



UNIVERSITY OF GOTHENBURG
SCHOOL OF BUSINESS, ECONOMICS AND LAW

Lean Product Development

-Performance Measurement System

Ali Mohammadi

Graduate School
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Supervisor: Rick Middel

Table of Contents

1-Introduction:	7
Motivation:	7
Research Question:	9
Thesis Structure:	10
2-Literature Review:	11
Lean Product development:	11
Lean concept:	11
Lean manufacturing VS Lean Product Development:	13
Lean Product Development Definition:	14
Practices and Techniques:	16
Performance Measurement in NPD:	19
Objectives:	21
Dimensions and Indicators:	22
Structure and measurement processes:	24
Summary:	24
3-Methodology:	27
Research Process:	27
Research Strategy:	27
Research design:	28
Data Collection:	29
Literature review:	29
Interview:	29
Delimitation:	30
Validity and reliability and replication:	31
4-Case Studies:	33
Case A Co.:	33
Company Information:	33
Product development:	34
Lean product development:	36
Performance Measurement:	37

Case B:	38
Company Information:	38
Product development:	39
Lean Product Development:	41
Performance Measurement:	42
5-Analysis:	43
Lean Product development:	43
Definition:	43
Tools and techniques:	44
Success factors:	47
Performance measurement system:	47
Objectives:	48
Dimensions and Indicators:	49
Structure and measurement processes:	50
6-Conclusion:	53
Objectives and contribution:	53
Managerial Implication:	56
Further studies:	57
7-Bibliography	58
8-Appendices:	61
Appendix 1: A synthesis of suggestions from the literature about the PMS designs	61
Appendix 2: Interview Questions	62

Abstract:

Lean product development (LPD) has been introduced as a concept which is able to improve Product development processes and firm's competitive advantages. The concept has been argued that has potential to reduce time to market of new product with higher quality and manufacturability. Performance Measurement system is a key factor in evaluating processes and effect of new concepts or changes on process efficiency. Managing and measuring performance in product development has been seen as a mean to ensure survival of business by increasing quality, reducing time and cost. Scholars argue identifying right metrics and measuring performance of Product development processes play a key role in success of Lean Product development. The aim of this project is to evaluate how firms measure performance of lean Product development. The foundation of the study will be on the definition of lean product development as a coherent whole and systematic way rather than focusing on a special technique or tool. The theoretical framework shows two approach of process oriented and outcome oriented in definition of lean product development exist. The firms consider the processes oriented approach while these processes are unique for each firm. Design of processes is dependent to current situation of company.

In case of performance measurement theoretical framework argue that a performance measurement system should have five elements of Objective, Dimension, Indicator, Structure and processes. The main dimension of performance in product development processes are efficiency and effectiveness while firm measure efficiency they fail to measure effectiveness. On the other hand setting standard and goal play an important role in success of performance measurement system and performance improvement. But some firms are failing in setting clear vision and goal for their processes.

Keywords: Lean Product Development, Performance Measurement System, Performance Dimensions, Indicators

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1-Introduction:

Motivation:

Fierce market competition forces companies to improve their efficiency in all processes. In the new millennium firms competitive advantage is coming from their knowledge management capacity and new product development is the frontier of knowledge management process. As it has been called “*age of change*” while emphasize is on creating new knowledge and products is like of which has never been (Tomkovick & Miller, 2000) . Product development has been seen as a reliable source for producing cash flow into firms and sustaining the cash flow is optimal aim of any manager. Sustaining growth and cash flow is possible with an efficient R&D which introduces new products or services in shortest possible time and aligned with customer requirements.

A successful product development is a light path for firms in order to improve and sustain their competitive position in market. Over the past thirty years several scholars have argued about significant role of product development in creating and maintaining market position in the competitive business environment (Schoonhoven, Eisenhardt, & Lyman, 1990; Van Echtelt, Wynstra, van Weele, Duysters, & Geert, 2008). Therefore, the product development process performance in order to reduce time to market cost and create higher value for customers became more demanding. Such an efficient process is in need of processes which are able to coordinate and improve their critical resources and capabilities (van Echtelt, Wynstra, van Weele, Duysters, & Geert, 2008).

The speed of delivering a product for a new firm to market is an important factor since: 1) gaining early cash-flow can lead to financial independent 2) creating legitimacy by developing external visibility in market. 3) Gaining early market share. 4) Higher likelihood of survival. (Schoonhoven, Eisenhardt, & Lyman, 1990). A study in 1982 found economic value of a new product is related to time from investment to gaining first return. Therefore Innovative organizations gain higher economic value from shorter time to market (Schoonhoven, Eisenhardt, & Lyman, 1990).

Lean product development (LPD) has been introduced as a concept which is able to improve Product development processes and firm’s competitive advantages. The concept has been argued that has potential to reduce time to market of new product with higher quality and manufacturability and less engineering hours and start-up problems (Karlsson & Ahlström, 1996). Finally it will increase possibility of success and improvement of market position by creating sustainable cash flow and market position.

Karlsson and Åhlström (1996) defined “Lean product development as a collection of interrelated techniques including supplier involvement, Cross-functional teams, Concurrent Engineering, functional integration, use of heavyweight team structure and strategic management of each development”. Implementing these techniques will help firms to introduce new product to market faster than competitors and achieve to a strategic tool in order to survive in a turbulent environment (Karlsson & Ahlström, 1996) Even though all the techniques which have been mentioned have existed in product development process but they have implied them as a package in their study with heading of Lean Product development. They argue the concept of lean product development should not be confused with techniques and implementing one technique does not mean achieving to lean product development. In this study, they stress lean Product development concept as a “coherent whole” (Karlsson & Ahlström, 1996).

In study by Reinertsen and Shaeffer (2005), researchers focus on differences and similarities of lean concept in manufacturing and Product development process. Variation limitation which is key concept in lean manufacturing has been mentioned as key difference in product development. Since variation is the driving force of developing new product concern here is on finding good or bad variations rather than eliminating all variations (Reinertsen & Shaeffer, 2005). Two benefits have been mentioned as keys for implementing lean concept in product development process: 1- adaptation for required variability in R&D and 2- faster cycle time or shorter time to market. (Reinertsen & Shaeffer, 2005).

The final aim from any process improvement or concept is achieving success compare to competitors. Performance Measurement system is a key factor in evaluating processes and effect of new concepts or changes on process efficiency. There is an old saying “If you want to manage it, you have to measure it” (Driva, Pawar, & Menon, 2000). Managing and measuring performance in product development has been seen as a mean to ensuring survival of business by increasing quality, reducing time and cost (Driva et al. 2000). Cooper & Edgett, (2008) and Reinertsen & Schaeffer (2005) argue identifying right metrics and measuring performance of Product development processes play a key role in success of Lean Product development. Efficiency in product development can be defined from different point of views. The common way for measuring efficiency is productivity of process which is output relative to input of any process (Cooper & Edgett, 2008). This measure is straight forward but it is not sufficient in order to evaluate lean product development. In this case we can go back to definitions which have been provided for lean Product development. Researchers argue lean thinking concern regarding customer view, process integration and continuous improvement through waste reduction and implementing. Although the terms for potential of lean concept in Product development are shorter cycle time ,increasing quality , less engineering hours and start-up problem.

Considering lean product development the suitable measures for evaluating process in addition to productivity can be seen as matrix of measures such as time to market, customer satisfaction ,supplier lead time, product met quality guideline, etc. (Driva, Pawar, & Menon, 2000).

The aim of this project is to evaluate how firms measure performance of lean Product development. The foundation of the study will be on the definition of lean product development as a coherent whole and systematic way rather than focusing on a special technique or tool.

Literatures regarding lean product development have focused mostly in two issues: bridging lean manufacturing and lean product development, Implementation of lean product development regarding challenges and difficulties. This study will contribute to lean product development literature by first defining lean product development considering different nature of variation in lean manufacturing and lean product development. In this part different approaches for definition of leap product development will be reviewed. Secondly, it will focus on performance measurement system in lean product development. The dimensions of performance measurement system will be analyzed in detail. Therefore this study can contribute to clarification of lean product development in practice and contribute to literatures in product development performance measurement and LPD.

In next part the research question will be developed and argued in more detail.

Research Question:

The main research question has been developed based on the argued background regarding lean product development. Since 1980s majority of firms have implemented lean concept in different levels of their organization with the ultimate goal of continuous improvement in their processes. As Carleysmith, Dufton, & Altria, (2009) mentioned just a simple research on Google will lead to more than Six million hits regarding Lean thinking and six sigma. The literatures in this case have focused on the issues such as: implementation, tools and techniques etc. This study will focus on performance Measurement system in lean product development. Hence the benefits of studies can be categorized in two categories: 1- providing an overview of lean product development 2- identifying suitable performance measurement system in LPD. In conclusion, the main research question focus is on performance measurement system in lean product development process. Consequently the main research question can be formulated as:

“How firms measure performance in lean product development?”

Thesis Structure:

The structure of this report in the following chapters will be as

Chapter 2: in the first part main theories and literatures regarding lean product development will be reviewed. It will provide a thorough overview about lean product development tools and techniques. In the second part the performance measurement systems and indicators in Product development will be reviewed. In this part a framework for analysis of performance measurement systems will be developed.

Chapter 3: comprehensive methodology of research and development of research process in order to achieve to the aim of research.

Chapter 4: empirical results and collected information from two cases will be argued thoroughly. Main concern in this part is on product development processes and performance measurement system.

Chapter 5: analyzing the results from empirical concerning the main theories which have been reviewed in chapter 2. Analysis has been conducted in two sections of “Lean product development” and “Performance measurement in LPD”.

Chapter 6: will be devoted to the conclusion of thesis. In this chapter contribution of research will be argued in addition to managerial recommendation. The chapter will end up with further studies which author believes can help in order to contribute to area of performance measurement in lean product development.

2-Literature Review:

In this section, literatures regarding Lean, Lean Product development and Performance Measurement in Product development have been reviewed.

In the first part aim is to review definitions and practices regarding Lean Product development in order to achieve a holistic vision and definition about product development for the empirical part. In this part tools and techniques which have been used in lean product development will be reviewed in order to clarify lean product development environment. Such a framework will help to analyze companies claim about implementing lean product development by comparison between theoretical framework and real situation.

The second part will focus on Performance Measurement in NPD. In this section existing theories and models of performance measurement have been argued which author believes can be related to Lean Product development (LPD). Since there is not any specific research in area of performance measurement system in lean product development, they study will focus on general concept of performance measurement system in product development rather than only Lean product development.

