workforce to achieve this reduction of waste without being forced to do so or monitored constantly. Here however managers showed great leadership in order to motivate and persuade workers to follow such actions (Toussaint and Berry 2013). Balle and Bouthillon (2011) found that for CEOs managing Lean companies one of the 5 most important factors was to develop leaders within the organisation rather than followers so that real Lean implementation could take place.

As stated earlier in this document Lean principles have been derived from manufacturing and too often copied and pasted into the services sector (Allway and Corbett 2002). In the manufacturing sector managers looked for ways to reduce waste in the various production processes, which would in turn increase profitability within the organisation (Levitt 1972). In such a scenario managers were asked to analyse the production process and identify all possible areas of waste, both direct and obvious as well as those indirect and less visible. They have often been guided by the 7 forms of waste as identified by (Ohno 1978). From the search for the reduction of waste came all of the principles we know today such as just-in-time (whereby there would be no storage and all of the expenses associated with this process) (Ohno 1978) kanban (which is the method of controlling the just-in-time principle with the use of cards controlling production processes) and kaizen (which is the constant search for improvement) as well as numerous others (Ohno 1978). The highlight in manufacturing also turned towards the quality of products and consistency of production. All defects were considered as the worst kind of waste as they required complete re-manufacturing and the aim was therefore to eradicate them. The role of leadership in these instances has been mainly to identify all forms of waste and derive ways to eradicate this waste or somehow reduce it. The more successful companies at doing this have often had managers with the ability to identify more forms of waste and who were able to create effective ways of reducing waste (Ifechukwude *et al.* 2014). The role of leadership in Lean evolved from there.

Flinchbaugh *et al.* (2008) state that the reason leadership is so crucial in Lean transformations is due to the fact that everything in the company, including the culture and employee mindset needs to change. It is also shown by a study conducted by Boyer (1996) that management commitment has a definite positive influence on the implementation of Lean. Boyer (1996) goes so far as to say that committed management with the relevant support structure guarantees the successful implementation of Lean. Quality leadership from the entire workforce, achieved through worker empowerment and thus cross company leadership is one of the key support pillars for Lean implementation (Boyer 1996). The view on the need to change worker mindset and hence the need for strong leadership rather than management is also supported by Pullin (2005). Due to the initial background of Lean in production as described in earlier sections there has been an association of Lean with tools used for the implementation

(Mann 2009). Mann (2009) further suggests that only 20% of the effort is related to the tools and 80% is to the leadership aspect of implementation through the establishment of conditions required for success. The advice to managers from Flinchbaugh *et al.* (2008) is to create an atmosphere where workers are allowed and even encouraged to try things out, experiment, innovate and take risks. These are the cornerstones of Lean and thus should not be suppressed (Flinchbaugh *et al.* 2008).

Lean Leadership in Services

In the services sectors the situation is far more fluid than in production. The products are not tangible and success/impact is more difficult to measure (Carlborg *et al.* 2013). The employees cannot see the waste and thus it is more difficult to reduce. As soon as the object you are trying to eradicate is not tangible the managers will have an even more difficult task of convincing the workers that the effects of the changes are taking effect (Chase and Garvin 1989). In situations such as these the leadership qualities of motivation and persuasion are in even higher demand from the managers. Strong leadership through change is often promoted and advocated (Heath 1998, Halling 2013).

Much of the current research and knowledge points to a need for strong leadership in the services sector when attempting to implement Lean (Halling 2013). The relatively low success of Lean implementation in services and engineering services as pointed out earlier makes the statistics difficult to back up by sheer numbers however the principles of Lean implementation clearly show that leadership and management commitment to the process are key and usually go hand in hand in all success stories (Oppenheim *et al.* 2011). Research by Soriano-Meier and Forrester (2002) has shown that Lean can be applied to any industry and to any extent which is deemed optimal for that specific situation. This also ties in with the advice of Demming on the implementation of Total Quality Management (TQM) which he stated could be applied to any situation or industry without a blueprint but rather through adaptation to specific situations (Gartner and Naughton, 1986). All of the literature cited above indicates that in order for Lean to be implemented successfully in services there is a need for strong leadership which will motivate the employees to embrace and take ownership of the change. In engineering services the complexity of the work is great and leadership is important for continuous growth and development.

Characteristics of Different Leadership Styles

A number of leadership styles have been identified in Section 2.4.2 due to their suitability to Lean transformation, innovation and the systems approach to solve complex problems. The characteristics and traits of these leadership styles are discussed in the following.