At the end of this chapter, reader will have a clear understanding of lean product development researches and performance measurement in product development which has been mentioned by different scholars. At the end of the chapter a list of applicable indicators in product development process are summarized.

Lean Product development:

Lean concept:

Lean Concept has been introduced first in Toyota Production System (TPS), as a tool in manufacturing process in order to increase efficiency by reducing wastes. TPS is the base of what has been called Lean thinking (Liker & Morgan, 2006). TPS focal point was about reduction of waste from value stream and most implication has been for high volume process with standardized products. The benefits of Lean system on performance are remarkable in case of improving quality, reducing cost, and delivery (Lander & Liker, 2007)

TPS most famous tools and concepts are: Pull system, Takt time, Leveling (heijunka), Continuous Flow, Jidoka, Just in Time (JIT), Standardized work. Nowadays lean thinking is widely used in service (banking, marketing, and insurance), healthcare, Laboratories and Product development (Carleysmith, Dufton, & Altria, 2009). Lean thinking emphasizes on customer view, upstream

and downstream integration and continues improvement through waste reduction (Liker & Morgan, 2006)).

There is two points of view in studies about Lean, in first group of studies lean thinking have been mentioned as a Philosophical concept regarding principles and goals (Womack & Jones, 1996; Spear & Bowen, 1999; Monden, 1983; Ohno, 1988), in contrary recent studies spotlight is on practical issues, techniques and tools which are required in order to achieve the goal (Shah & Ward, 2003; Li et al., 2005).

Best seller authors Womak and Jones (2003) mentioned that Ohno in TPS has focused on seven types of wastes. Identification and reduction of these wastes is the core of lean concept. These wastes are:

1. Over production: firms due to inability to forecast market demands and using push system tend to produce more than demand which they are not able to sell in market prices.
2. Transportation: materials and products are transported without any processing or value adding activities due to layout of factory or location of factory. Therefore correct design of layout and location of factory can reduce unnecessary transportation.
3. Waiting: goods and products should wait between different production stages which lead to increasing lead time. Therefore by balancing product line and creating necessary buffers they can reduce waiting time and create a smooth flow of material.
4. Inventory: all materials, work in progress and final products which have not been processed to next step are considered as inventory and wastes. The aim in lean concept is minimizing inventory. Pull system and accurate forecasting helps firms to reduce inventory.
5. Motion: layout design of factory or choice of machines in factory can lead to unnecessary movement of people or material during processing.
6. Over processing: poor tools or product design can lead to processing activities which can be avoided. Better design or tools will help to reduce processing activities.
7. Defects: any process can create defects which need to be detected and fixed. Zero defect is the ultimate goal of any process improvement in order to eliminate inspection and fixation cost.

Ohno vision emphasized on clear understanding of the system by distinguishing value added activities from non-value added one by giving an important role to human factor (Lander & Liker, 2007). Sugimori et al (1977) argues TPS approach was not about special tools or techniques but to create social and technical capabilities in order to fit the circumstances. In their study they describe TPS based on two concepts ,technical aspect include tools of Just In

Time and Jidoka and other concept is about maximizing utilization of workers in social aspect. The latter focus is on role of human being in improvement of processes rather than just tools. People are the one who function in teams in order to achieve a shared objective. They not only need to use their skills but also need to provide feedback about processes and improve those (Liker & Morgan, 2006).

In order to implement Lean in other functions such as service, banking and product development or in Production systems which have different characteristics than high volume and standardized product, there are some difficulties. For example variation has different effect in R&D than manufacturing. Therefore some tools and techniques for variation reduction seem not applicable in R&D processes.

Lean manufacturing VS Lean Product Development:

Since implementation of TPS in Toyota, several scholars have studied lean manufacturing. Also companies all around the globe have implemented lean in their manufacturing processes. On the contrary Implementation of Lean in R&D processes is in the beginning of the journey compare to lean manufacturing. Since R&D has different characteristics in case of economics and value creation process compare to manufacturing process, lean Product development vary significantly from lean manufacturing (Liker & Morgan, 2006).

Variation limitation which is key concept in lean manufacturing has been mentioned as main difference between product development and manufacturing. Since variation is the driving force of developing new product so concern in product development is on finding good or bad variations instead of eliminating all variations in process (Reinertsen & Shaeffer, 2005).

Reinertsen & Shaeffer, (2005) have mentioned three main differences between lean manufacturing and lean R&D by considering Manufacturing as a repetitive process which happens in sequences in order to produce goods. These processes can be repeated several times and create value. In manufacturing risk-taking does not have significant role in value creation. In a different way Product development is non-repetitive and non-sequential that creates knowledge and information in addition in R&D risk-taking is key point in value creation.

The first difference is about repetitive and non-repetitive activities. In repetitive ones elimination of variability is important in process improvement while in R&D eliminating all variability will eliminate added-value. In this part a different view about variability is needed by distinguishing bad and good variability. Good variability is the ones which creates value in R&D (Reinertsen & Shaeffer, 2005).

Secondly, manufacturing process adds value to physical products and these products can be only in one place and it requires sequential activities. On the contrary, value creation in R&D happen as information and can be in more than one place simultaneously. This characteristic let them to work non-sequentially and create feedback which is not possible in manufacturing (Reinertsen & Shaeffer, 2005).

Thirdly, manufacturing processes are bounded rigorously by a defined start and finish line and the process should match the requirements. In contrast in R&D, managers need to decide and asses constantly the economic gain of improvement against associated costs (Reinertsen & Shaeffer, 2005).

Considering difference between product development processes and manufacturing, wastes which are core of lean concept should be redefined and adapted in LPD with characteristics of Product development processes. Womak and Jones (2003) redefined seven wastes of lean manufacturing by considering product development characteristics:

1. Over Production: extra analysis and studies, too much information, unnecessary stages such as prototypes
2. Transportation: flow of information and information sharing, ineffective communication
3. Waiting: delay due to approval or testing,
4. Inventory: redundant, stoppage in information and data system, unsynchronized processes
5. Motion: wrong flow of information to people, seeking for unessential approval
6. Over processing: extra gates due to design of stage gate processes, unnecessary analysis, and circulation of wrong decisions and out of place information.
7. Defects: failure in tests, inaccurate data, and warranty costs.

Lean Product Development Definition:

Because on difference in nature of product development and Manufacturing: LPD should be considered in an independent context than lean manufacturing. Therefore LPD is not just using tools and techniques of Lean manufacturing in product development processes. On the contrary LPD has been considered as a process improvement concept by adapting lean thinking into product development by maximizing utilization of people and processes (Liker & Morgan, 2006).

Considering previous studies in LPD, two kinds of definitions has been identified: Processes oriented and Outcome oriented. Processes Oriented definitions focused on how can firms achieve to an efficient and lean product development processes by considering lean thinking fundamentals. On contrary, outcome oriented definitions look at the performance of firms

which are outstanding in comparison with industry, and then studied how they achieved to this stage. In latter one researchers did not limit themselves to TPS and lean tools instead they have a general look toward lean processes as efficient processes (Cooper & Edgett, 2008). In this part three process oriented definitions and one outcome oriented will be discussed.

Process Oriented:

Liker and Morgan (2006) defined lean product development as: *“a knowledge work job shop, which a company can continuously improve by using adapted tools used in repetitive manufacturing processes to eliminate waste and synchronize cross-functional activities.”*

The following definition Bridges between LPD and lean manufacturing. In the same time it highlighted differences between LPD and lean manufacturing by considering it as knowledge work job shop rather than a material job shop. In addition Liker and Morgan (2006) underlined importance of adaption lean manufacturing’s tools and techniques in order to be able to eliminate waste and optimize product development processes.

Similarly, Oppenheim (2004) defined LPD based on lean principles by focusing on product development values. These values are: a) product quality assurance b) reduction of cost and time by eliminating waste.

Karlsson & Ahlström, (1996) have different perception from LPD and defined it as: *“a collection of interrelated techniques including supplier involvement, Cross-functional teams, Concurrent Engineering, functional integration, use of heavyweight team structure and strategic management of each development”* which will reduce time to market. Their interpretation from lean product development comes from influential book *“the Machine than changes the world”*. In their point of view LPD should not be confused with mentioned techniques. They underline a *“coherent whole”* rather than single technique. They argue a firm will not achieve a lean product development without implementing all of these interrelated techniques.

Outcome Oriented:

On the other hand, Cooper & Edgett (2008) described seven practices which they have collected from best practices and companies with high productivity in their product innovation. They believe implementing these practices will lead to Lean, rapid and profitable Product development. They related their expectation from lean product development to current performance of firms compare to other firms. In the other word they defined lean product development as successful and profitable product development processes. The success has been measured by NPD productivity as sale (profit) from NPD relative to R&D expenditure. All of

these practices described in their study are supported with empirical data from firms or projects which implemented them and achieved significant performance results (Cooper & Edgett, 2008).

By considering both approaches for defining LPD, in this study LPD will be considered as a “systematic managerial tool which is able to improve efficiency of product development processes”. In the next part the practices and techniques that can facilitate this process will be reviewed.

Practices and Techniques:

As it has been mentioned Cooper and Edgett(2008) identified seven practices which companies with an efficient and lean product development processes apply them. These practices are:

1. Customer focused: one of the most important factors in success of NPD is products which are differentiated and has ability to solve customer problems and create value for them. Low productivity of NPD in most of cases is due to lack of “wow” factor in development projects. Customers are concerned about three issues of product, schedule of delivery (time) and cost. On the other hand customer commitment will be created only if products satisfy her needs, available in time and worth its cost (Pillai, Joshi, & Rao, 2002). Six methods have been observed in order to undertake Voice of customers:
 - A. Customer visits with in-depth interviews.
 - B. "Camping out" or ethnography.
 - C. Lead user analysis.
 - D. Focus group problem detection sessions.
 - E. Brainstorming group events with customers.
 - F. Crowd sourcing using online or IT-based approaches. (Cooper & Edgett, 2008)
2. Front –End Loaded: Prior assessments in case of technical and market in development project will have pay off and will avoid extra costs in late stages and increase success rates.
3. Spiral Development: in contrast to linear development a smart team will develop first a version of product or prototype and seek for customer opinion and feedback. By use of these feed backs they will develop product to achieve a working model (Cooper & Edgett, 2008).
4. Holistic approach driven by effective cross-Functional teams: best practices view toward NPD is as a business function rather than just R&D activities. Having a cross functional team is the key factor in time to market reduction. Collecting all technical and market abilities in product development will help to avoid late adjustment with other processes.
5. Metrics, Accountability and continuous improvement: measuring the performance is necessary in order to manage the process. Most of the firms are missing a correct system

of measurement and only 30 percent of firms, measure outcome and performance of NPD project after launch to market. Establishing success criteria for each project is an important factor in success of NPD and further improvements. Reinertsen and Shaeffer (2005) also mentioned the role of controlling right parameters in success of lean and lean practices in product development. The most popular metrics by best practices are related to sales and profit: Actual revenue vs. forecasted one, Profitability, customer satisfaction, time to market.

- 6. Effective Portfolio management: Choice of the rights ongoing project is a key factor in success of NPD. Most of businesses fail to balance their development projects by taking too many projects which lead to resource shortages and failure to focus on important development projects. Right prioritizing and ranking of projects will facilitate making Go/Kill decision and allocate resources effectively (Cooper & Edgett, 2008).
- 7. Modern stage-Gate Process: the traditional stage-gate processes create bureaucracy and waste-times. Best practice companies made their NPD lean by removing inefficiencies by application of value stream mapping in NPD. It will lead to more adaptable and flexible stage-gate process which adapt to changing situations and information. The notion of Simultaneous execution and scalable process refer to key activities over lap and happen parallel and able to handle different risk levels (Cooper & Edgett, 2008).

In figure 1 it has been shown in what extend high-productive firms use these practices compares to average of firms. Numbers in figure 1 are representing practices which have been mentioned above. Cooper & Edgett (2008) concluded if firms want to adopt an efficient and lean product development process these practices are good starting point.

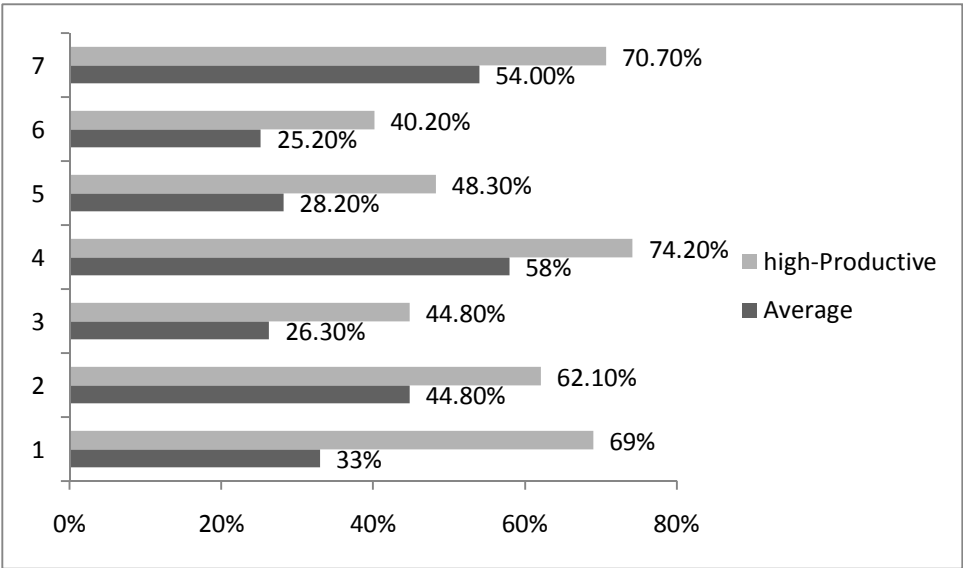


Figure 1- application of practices by high-productive businesses and average of businesses (Cooper & Edgett, 2008)

On the other hand The following Techniques have been extracted from definition of lean product development by Karlsson & Ahlström, (1996) which defined lead product development as: *“a collection of interrelated techniques including supplier involvement, Cross-functional teams, Concurrent Engineering, functional integration, use of heavyweight team structure and strategic management of each development”* .

These techniques can be compared to seven practices in Cooper & Edgett, (2008) study.

1. Supplier Involvement: suppliers are active participant in development projects from early stages of projects. On contrary in traditional practices supplier were involved when detailed design specifications have been developed (Karlsson & Ahlström, 1996). This concept is a part of front-end loaded principle in Cooper & Edgett, (2008).
2. Concurrent engineering (simultaneous engineering): different activities and tasks in development projects are performed simultaneously and parallel. Linear works in traditional development has longer lead-time in comparison to parallel works (Karlsson & Ahlström, 1996). It can be compared with spiral development in Cooper& Edgett (2008).
3. Cross-Functional team: in order to facilitate processes, teams consisting of people from different functions are used in development projects. The goal is to bring all operation aspects into process from beginning. Participants from different functions can provide vital feedbacks and inputs from early stages of developing a product or process (Karlsson & Ahlström, 1996). Cooper & Edgett, (2008) have also mentioned the role of cross-functional team in successful NPD.
4. Heavyweight team structure: increasing project manager role which has direct access to work of all team members will improve communication and build commitment to project by bringing focus in team (Karlsson & Ahlström, 1996).
5. Strategic management of development project: in this case projects are managed through visions and objectives not detailed specifications (Karlsson & Ahlström, 1996). This issue is similar to effective portfolio management in Cooper & Edgett, (2008).

Karlsson & Ahlström, (1996), concluded that achieving to LPD requires: Tight development schedules, Close cooperation with customers, highly competent personnel, active participation and support of top management.

In addition Liker and Morgan (2006) highlighted the importance of visualization which can align organization and facilitate flow of information. In LPD visualization is not only about posting on wall it can be also elements that are able to get attention to processes. It can be possible by a) events which can bring team together and enhance their attention to processes. b) Metrics that

underline wastes in processes. c) Documents that impel questions and create organizational memory.

By comparison of these studies we can create a matrix of practices and techniques which they believe can lead to an efficient and lean product development. The following table will summarize all practices and techniques which have been mentioned in this part.

Table 1-summary of Lean Product development practices and techniques

LPD practices and techniques	Scholar
1. Customers Focus	(Cooper & Edgett, 2008)
2. Front –End Loaded (Supplier Involvement)	(Cooper & Edgett, 2008), (Karlsson & Ahlström, 1996)
3. Spiral Development(Concurrent engineering)	(Cooper & Edgett, 2008), (Karlsson & Ahlström, 1996)
4. Holistic approach driven by effective cross-Functional teams(Cross-Functional team)	(Cooper & Edgett, 2008), (Karlsson & Ahlström, 1996)
5. Metrics, Accountability and continuous improvement (Control the Right Parameter)	(Cooper & Edgett, 2008), (Reinertsen & Shaeffer, 2005)
6. Effective Portfolio management(Strategic management of development project)	(Cooper & Edgett, 2008), (Karlsson & Ahlström, 1996)
7. Modern stage-Gate Process	(Cooper & Edgett, 2008),
8. Heavyweight team structure	(Karlsson & Ahlström, 1996)
9. Visualization	(Liker & Morgan, 2006)

Performance Measurement in NPD:

There is an old saying “If you want to manage it, you have to measure it” (Driva, Pawar, & Menon, 2000). As it has been mentioned in Cooper & Edgett, (2008) and Reinertsen & Schaeffer (2005) identifying right metrics and measuring performance of Product development processes play a key role in success of Lean Product development since it will facilitate identifying improvement areas and provide a road map. The following section will focus on literatures of Performance measurement in Product development. The study will follow Chiesa and Frantini (2007) framework in order to study an effective performance measurement system in product development.

Competitive business environment demands effective product development investment. Performance measurement (PM) can help to achieve these objectives by assisting managers to evaluate performances and identify areas which require improvement (Cedergren, Wall, & Norström, 2010). In managerial point of view PM system in new product development is important in situations like revising development strategies, starting with new strategies and analyzing development projects and effect of them on value of firm (Molina-Castillo & Munuera-Aleman, 2009).

Performance measurement in R&D activities compared to other parts of operation is associated with more problems because of: a) high uncertainties in R&D processes and outcomes. b) Complicatedness in following negative and positive effect of innovations. c) Close relationship between R&D processes which many sources can affect outcome of R&D activities. d) Difficulties in measuring processes with quantitative indicators. e) Claiming credit for different actor after accomplishment is a political problem (Geisler E. , 1994).

Geisler (1995) classified studies in R&D performance measurement into four streams. The first category considers economic impact of research and development. The second one includes productivity of researchers and research teams. The third one measures performance of research activities with outcome indicators such as number of patents. The fourth one considers a subjective qualitative assessment by experts.

These four streams can be classified in three general models of 1) performance (output) 2) Cost (input) 3) cost-performance models. (Geisler E. , 1994). In a cost model, input of R&D process considered as measures of investment in R&D and comparison with other input or output indicators. On the contrary a performance model considers development of key output indexes for different stages of R&D processes (Geisler E. , 1994). Geisler (1995) categorized these outputs in four stages of: *“a) immediate/direct b) intermediate c) preultimate d) ultimate”*.

Considering mentioned model, it is important to verify the level of analysis in R&D processes since the performance dimensions are dependent to the level of assessment. Level of analysis can be categorized in three levels of firm, program and project. Performance in firm level can be measured with indicators such as sales growth or profitability while in program level impact and profitability of program is important. For assessing single project financial indicators, time and customer satisfaction can be suitable indexes (Molina-Castillo & Munuera-Aleman, 2009).

All measures which will be mentioned in performance indicators section are important but an integrated performance measurement system (input-output) seems essential since these measures are either output oriented or resource oriented (Cedergren, Wall, & Norström, 2010).The modern product development by use of lean and concurrent engineering where there

are overlapping activities, cross functional teams, customer focus and continuous improvement requires an integrated tool for performance measurement (Driva et al.,2000). Several literatures concluded firms' PM system focus is not on what is important, they measure what is simply assessable. This issue lead to that PM system is not supporting decision making and continuous improvement (Cedergren et al., 2010; Driva et al., 2000).

Gharajedaghi (2006) argued clear understanding of performance criteria is essential in an effective performance measurement system. PM system is unique to each business and should change dynamically by time (Nixon, 1998)since PM System in R&D should be aligned with “*the way R&D is organized, planned and budgeted, Including management structure, decision-making process, links to other functions and prevailing R&D culture.*” (EIRMA, 1995, P.46).