Transformational leadership style

The transformational leadership style has been highlighted as the one suitable to Lean implementation, innovation and the systems approach to problem solving. The transformational leadership style is said to be the one which brings in major, positive change to an organisation (DuBrin 2010). The transformational leadership style has one major characteristic which is the ability to transform people. Transformational leaders are also highly enthusiastic about change (Nusar *et al.* 2012). They transform people by raising awareness about the key issue, they look past themselves and are selfless, have a sense of urgency, help workers realise the need for change, have a long term view, build trust, concentrate resources into areas most needing change and help people fulfil themselves (DuBrin 2010). Transformational leaders are also said to be ones who think big (Hewitt *et al.* 2014).

DuBrin (2010) outlines several steps that transformational leaders undertake to achieve their goals and these steps will shed more light on the traits and processes followed by a transformational leader. Firstly transformational leaders raise awareness and effective communication is key throughout this process. The aim is to set a target for the employees, appeal to their pride and identify rewards for reaching goals (DuBrin 2010). The transformational leader then persuades employees to consider organisational interest first, whilst also enabling employees to search for self-fulfilment (ibid). A transformational leader's next step in the transformation process is to ensure that the employees understand that there is a need for change. There might be emotional conflicts with staff in this process as people are generally reluctant to change but the transformational leader uses their listening skills and emotional intelligence qualities in this step (ibid). Creating a sense of urgency and commitment to greatness are the next two steps a transformational leader will typically take and here leading by example is key. Leading by example is a quality which transformational leaders often rely on and which motivates followers (Holmberg 2014).

The next step for a transformational leader is to consider and convey long-term plans for the organisation. This shows visionary qualities and gives employees a sense of security (DuBrin 2010). Instilling trust is the next step and is important to implementation, as distrust is usual during changes. This is usually done through organisational transparency (ibid). Finally a transformational leader is analytical enough to realise which areas need the most change, will yield the best results and to concentrate resources on change implementation in these areas (ibid). It is obvious to see how transformational leadership can therefore enable change and also innovation. Leadership styles are fortunately something which can be learnt and adapted to.

The Charismatic Leadership Style

The charismatic leadership style has been identified as one suited to innovation and change/Lean implementation situations. The charismatic leadership style is explained as one which promotes vision (DuBrin 2010). Some of the characteristics of charismatic style leaders include excellent communication skills, their ability to make others around them feel capable, emotional expressiveness and warmth as well as the ability to gain trust (DuBrin 2010). Charismatic leaders also possess vision and their communication style is such that it is storytelling and inspiring (DuBrin 2010). One can see why the above mentioned qualities in charismatic leaders make it suitable for the implementation of Lean Innovation in engineering services. The ability to inspire confidence in others would enable them to perform better through the undeniably difficult time of Lean implementation. Gaining trust is of course crucial in such a step and the combination of these qualities also inspires followers to express themselves thereby aiding innovation. Charisma itself is actually a large part of transformational leadership also (DuBrin 2010).

The Participative Leadership Style

The participative leadership style is identified as favourable for major change processes. The participative leadership style is characterised by leaders involving others in the decision making processes and especially when making major decisions (Rossberger and Krause 2015). In this style it is very important that leaders, and invariably managers, listen to ideas from below them in the organisational hierarchy (DuBrin 2010). The applicability to change situations is thus evident as the workforce feels included and more receptive to change.

The Entrepreneurial Leadership Style

The entrepreneurial leadership style is identified as being suited to a systems implementation approach (DuBrin 2010). The entrepreneurial leadership style is able to inspire others, has a visionary aspect to it and is quick to identify and pounce on opportunities (Renko *et al.* 2015). It has also been found that the entrepreneurial leadership style is more prevalent among founder leaders, thus people who were able to build a company from the start up (Kotter 2013). This shows that the entrepreneurial leadership style is thus able to follow ideas through the process of implementation and build an organisation or change.

Appendix E - Interview Guideline and Expert Profiles

Interview Guideline

Proposition 1.

Focusing on the value creation rather than the waste elimination aspect promotes Lean Innovation in an engineering organisation.

Proposition 2.

Lean Innovation necessitates the separation of the R&D and manufacturing systems in an engineering organisation.

Proposition 3.

Lean's interaction across different sub-systems within an engineering organisation needs a holistic perspective in promoting innovation.

Proposition 4.

Complexity and unpredictability of a Lean Innovation process are effectively resolved by the backcasting from principles systems approach backed by transformational leadership.

Proposition 5.

The systematic incorporation of open innovation in a Lean engineering organisation leverages its innovative capability.

Proposition 6.