The questions that PM system should be able to answer are: “how well is R&D doing?” “Will its performance be likely to change in the foreseeable future?” and “to what extent is R&D satisfying its publics or meeting their needs?” (Geisler E. , 1994).Chiesa et al. (2007) has drawn a synthesis of suggestion from literatures regarding design of an effective performance measurement System in product development (Appendix 1). Chiesa and Frantini (2007) concluded that PM system in NPD is consisting of five elements of 1) Objectives 2) Dimensions 3) indicators 4) structure and 5) measurement process. These elements are highly correlated and each element has influence on design of other ones. For instants objective of measurement system will influence strongly design of other elements. The rest of this section is developed based on Chiesa and Frantini (2007) framework regarding performance measurement system in Product development processes.

Objectives:

PM is acknowledged by several scholars, to motivate people, Support decision making process, improve communication and stimulate learning and lead company toward its objectives (Chiesa et al., 2007). In addition to above benefits Godener and Soderquist (2004), mentioned application of PM system will improve relevance and coherent of developed products and introduce correction in projects. These findings are consistent with EIRMA (1995) that the most important result of an effective PM system is better communication with all stakeholders including investors , managers and sometimes customers (Nixon, 1998).

In managerial point of view PM system in new product development is important in situations like revising development strategies, starting with new strategies and analyzing development projects and effect of them on value of firm (Molina-Castillo & Munuera-Aleman, 2009).

Therefore Identification of The objectives of the PM system is the critical factor in design of PM system in NPD (Driva et al., 2000; Chiesa & Frattini, 2007). Chiesa and Frattini (2007) categorized these objectives into seven main categories. These categories are listed in table 2.

Table 2-Objectives of PM system in NPD (Chiesa and Frattini, 2007)

Objectives of PM system in NPD
Supporting decision making
Enhancing R&D performance
Motivating personnel
Supporting the incentive scheme
Fostering organizational learning
Enhancing communication and coordination
Reducing R&D risks

Dimensions and Indicators:

Dependence of companies on technology increases Research and development costs and makes managers and investors interested in finding better measures for R&D performance (Nixon, 1998).

Chiesa and Frattini (2007) categorized them in a more discreet way into 4 groups of: effectiveness, efficiency, Contribution to value and time. In order to measure these dimensions effectively managers should select suitable indicators for each dimension (Sandstrom & Toivanen, 2002; Ojanen & Vuola, 2006). The most common indicators which can be applied in PM of NPD are described in table 2.

Table 3- Performance indicators for R&D activities (Chiesa and Frattini, 2007)

Indicators	description
Quantitative objective	Numeric regardless of person in charge of measurement (percentage of projects accomplished on time, number of citations of company's researchers publications)
Quantitative subjective	numeric based on personal perception
Qualitative subjective	Personal judgments which are not expressed numerically

In study by Cadergren et al (2010) managers have been asked about their perception of performance in NPD. The answers verified that focus is on the efficiency of the later stages of

NPD in term of cost, time and quality. The effectiveness (correct choice of product) is not measured in the most of cases. It is essential that an effective PM system evaluate product development processes concerning both factors (Cedergren, Wall, & Norström, 2010). It is consistent with Driva et al (2000) finding in comparison of practices with theories, they concluded that firms are using time, cost and quality measure while academics give emphasis to customer related measures. Chiesa and Frattini (2007) have developed performance dimensions of Product development in addition to Efficiency and effectiveness to internal and external customer focus and alignment with corporate strategy.

Assigning a suitable indicator to each dimension is essential. Driva et al (2000) in their survey from 150 firms in UK, USA and mainland Europe have found the top five measures which are currently used by firms in their NPD are: Total cost of Project, On-time delivery, actual project cost relative to budget, actual time compare to target time and lead time to market.

They also asked firms what are measures which they want to use in future and their response in order were: Number of bottlenecks, Number of design changes to specification, number of defects detected in development stages, time spent in meetings, development cost of product which do not reach to commercialization. (Driva, Pawar, & Menon, 2000). These indicators measure mostly wastes in R&D process. Driva et al (2000) concluded the indicators in R&D have been ignored previously but due to increasing in competition companies considerably are interested in performance measurement and indicators in product development.

In a recent study from U.S. firms the most common measures in NPD have been identified as: 1) R&D expenditure relative to sale, 2) total patents, 3) R&D headcount, 4) Percentage of sales coming from new products. 5) Number of new Products (Teresko, 2008,).

In analysis of performance dimension and indicator, the level of analysis in R&D processes is an important factor (Chiesa & Frattini, 2007). Level of analysis can be categorized in three levels of firm, program and project. Performance in firm level can be measured with indicators such as sales growth or profitability while in program level impact and profitability of program is important. For assessing single project financial indicators, time and customer satisfaction can be suitable indexes (Molina-Castillo & Munuera-Aleman, 2009).

As it has been mentioned in LPD literatures changes in early stages of PD is easier and less costly therefore with the earlier application of measurement system there is higher possibility of correcting actions and controlling projects in right direction. Application of stage-gate models which have well-defined measures for each stage will facilitate management and performance measurements of NPD projects (Cedergren, Wall, & Norström, 2010).

Structure and measurement processes:

Chiesa and Frattini (2007) argued that an effective performance measurement system in Product development require well-defined structure and processes. First step in designing PM system's structure is identifying control objects and assign an indicator to performance of the object and also assigning responsible person for controlling each objects (Nixon, 1998). These control objects can be Researcher, laboratory, team, Project, program and R&D unit (Chiesa & Frattini, 2007).

Driva et al (2000) show success of the performance measurement system is dependent on how it will be implemented and performed. The main elements of measurement processes are:

- 1) Intensity of involvement of people in the following phases: a. Design of performance measurement system b. collecting data c. Analysis of data and identifying corrective action (Driva et al, 2000).
- 2) Frequency of control for each dimension and indicators (Chiesa & Frattini, 2007).
- 3) Setting standards or references which they can compare measures against it (Nixon, 1998). Chiesa and Frattini (2007) proposed two ways for setting references: (a) Future objectives: standards are defined as vision for future which firm is aiming to achieve in long-term or short-term. It helps firm to compare its performance with its objective. (b) Benchmarking: company should monitor performance of industry or competitors. It requires a thorough analysis in past and present situation in order to set standards for its own processes.

In conclusion, an integrated performance management system which is able to evaluate R&D activities from start till end is required in lean product development. Integrated system will provide an insight about wastes in process and facilitate continuous improvement by identifying areas which require improvement. Lack of an integrated performance measurement system can provide a poor assessment on overall performance hence bridging different phases by an integrated PM system is essential (Pillai, Joshi, & Rao, 2002). In design of PM system in NPD is important considering five elements of 1) Objectives 2) Dimensions 3) indicators 4) structure and 5) measurement process.

Summary:

In summary, Firms try to adopt lean product development in order to increase efficiency of their product development process. Measuring the performance is necessary in order to achieve to lean product development. Most of the firms are missing a correct system of measurement and only 30 percent of firms, measure outcome and performance of NPD project after launch to

market (Driva, Pawar, & Menon, 2000). Establishing success criteria for each project is an important factor in success of NPD and further improvements. The most popular metrics by best practices are related to cost and time (e.g. Actual revenue vs. forecasted one, Profitability, time to market).

In the first part of this chapter lean product development has been studied. Lean product development definitions have been categorized as: processes oriented and outcome oriented definitions. The processes oriented ones try to by considering dissimilarity between product development and manufacturing highlight a path for achieving efficient processes. While on contrary outcome oriented adapt a benchmarking approach by considering how the successful firms achieve to this stage.

Practices and techniques which facilitate achieving to efficient processes have been reviewed. Nine significant practices have been studied. These practices are: 1- Customer focus, 2- Front-End Loaded, 3- Spiral Development, 4- Cross-Functional team, 5- Control the Right Parameter, 6- Effective Portfolio management, 7- Modern stage-Gate Process, 8- Heavyweight team structure, 9- Visualization.

In the second part researches about performance measurement systems in product development have been reviewed. The main five elements for comprehensive performance measurement systems are: 1- objectives, 2-Dimension, 3- Indicators, 4- Structure and 5- Processes. Each element has been studied in order to elaborate a well-defined performance measurement system. PM is acknowledged by several scholars, to motivate people, Support decision making process, improve communication and stimulate learning and lead company toward its objectives.

While in case of dimension is has been argued performance measurements main dimension are efficiency and effectiveness of processes. The researchers believe that firms focus is on the efficiency in term of cost, time and quality. The effectiveness (correct choice of product) is not measured in the most of cases. In order to measure each dimension assigning a suitable indicator to each dimension is essential. Different Indicators which firms use in product development processes have been identified. Indictors have been argued are quantitative indicators which measure mostly efficiency of R&D process rather than effectiveness. These indicators measure three factors of cost, time and quality but there is a tendency between firms to measure wastes in process in order to reduce it. Table 5 will show all of these indicators .In this table; indicators have been divided relative to dimension which they can measure: Cost, Time, Quality and Others.

Table 4- performance indicators relative to performance dimension

Cost	Time	Quality	others
Total cost of Project	Time to market	number of defects detected in development stages	Number of bottlenecks
actual project cost relative to budget	On-time delivery	Number of design changes to specification	time spent in meetings
Percentage of sales coming from new products	actual time compare to target time	development cost of product which do not reach to commercialization	Number of patents
R&D expenditure relative to sale			R&D headcount
Return on investment			Number of new Products
			customer satisfaction

It has been argued also that an effective performance measurement system in Product development require well-defined structure and processes. In designing PM system's structure is important to identify control objects and assigns an indicator to performance of the object and also assigning responsible person for controlling each object. The control objects can be researcher, laboratory, Team, project or Program. In addition performance measurement processes should clarify: Intensity of involvement of people, Frequency of control for each dimension and indicators, Setting standards or references.

In the empirical section how firms measure their performance in lean product development and which indicators they use for measuring performance will be investigated.

3-Methodology:

Research Process:

In order to answer the research question we have to define the required steps and path for achieving to the best result. The nature of this research due to small amount of literature in this field is exploratory. The project has been divided to 2 stages which will happen in the consequential order.

First step: the research will start with review of the available literature on lean product development. The aim in this stage is to create an understanding about the context of researches in this area and at the end provide a definition for lean product development and techniques related to lean product development in order to distinguish firms which are implementing lean product development. Then different indicators and performance measurement which are available for product development and lean product development will be studied .The aim in this stage is to establish suitable performance measurement system for lean product development which can grasp expectations and characteristics of lean product development. Second stage: after reviewing performance measurement systems and indicator in literatures, how firms in practices measure product development performance in lean Product development will be investigated.



Figure 2: research process

Research Strategy:

As Bryman and Bell (2007) discussed research strategy helps researchers to clarify and demonstrate different orientations in research conduction. Strategies are categorized in two main approaches of qualitative and quantitative. The fundamental of this categorization is the type of gathered data. In this study the focus is on qualitative research.

Qualitative research method is usually associated with phrases and words which are sources of information. This strategy typically is used in inductive researches which it about theory making

from empirical results. It is associated with interpretive which is concerned about distinction between social science and human. In this case research can be considered scientific without necessity of collecting and interpreting measureable data (Bryman & Bell, 2007). Qualitative research strategy does not follow generalization of every research. On the other hand it is associated with constructionism. Constructionism brings social factors such as culture and organization into consideration. Therefore by considering these social factors it challenges generalization in social science. In contrary objectivism consider social phenomenon as mechanical processes which are independent of social actors (Bryman & Bell, 2007).

In this research since sources of data are interviews with managers in product development which lead to immeasurable observations. The research strategy is qualitative. Also in this research generalization without considering social actors will be avoided. Factors such as nature of business, business strategy, organizational structure and values will be considered. Therefore the research follows constructionism approach. On the contrary this research is not inductive and will not try to build any theory from empirical results. The nature of research is exploratory which seems suitable due to small amount research in this area.

Research design:

In this project the multiple- case studies have been used. Some scholars have used term of the Comparative case methods for multiple-case studies (Yin, 2003). In a multiple-case study same as case study the dominant research approach is qualitative while the quantitative approaches can be used for clarification (Yin, 2003). Yin (2003) define 5 main proposes of explanation, description, illustration, exploration and evaluation for use of case studies in social science. Based on Yin (2003) in this study application of case study is suitable since the project will try to illustrate the effect of lean product development by exploring suitable definition and PM system for Lean Product Development and evaluate this effect. Use of case study will help us to investigate our finding in theories with real-life industry. As Yin (2003) argued case study is suitable strategy in order to answer the question of “why” and “how”. In this project the aim is to know how firms measure performance in Lean product development.

The cases are 2 companies which are established in Sweden with active new product development. Having more than one case is a great help in order to create a better view about the topic in practice. It also will help to reduce biases in information since the sources of information increase. But it also can create problem in order to analyze data because of amount of data and different interpretation and expectation in different industries. On the other hand limitation of sources of data to two Swedish firms and lack of similar study for comparison will create problem in case of external validity of results. In the research strategy researchers should deal with four issues: what is research question, relevant data, collecting

relevant data and analyzing collected data (Yin, 2003). The research question have been argues in the first chapter and the remaining issues will be argued in methodology section. In a case study 5 components of research design are important: research question, propositions, unit of analysis, logic of relating data with propositions and the criteria for interpretation of data (Yin, 2003).

In this study the research question is looking forward for performance measurement system in lean product development. Analyses are limited to the firm level and in the firms the product development process is the unit of analysis.

Data Collection:

Literature review:

Gathering Information in this project is based on the described research process, the first stage require vast amount of data gathering and literature review. Ascertaining information due to definition of Lean Product development (LDP) is the key points in the next stages. Reviewing available literature is for two main purposes of recognizing discovered issues and help to distinguish differences in findings of researches (Bryman & Bell, 2007).

The research will start with review of the available literature on lean product development. The aim in this stage is to create an understanding about the context of researches in this area. At the end provide a definition for lean product development and techniques related to lean product development in order to distinguish firms which are implementing lean product development. Then performance measurement systems in product development and lean product development will be studied .The aim in this stage is to establish suitable performance measurement system for lean product development which can grasp expectations and characteristics of lean product development.

In this part, two main databases of “Science Direct” and “Business Source Premier” from University of Gothenburg library have been used. The Keywords for search are: Lean, Product Development, R&D, Lean Product development, Performance Measurement, Performance indicators. The search leads to around 60 papers which around 35 of them have been used in this research.

Interview:

In the second step literature review will be used with help of information gathered from interviews. The interview with firms will be a great help in order to understand the nature of indicators in practice and compare it with theories which comes from literature review. The

interviewee in A Co has the position of global process manager in product development and in B Co is the head of R&D units. Both interviewees have long experience in company and have knowledge about all processes. The design of interview will be discussed in more detail in this chapter.

Interview design:

Interviews in this project have a critical role in order to communicate the project aim with interviewees and evaluate their expectations about LPD by defining suitable indicators. The interviews are also the most important source of information in empirical part. Therefore the design of interview plays an important role in success of project. In this thesis semi-structured interview will be used. Since it provides flexibility of unstructured interview and let interviewee to provide details about topic but it also helps interviewer to cover main topics. The interviews are conducted face to face in an hour session. In this part different stages of interview will be described and the manuscript of the interview questions in detail will come in appendixes. Interview questions are categorized in three categories of:

Company Information: in the first part of interview the question are regarding company operation and product development. The required information is about the number of employees in product development, the history of company NPD process, the role of product development in firm performance. In this part the aim is to create a clear picture about firm and PD process which be a great help for further analysis.

Lean Product development: this part of interview should be accomplished by definition of lean product development in the theory part. The aim in this part is to evaluate if the firm is implementing lean product development or not. The questions will focus on techniques and tools which have been used in Product development process. In this part also the question emphasizes on perception of managers from lean product development what they have considered lean product development also what was the reason of moving toward it.

Performance measurement system: in this part the interviewer tries to find out about performance measurement in product development based on framework developed in theory. So main concern of questions is about how firm measures performance in lean product development and why they have used such a performance processes.

Delimitation:

In order to meet the time requirement of the project in the context of a master thesis defining suitable border for study seems necessary. In this study focus is only on lean product

development as a Coherent whole not the techniques and tools. In case of effect of lean product development analysis is limited on its effect on product development process and studying the strategic impact of it on firm's performance has been avoided.

In case of chosen firms for this study, both of firms are active in Sweden which increases the availability of firms and required information through face to face interviews.

Validity and reliability and replication:

The reliability main concern is "inter-observer consistency" (Bryman & Bell, 2007). It means two observers with same results will reach to the same observation. In order to increase the reliability of data which are coming from interviews, the interviews have been transcribed and send back to the interviewee in order to minimize misinterpretation.

Since in this paper author has used an exploratory research is not facing with issue of external validity. Validity has been argued in three dimension of measurement validity, internal validity and external validity and ecological validity (Bryman & Bell, 2007). Measurement validity is related to quantitative researches which in this research a qualitative research, measurement validity is not primary concern. Internal validity main concern is issue of causality (Bryman & Bell, 2007). In this part concern is about relationship between variables and confidence about influence of variables on each others. Since this research is exploratory and does not test any special hypothesis the issue of internal validity is not primary concern. External validity main concern is about generalization of results (Bryman & Bell, 2007). In this research multiple case-studies have been used which can help generalization but since the cases are limited to two case in Sweden, generalization of results seems in appropriate. On other hand using constructionism will create more difficulty in generalization of results. Ecological validity main concern is application of finding in different situation and social settings (Bryman & Bell, 2007). This research consider just product development as level of analysis and considered just lean product development as primary criteria therefore is not applicable in all social setting and such a limitation should be considered in results.

In order to facilitate replication the processes have been described in details in both case of literature review and empirical data collection. The interviews have been conducted based on provided protocol in appendix 2 and all interviews has been transcribed and controlled with interviewees.

At the end of this chapter the following table will provide a summary of research framework.

Table 4: summary of research framework

	Step 1:	Step2:
Research Process	Defining Lean Product Development	Performance measurement in LPD
Research design	Multi-case studies	Multi-case studies
Research strategy	Qualitative	Qualitative
Data Sources	Literature review	Interview, Literature Review
Data Analysis	Qualitative analysis	Qualitative analysis

4-Case Studies:

In this chapter the two cases will be reviewed. Each case is described in two sections, in the first section the general information about firm will be reviewed and the second part focuses on product development processes, Lean product development and performance measurement in product development.

All the selected cases are large MNCs which their head quarters are in Sweden and are active in international market. The business is driven by introducing new products to the market. Following table will summarize basic information about cases.

Table 5-overview of cases

Case	activities	Number employees	of Main products
A Co.	Development and manufacturing diesel engine and gearbox	8143	Diesel engine
B Co.	Contract developer and manufacturer	1400	Mechanical, electronics and medical instruments

Case A Co.:

Company Information:

A Co. is a part of Mother Company which is consisting of 21 companies in different industries. A Co is responsible for providing diesel engines and gearboxes for other companies in the group. In order to have better development and research group with higher efficiency in manufacturing processes all the companies within group use same engine platform which are developed in A Co. The company has been established in 2002 as a separate firm and nowadays is a world leader in its own business. The headquarter is in Sweden but is active globally with units in South America, North America , Europe and Asia in four countries of Brazil, USA, France, Japan. The mother company has around 90000 employees which 8143 of them work directly within company A Co in different sections. Company has 2 main competitors which are established in Europe.

Since company A Co deals directly with parent company and does not have any other customer and operate as supplier for parent company the financial data for A Co are not available. As the

A Co performance is strongly correlated with group performance and any fluctuation in parent company will influence A Co's operation directly in order to provide a general view, information about parent company situation will be described which has direct relationship with A Co. Table 8 summarize financial performance of parent firm in 2008 and 2009. Due to financial crisis company was facing a dramatic year in 2009. Performance in 2009 lead to operating loss of 17,013 SEK bn and return on equity of equal to negative 19.7% and sale has reduced 28% compare to 2008(A Co Annual report, 2009).

Table 6-financial performance in SEK bn

	Net sale	Operation Income	Return on equity
2009	218,361	(17,013)	(19.7)
2008	304,602	15,851	12.1

The dramatic performance in 2009, created driving force for company to establish their 2010-2012 focus on "product renewal and internal efficiency". This vision has been translated into product development process in A Co. as 20% lead time reduction in 2010. The company wants to maintain their position as market leader and improve utilization of resources without necessary cut in resources by improving efficiency in term of time and cost.

Product development:

The company has one R&D unit which has three different departments. 2000 employees work directly in research and development unit which is 25% of total employees. Employees are distributed globally in different countries but the management system is concentrated in Sweden. Company spends in average 6% of annual sale as R&D expenditure. The following table summarizes fact about product development in A Co.