Lean Innovation through an early and regular customer engagement is achievable with backcasting from principles in a passive and flexible manner.

Proposition 7.

The optimised flow of information and processes through a backcasting from principles' framework drives Lean Innovation.

Proposition 8.

Cross-functional and empowered teams in a flat organisational structure led by multi-skilled and strong leaders drive Lean Innovation.

Proposition 9.

The utilisation of integrated digital simulation tools helps mitigate risk faced by a Lean engineering organisation seeking innovation.

Expert Profiles

Tomasz Krysinski

Tomasz Krysinski re-joined Airbus Helicopters as Vice-President Research and Innovation in May 2014. In his role, he contributes to the definition and the cascading for the company strategy & objectives, communicating and translating these into a clear set of implementation activities; ensuring their successful delivery across the company. From 2011 to May 2014 Krysinski was in charge of the innovation laboratory at PSA Peugeot Citroën.

Krysinski, who was born in Lodz in Poland, holds a Master of Engineering from the Ecole Nationale Supérieure d'Arts et Métiers (ENSAM) Paris and the Ecole Nationale Supérieure des Pétroles et des Moteurs (IFP) as well as a Master of Science in Energy Processes from Université Paris VI.

Elaine Daly

Daly is a programme assistant at the Sustainability Assessments Group and the Sustainable Product & Service Innovation Theme at the School of Engineering, Blekinge Tekniska Högskola (BTH), Karlskrona, Sweden. Elaine currently lectures several courses at BTH in the fields of systems approaches to sustainable development.

Daly holds a Bachelor of mechanical and manufacturing engineering along with a Bachelor of Arts in Mathematics from Trinity College Dublin in Ireland and a Master's degree from the MSLS programme. She has worked as a consultant in the private and NGO sector in Ireland, Uganda and South Sudan, in the areas of finance, systems design, modelling and business process analysis. She also ran her own practice as a coach and holistic health practitioner. Her passion is in creating spaces for catalysing change and prototyping new behaviours and ways of being in order to create a healthy, harmonious and vibrant planet.

Denver Dreyer

Denver Dreyer is currently employed as an executive of the Hydrocarbons, Resources Infrastructure and Power Operations at Worley Parsons South Africa. Prior to his current role he has held positions of Executive of Business Development and Strategy, General Manager of Minerals and Metals South Africa and Business Unit manager all at Worley Parsons South Africa. He started his career in engineering manufacturing in 1997. Dreyer holds a BSc. in Electrical Engineering from the University of Cape Town, South Africa.

Henry Jonker

Currently Henry Jonker holds the position of General Manager Johannesburg - Worley Parsons, which is the global hub for Minerals, Metals and Chemicals (MMC) at Worley Parsons. Henry Jonker started working in the mining industry in 1986 at Goldfields SA and later at West Driefontein Mine. In 2001 Henry joined TWP Projects. As a project engineer and project manager he excelled within the TWP group. In 2003 he was tasked with establishing a consulting service within the Limpopo province. Under his guidance in the capacity as Managing Director of TWP Limpopo, it became a very successful service provider to the mining industry. In the past he has also been involved in major projects such as the Bulyanhulu Gold Mine Project (Tanzania) and the Palaborwa Underground Mining Project (South Africa). Henry holds an electrical engineering degree, government certificate of competency and obtained his Executive MBA earlier this year.

Prof. Norman Faull

Norman Faull was among the first wave of researchers in South Africa to introduce innovative manufacturing and supply chain efficiency concepts, such as Lean Manufacturing, into the country. Faull has initiated a range of executive short courses in operations at the University of Cape Town Graduate School of Business (UCT GSB), particularly in the Lean thinking area, and has led study tours to Japan and Germany in recent years. He has recently explored the application of Lean principles to the healthcare sector. Faull is currently the Vice President for Europe and Africa of the Production and Operations Management Society. He has a BSc and BEng in Aeronautical Engineering from Stellenbosch University, an MSc from Cranfield University in the UK, and a PhD and MBA from the University of Cape Town.

Rogier van Beugen

Van Beugen is the Director of Innovation at KLM Royal Dutch Airlines. Over the past decade, he has held a number of leadership roles at KLM Royal Dutch Airlines. He has had roles in general management as well as in commercial management, focused on (B2B) sales and business development. The focus of the past three years has been organisational change, including innovation. Van Beugen is responsible for stimulating employees to be innovative and optimising innovation by bringing in external ideas and inspiration. Van Beugen holds degrees of Master of Business Economics and Master of Science from the University of Amsterdam in the Netherlands.