Table 7- product development facts, Company A

	R&D units	R&D departments	employees	R&D expenditure	Geographical distribution
Company A	1	3	2000	6% of sale	South America, north America, Europe, Asia

The company produces engines in different families. These engines can be installed as a light engine diesel used in small construction equipment and truck or heavier engines and also

industrial engines. In average introduce a new product for each family every three to four years.

The company has well-defined product development procedure called Global Development process (GDP) which is practiced in all companies related to parent company. In GDP development projects have been divided in three groups based on required budget. These groups are: Less than 5 MSEK, 5-50 MSEK or more than 50 MSEK. Based on this classification they follow different gates and steps. Number of gates increases with value of projects. The following figure shows different steps in GDP. As it can be observed a project in class 1 with value less than 5 MSEK pass through three gates of Concept study, Industrialization and follow-up while a project in class 3 should pass through all 9 gates till end of process. There is established and well-defined check list for each gate, which should be fulfilled before passing any gate. In brief five phases of GPD processes since managers they conduct pre-studies, invest funds for project and follow up has been described in table 9.

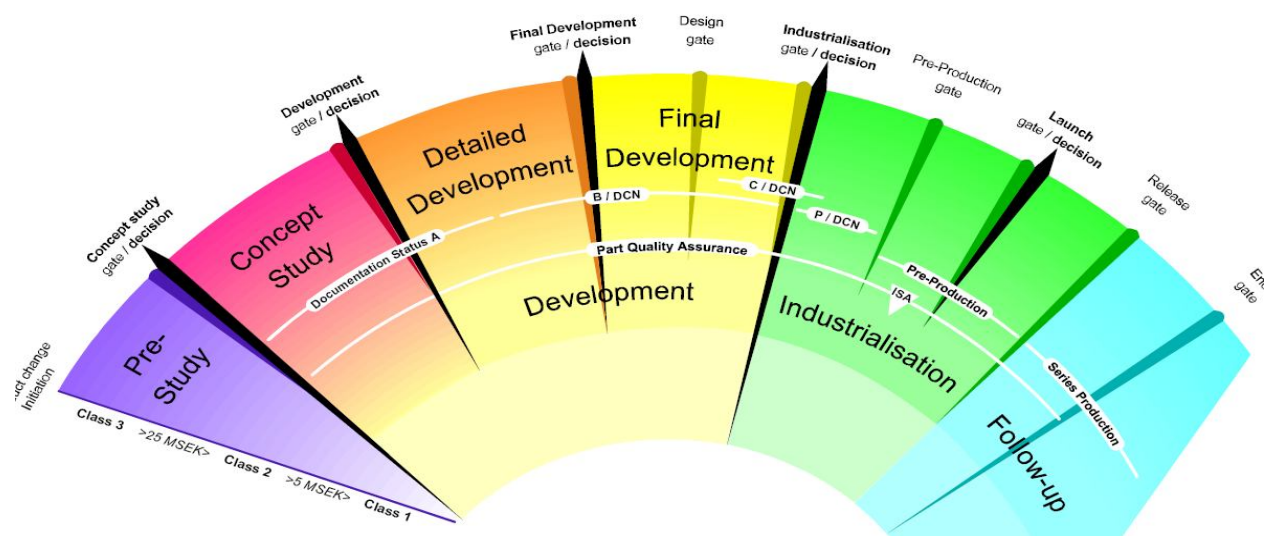


Figure 2- Global Development Processes

Table 8-phases in Global Development Process (Kardemark, 2002)

Phase	description
Pre-Study	Feasibility investigation of market and technical characteristics
Concept Study	Evaluation and selection of concept by requirement setting
Detailed Development	Development and documentation of details
Final Development	Testing, building and adjusting products and processes
industrialization	Preparation ,installation and verification of production system
Follow-up	Closure and project validation

Simultaneously there are different processes which are integrated into GDP. These processes are: *supplier selection, purchasing, documentation, customer satisfaction, vision and strategy*. For example the documentation process has four stages of A (Concept), B (release), C (release begin) and P (Production). They are embedded into GDP as it is shown in following figure. The projects which pass the P will reach industrialization stage and delivered to market as a product.

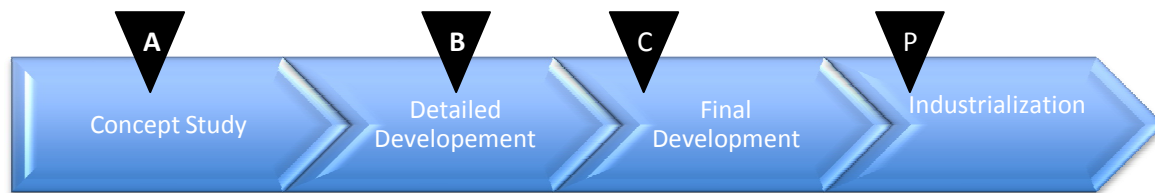


Figure 3-Documentation Process in GDP

For each developing project a Chief Project Manager (CPM) will be assigned, he leads a team of project managers which leads sub-projects. Role of CPM is to control and Monitor project and report to steering committee.

A project team is consisting of 10-200 members depending to importance of projects which are coming from different department. Company A tries to create cross-functional teams with participation of design, purchasing, manufacturing and suppliers.

Lean product development:

The company has started officially to implement lean product development (LPD) from January 2010. The executive management set it as 2010 strategy. As it has been mentioned the driving force for implementation of LPD was economic crisis and dramatic year that company had. The main issue was lack of cash flow during financial crisis since company had a lot of locked capital in organization. Therefore they decided company need to increase efficiency and reduce costs without cutting resources.

Manager defined LPD as a process that people continuously identify wastes and eliminates them to improve process, is a way to eliminate wastes and increase efficiency by increasing quality and reducing cost and time. Meanwhile they are aware of differences between lean manufacturing and lean product development. In the first step they are conducting a gap analysis in order creates a clear picture about their current situation in comparison to their aim.

Gap analysis starts by evaluating current situation then they compare it with benchmarks of other firms in business and firm's vision. In parallel company tries to run training for different groups of employees in product development and teach them application of tools such as value stream mapping. But company is aware that training of more than 1000 people requires time and is associated with cost. In addition value stream mapping as key tools has been introduced in order to help them to identify wastes in processes. Interviewee believes the main challenges for them are coping with resistance in organization for changing old way of working and increasing commitment of top managers.

Regarding tools and techniques in lean product development in addition to having cross-functional teams they involve suppliers from beginning of projects. Company has long term relationship with suppliers and they participate actively in product development processes. In some cases supplier based on their capabilities and know-how take responsibilities in developing one or more parts of projects. Purchasing department is intermediary between suppliers and company. They constantly evaluate suppliers and collaborate with them to improve their internal capabilities.

Meanwhile natures of products are modularized and every module will be developed separately. Modularization helps them to develop each module simultaneously and reduce development time. Also firm employ parallel project management which is led by a section called, business office. The responsibility of business office is to optimize allocation of financial and human resources to projects. The organizational structure is light-weight structure rather than heavy weight.

Performance Measurement:

As it has been mentioned assigned chief project manager (CPM) is responsible for controlling and monitoring projects. CPM reports directly to steering committee which is consist of executive managers and leading by research and development vice-president.

They use usual financial indicators such as return on investment for controlling process but they have three dominant indicators which should be reported directly to vice-president. These indicators reflect on cost, time and quality.

- a. Direct runner: as it has been shown one of integrated processes in the GDP is documentation process. In this process there is four stages of A (Concept), B (release), C (release begin) and P (Production). The number of direct runner shows how many of projects are passing through C and reaches to (P) production without any big changes. It shows how good is company in design and development which modification is not

necessary in this stage. Since any modification is associated with cost and increase lead time. Direct runner is the most important KPI for company.

- b. Cost for poor quality: When firm introduces a product they face problems which should be fixed. In this case they need to bring back the product and fix the design. These issues will be documented in quality journal. Considering if there was no problem in the first time, they did not need to fix the product. So all the costs here is cost of poor quality. Usually projects managers due to experience are aware of bottlenecks but they do not have enough motivation to take corrective actions. The reason they usually mention is lack of enough resources. Cost of poor quality helps company to show them how much they are losing but not taking corrective action and then can have better estimation about gains from corrective actions. It is a way of encouraging improvement.
- c. Lead time: firm also measure the time to market for projects or project lead time. Project lead time is from initiating project and to launch of product. Company aim is by introducing lean product development reduces project lead time by 20% in 2010.

Manager of documentation process control all these KPIs and reports to vice-president and steering committee. After evaluation by steering committee if some results are not satisfactory the process manager is responsible to analyze the problem and take action on issue by communicating with project managers.

Since implementation of lean product development all the teams are obligated to run weekly meeting which people. In these meeting they bring up the problems they are facing, and then they document all of problem. And every two weeks they review these problems and check their progress in solving the problem. It is a way to encourage people to work with continuous improvement. Some problems should be escalated to other sections or process. They have another meeting every 4 weeks which they can share problem with all sections and work cross-functionally.

Case B:

Company Information:

B Co. is a contract developer and manufacturer which develops and manufactures instruments and products for leading firms in business-to-business sector of Europe. B co. has a long history from 15th century but they have started working as contract developer and manufacturer at 1995. The head office is located in Sweden and has offices in Sweden, Norway, Finland, UK, USA, China and Poland. Around 1400 employees work within different departments of company. They develop and manufacture mechanical, electronics and mechatronics products for customers from six market of defense and maritime, Industry, information technology,

Medical instrumentation, Cleantech and point of sale application. The company vision is “to be the obvious choice for business-to-business contract manufacturing” (annual report, 2009). B Co. has few large competitors such as Kitron and Enics with global operation also small firms in local markets which they are active.

The following table shows financial performance of firm in 2009 and 2008. Due to economic recession in 2009 net sale of company reduced by 15% compared to 2008. In addition company performance leads to 3.5 MSEK operating loss. In their forecast growth rate for next year is 4-5%.

Table 9- financial performance of B Co. (MSEK)

	Net sale	Operation Income	Return on equity
2009	2,148	(3.5)	(4%)
2008	2,529	28.5	0.9%

Product development:

B Co. has three R&D units in Sweden, Norway and Finland which are working in three disciplines of Mechanical, software and electronics. In total 50 employees works directly in research and development department which is a small number compare with total number of employees (3.5%). The nature of business as a contract developer and manufacturer lead to very small amount of investment to the development, the R&D investment focuses on skills of developing department. Since company receive directly money for each development project separately.

Table 10- Product development facts, B Co.

	R&D units	R&D departments	employees	R&D expenditure	Geographical distribution
Company A	3	3	50	N/A	Sweden, Finland, Norway

Development time varies for different family of products in some cases is around 1-2 years while for medical instruments time is longer about 3 years. B Co. designs to specification for a specific company. The products here are coming from a sheet of paper which initiated from first meeting with customers and each product is unique.

The product development process starts from specification work with customers. In this stage the market specifications will be identified and then will be transformed to technical

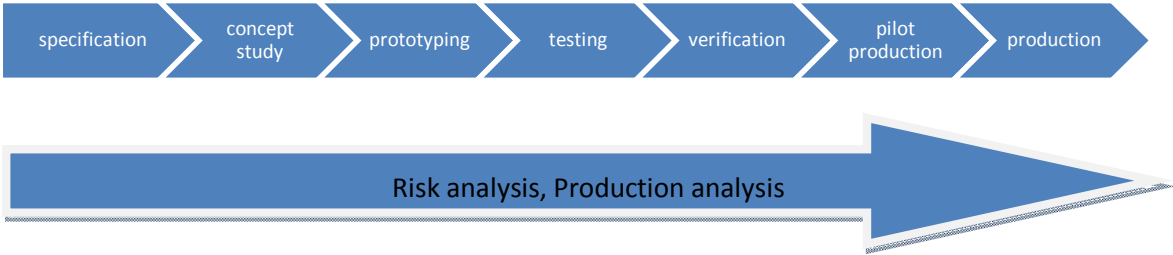
specification. In this step technical specification will be broken down to three disciplines which product development is working: mechanical, software and electronics. From these specifications the concept design will start. In this process customer and production department are involved. At the same time risk analysis will start from this stage till last stage of product development process. In risk analysis all possible risk in each stage will be identified and level of risk will be evaluated. Then for each risk correction action will be assigned if occurred.

Then concept design will be broken down to sub-modules and these sub-modules will be developed in different sections and will be tested separately. Then all the sub-modules will be combined in sub assembly stage in order to create prototype number one. In this step production department participate directly in order to learn about product and provide feedback about product.

After analyzing all the problems and risks associated with product, the correction action will be executed and prototype number two will be assembled. In this stage assembly responsibility will be devoted to production department in order to learn how to work with product. In this stage designers will observe. In parallel design department should update drawings and develop assembly and test instructions. Test equipment will be developed meanwhile prototype number two will go to verification department. In this section they verify the product can satisfy all demands in technical specification. For complex products it is possible that reach to 3 or 4 prototype but generally two prototypes is enough.

After verification they start to produce zero series (pilot series). In this stage all the tooling, assembly line and test equipments should be ready. Assembly and test instruction will be used and revised. In this stage still adjustments are possible. After this stage when all the issues are solved and production reach to required time and speed product will be launched.

Figure 4-Product Development Processes, B Co.



Lean Product Development:

B Co. defines LPD as a way to shortening the communication during the project life cycle. Since they believe shortening communication will reduce project lead time significantly. The argument behind it refers to flow of information and communication as biggest identified waste in product development processes. Therefore they have designed a new tool in order to spread all information in shorter time period between all members. Visualization of information which everyone can read and understand the situation of project according to time plan, cost and quality has been chosen as a suitable way for shortening communication.

The team tries to have short meeting in standing groups rather than sitting for hours. In the meeting room they have prepared a wall that they visualize the projects. The team works with colors (red, yellow and green) in order to create signals. So reporting system is by use of these colors in the project in order to visualize for the entire group. Red means something is not working according to plan and team need to act on it. Therefore managers should follow it very carefully. Yellows means a risk occurred and team should be ready to act in order to avoid red situation. Finally green means work is based on plan from technical, time and economic point of view.

B Co. has started using this technique from half a year ago and started with group of project managers reporting not only to head of R&D departments and steering committee but also to rest of project managers by visualizing all processes on the wall. The need for implementing this technique initiated from managers believes that communication is the major waste in the product development processes. Therefore they think it is necessary to spread information in the team in a more efficient way. They believe if everyone in project understands the current situation of projects faster, team members will be engaged in projects easier. So project lead time will reduce due to smooth flow of information.

Company at the same time is in process of implementing Lean Production. Therefore head of R&D department has sent all developing team to participate in lean production program and training. Manager believes this way will help them to develop mind set of developing team in progress with implementation of Lean Product Development in their department.

In manager point of view the challenge in this process is to change way of working. Since developing team has worked with a defined process for several years it is necessary to rethink and set the minds for the new goals. This change should happen from both side of managers and team members. It seems for developing members is easier adopting new ways in

comparison with managers. Since developing team are engineer which are willing to try new ways but managers have tried special way of working for longer time.

In case of evaluation processes, manager believes using visualization technique will facilitate and accelerate evaluation processes. Since evaluation is happening as an ongoing process in all stages of project.

In this process the most obvious change that happened in organizational structure is company has moved toward project organization. They have raised projects managers' positions in company. Today there is just one line manager in R&D unit which is head of department. The head of unit is the only resource holder in the R&D process. The rest of line managers for different disciplines (mechanics, electronics, software and verification) have been diminished while more responsibilities have been devoted to project managers in order to create a project organization.

Performance Measurement:

B Co. has been working without strict tool-gates in Product development process. But today they are improving their tool-gate processes by reducing number of gates from 7 to 5 by merging processes in order to reduce time of projects. And the checking in each gates are more defined and strict. In product development processes projects manager is responsible for controlling and monitoring process and report it directly to steering committee.

B Co. Controls process in three dimensions of time, cost and quality. The most important dimension between these three dimensions is cost in summarizing the projects. There is not any defined strategic indicator within these dimensions. The projects are controlled usually by comparing the actual time, cost and quality with planned one. The manager believes there is not any special measure for quality since projects are not allowed to pass till it meets all the demands in technical specification.

Department vision is to create a cost effective developing department that works faster and is more competitive. But there is not a clear vision in term of indicators improvement for following periods.

5-Analysis:

The following chapter addresses two main issues; first issue considers lean product development in theory and practice. In this part definition of Lean Product Development in theory and practice will be studied. In addition tools and techniques in lean product developments will be reviewed. This section will end with analyzing success factors in theory and practice.

The second one considers actual performance measurement systems regarding theories. In this Part performance measurement system in product development based on Chiesa and Frattini (2007) framework with five elements of: objective, dimension, Indicator, structure and processes will be analyzed.

Lean Product development:

Definition:

As it has been showed in theory section there two category of academic definition for LPD : process oriented and outcome oriented. Liker and Morgan (2006) definition is a process oriented one by bridging between lean product development and lean manufacturing. It Also highlighted importance of adaption of lean manufacturing tools for lean product development. Another process oriented definition has been developed by Karlsson & Ahlström, (1996), which defined LPD as interrelated techniques which most of companies already implemented in product development processes under one title of LPD. On the contrary Cooper and Edget (2008) take a different approach, by studying performance of firms. Then they looked at practices that successful firm used in order to achieve efficient development processes. This practical approach has been mentioned as outcome oriented.

Empirical studies show that industries are aware of lack of a comprehensive and universal definition of LPD. It seems both firms have considered Lean concept focal point which was about reduction of waste from value stream (Liker & Morgan, 2006). A Co started using tools such as value stream mapping in order to identify wastes and improve their processes besides running training for employees in different levels. B Co's managers have found the communication and flow of information as the major waste in processes. They try by visualization of product development processes improve communications and facilitate flow of information in all member of organization.

Therefore by considering different definitions have been argues in literatures, firms emphasize on processes oriented definitions rather than outcome oriented.

Table 11-LPD definitions

Source	Definition
Liker & Morgan (2006)	<i>a knowledge work job shop, which a company can continuously improve by using adapted tools used in repetitive manufacturing processes to eliminate waste and synchronize cross-functional activities</i>
Karlsson & Ahlström, (1996)	<i>a collection of interrelated techniques including supplier involvement, Cross-functional teams, Concurrent Engineering, functional integration, use of heavyweight team structure and strategic management of each development</i>
A Co	A process that people continuously identify wastes and eliminates them to improve process
B Co	A way of shortening the communication during the project life cycle by visualization

Tools and techniques:

According to theoretical studies lean product development is included several tools and techniques in order to increase efficiency of processes. Considering Karlsson & Ahlström, (1996) definition of lean product development as: *“a collection of interrelated techniques including supplier involvement, Cross-functional teams, Concurrent Engineering, functional integration, use of heavyweight team structure and strategic management of each development”*. Also seven practices described by Cooper & Edgett (2008) which companies with lean, rapid and profitable product development implemented have been summarize in table 1.

The empirical work shows that firms use most of these techniques already in their processes. Table 12 is on based data from interviews summarizes techniques that companies use in their product development processes. It also includes modularization since when companies have been asked about concurrent engineering, the answer was negative. But interviewer noticed in the process description modularization and parallel developments are part of processes.

Table 12- Tools and techniques

	Case A	Case B
Tools and techniques:		
1-Customers Focus	√	√
2- Supplier Involvement	√	√
3- Concurrent engineering	X	X
4- Cross-Functional team	√	√
5- Control the Right Parameter	√	X
6- Effective Portfolio management	N/A	N/A
7- Modern stage-Gate Process	√	X
8-Heavyweight team structure	X	√
9- Modularization	√	√
10- Visualization	X	√

Customers Focus: one of the most important factors in success of NPD is products which are differentiated and has ability to solve customer problems and create value for them (Cooper & Edgett, 2008). A Co develops their product based on needs of focal company and adjusted to their products. Here is a complicated situation since the customer is owner of A Co. On the other hand B Co is a contract manufacturer which develops unique products for each customer. customer are involved in developing processes since beginning of all processes by defining market and technical demands on any product. All products are developed based on customers' needs and requirement. Participation in product development processes will increase ability of products in order to create value for them and satisfy their needs.

Supplier involvement: in lean product development suppliers are active participant in development project from early stages of projects. On contrary in traditional practices supplier were involved when detailed design specifications have been developed (Karlsson & Ahlström, 1996). Both firms have strategic suppliers which are actively involved in product development processes even sometimes take responsibility for developing a part or device related to their specialty. Both firms involve suppliers in product development from early stages of development in order to speed up their processes. It also helps them to avoid misunderstanding and reworks.

Cross-functional teams: Kalsson and Ahlström (1996) argued in lean product development In order to facilitate processes, teams consisting of people from different functions are used in development projects. Having a cross functional team is a key factor in time to market reduction (Cooper & Edgett, 2008). A Co. creates cross-functional teams from different departments such as production and purchasing. The same procedure has been used by B Co. The goal is to bring all operation aspects into process from beginning. Participants from different functions can provide vital feedbacks and inputs from early stages of developing a product or process (Karlsson & Ahlström, 1996). It also speed up supporting processes such as purchasing and production since they are informed about progress in product development processes.

Control Right parameter: Measuring the performance is necessary in order to manage the processes. Most of the firms are missing a correct system of measurement and only 30 percent of firms, measure outcome and performance of NPD project after launch to market (Cooper & Edgett, 2008). A Co. has a well-defined performance measurement system with assigned person. They also control strategic indicators by senior managers in order to control processes and identify problems as Cooper &Edgett (2008) mentioned that establishing success criteria for each project is an important factor in success of NPD and further improvements. These strategic indicators are direct runner, cost for quality and time to market and there is a clear vision for improvement of each indicator. While in B co. it seems they try to control for cost,

quality and time but the processes are informal and general compare to A Co. This issue will be elaborated by detail in the next part.

Stage-gate processes: Cooper and Edgett (2008) believe that traditional stage-gate processes create bureaucracy and waste-times and best practice companies made their NPD lean by removing inefficiencies by application of value stream mapping in NPD. It will lead to more adaptable and flexible stage-gate process which can adapt to changing situations and information. A Co. has well-defined stage-gate processes but they implement value stream mapping in order to improve their processes. A Co. revises their stage-gate model continuously in order to reduce deficiencies. While B Co. has defined stage-gate processes but they are not so restricted and work with more flexibility which let them do some processes in parallel. More flexibility is because they can start next phase and go on without passing previous gate and they can pass through gates later. Therefore phases can be run in parallel and save more time. B Co. does not use value stream mapping for improvement of stage-gate processes.

Heavy weight team structure: Karlsson and Ahlström (1996) mentioned that increasing project manager role which has direct access to work of all team members will improve communication and build commitment to project by bringing focus in team. In heavy weight structure project managers are senior managers which have control over resources with less interaction with line managers. B Co. has changed the organizational structure by removing all the line managers and kept just head of R&D department as only resource holder. Therefore they have moved toward a project organization that project managers has full responsibility over projects and just need to report to head of R&D units. Such a structure facilitates communication between project managers and head of unit and can save unessential communication. As a result more responsibilities and authorities have been transferred to project manager. While A Co. uses a light weight project organization in matrix structures which there are several line managers and business office is the resource holder. On contrary to B Co, project managers in A Co should communicate with line managers and business office as resource holder which can create extra communication. Extra communication between several actors can delay processes and increase lead time.

Visualization: Liker and Morgan (2006) highlighted the importance of visualization which can align organization and facilitate flow of information. B Co use visualization as core of lean product development concept. The firm believes use of visualization tools will facilitate flow of information and get attention to wastes in processes. It happens by meetings and visual aids on office walls. Colors play an important role in creating signal about flow of processes.

Success factors:

Karlsson & Ahlström, (1996), concluded that achieving to LPD requires: Tight development schedules, Close cooperation with customers, highly competent personnel, active participation and support of top management.

Both firms are in the beginning of implementing Lean Product development but regarding these factors. A Co has a clear plan and vision for each year and they established 2010-2012 focus on “product renewal and internal efficiency” which has been translated into product development process in A Co. as 20% lead time reduction in 2010. While B Co is trying by implementing lean product development to improve NPD processes but they do not have any tight plan and vision for following years. Therefore it seems based on Karlsson & Ahlström, (1996), in order to success of LPD B Co. need to have clear vision and schedule for improvement of processes.

Both firms have close connection to their customers. A Co customer is the owner of company therefore the relationship is so close since they both follow same corporate and market strategies. B Co also is a contract manufacturer which develops unique devices and product for customers. Customers are involved in product development process from specifying market and technical demands at the beginning of development process till launch of product.

Lean product development program has been initiated in A Co with full support of executive managers by setting 2010-2012 focus. Executive managers actively participate in processes and control different indicators. Similarly head of R&D unit in B Co has initiated the Lean product development program and participated actively in all steps in order to control development of processes. Therefore both firms have support of top managers in implementing LPD and improving processes.

In order to increase competency of employees both firms conduct training and workshops for engineers and designers in product development department. B Co. has combined the LPD training with Lean Manufacturing trainings since they are implementing lean manufacturing at the same time.

Performance measurement system:

Chiesa and Frattini (2007) concluded that PM system in NPD is consisting of five elements of 1) Objectives 2) Dimensions 3) indicators 4) structure and 5) measurement process. In this section performance measurement system in A Co and B Co will be analyzed based on Chiesa and Frattini (2007) framework.

Objectives:

A performance measurement (PM) system helps managers in new product development for revising development strategies, starting new strategies and analyzing development project and evaluating effect of them on value of firm (Molina-Castillo & Munuera-Aleman, 2009). Godener and Soderquist (2004), mentioned application of PM system will improve relevance and coherent of developed products and introduce correction in projects. These findings are consistent with EIRMA (1995) that the most important result of an effective PM system is better communication with all stakeholders including investors, managers and sometimes customers (Nixon, 1998). Chiesa and Frantini (2007) summarize objectives of PM system in new product development in seven categories: 1) supporting decision making, 2) Enhancing R&D performance, 3) Motivating personnel, 4) Fostering organizational learning, 5) supporting incentive schema, 6) Enhancing communication and coordination, 7) reducing R&D risks.

A Co uses PM system in order to support decision making by providing a clear picture from current situation and future. They use strategic indicators in order to communicate managers' vision for future by interpreting it into changes in indicators. They established 2010-2012 focus on "product renewal and internal efficiency" which has been interpreted as in 20% lead time reduction in 2010 in product development processes. Running weekly meeting with project team and reviewing every two weeks identified problems and check their progress in addition to meeting every 4 weeks with all sections enhance organizational communication by providing a common and measurable language. Having a clear vision and organizational understanding will lead to performance improvement.

Using strategic indicator of cost for quality has been used for motivating project managers to act upon problems by showing them how much they are losing but not taking corrective actions and they can have better estimation about gains from corrective actions. It also helps to follow performance of different projects and reward them on good performance and improvement. All the processes have been designed in order to identify problems in processes and eliminate wastes by taking corrective actions. PM system helps A Co to facilitate organizational learning and development by clarifying success and failure of processes. It also helps employees to identify waste and communicate it in organization.

On the other hand lack of improvement vision in B Co hinders decision making and incentive schema. It also can reduce motivation of employees since there is no picture about future. But visualization of processes will facilitate organizational communication and learning. Using colors and visualization will create smooth flow of information and get attention which will help B Co to identify wastes in processes and improve performance of R&D unit. It also reduces risk of

R&D processes by creating suitable alerts and signs for corrective actions. Each color provide suitable signal and they can be prepared for possible risk which can occur since they have been identified in advance.

Dimensions and Indicators:

Chiesa and Frattin(2007) have categorized dimension of performance in R&D into 4 groups of : Effectiveness, Efficiency, and Contribution to value and time. In order to measure these dimensions effectively managers should select suitable indicators for each dimension (Sandstrom & Toivanen, 2002; Ojanen & Vuola, 2006).

Table 13-Dimension of performance in product development, (Chiesa & Frattini, 2007)

Dimensions of performance
Effectiveness
Efficiency
Contribution to value
Time

A study by Cadergren et al (2010) showed that managers’ perception of performance in NPD is about the efficiency of the later stages of NPD in term of cost, time and quality. The effectiveness (correct choice of product) is not measured in the most of cases. It is essential that an effective PM system evaluate PD processes concerning both factors (Cedergren, Wall, & Norström, 2010). It is consistent with Driva et al (2000) finding in comparison of practices with theories, they concluded that firms are using time, cost and quality measure while academics give emphasis to customer related measures.

Empirical results are consistent with theoretical findings that performance measurement systems in practice only focus on efficiency in term of quality, cost and time rather than effectiveness. A Co measures performance in R&D processes by three strategic indicators of” Direct runner”, “cost for poor quality” and “time to market” in addition they use financial measures such as return on investment and actual cost relative to planned budget.

Direct runner by showing number of products which reaches production stage without any major modification measures the quality of product development process. Cost for quality which measures associated cost for fixing problems in products after production is reflecting on quality and associated cost. As it is clear time to market and financial indicators reflect on time and cost. But there is not any measure for controlling effectiveness of processes.

While B Co does not have defined strategic indicators on efficiency but they control on cost and time. Cost has been controlled by use of relative measures in comparison to planned budget. Time is measured by two measures of time to market and actual time relative to plan. They do not have any special measure for quality since they claim a product cannot reach the final production phase without satisfying all the technical and market demands.

Table 14-performance dimension and indicator

Dimension	Efficiency	Quality	Time	Effectiveness
A Co	Return on investment,	Direct runner,	Time to market	No indicator
	Actual cost relative to plan	Cost for poor quality		
B Co	Actual cost relative to plan		Time to market,	No indicator
			actual time relative to plan	

The level of analysis in R&D processes influence performance dimensions and indicators (Chiesa & Frattini, 2007). Level of analysis can be categorized in three levels of firm, program and project. Performance in firm level can be measured with indicators such as sales growth or profitability while in program level impact and profitability of program is important. For assessing single project financial indicators, time and customer satisfaction can be suitable indexes (Molina-Castillo & Munuera-Aleman, 2009).

Empirical findings in this section have focused on two levels of program and project. A Co strategic indicators measure performance of R&D activities in program level while other indicators such as actual cost to planned budget is measuring in project level. Same situation exists in B Co, since they measure performance in comparison with actual plan; performance measurement system is in project level.

Structure and measurement processes:

Chiesa and Frattini(2007) argued that an effective performance measurement system in Product development require well-defined structure and processes. First step in designing PM system’s structure is identifying control objects and assign an indicator to performance of the object and also assigning responsible person for controlling each objects (Nixon, 1998). These control objects can be Researcher, laboratory, team, Project, program and R&D unit (Chiesa & Frattini, 2007). Driva et al (2000) shows that success of the performance measurement system

is dependent on the way it will be implemented and performed. The main elements of measurement processes are:

1) Intensity of involvement of people in the following phases: a. Design of performance measurement system b. collecting data c. Analysis of data and identifying corrective action (Driva et al, 2000).

2) Frequency of control for each dimension and indicator (Chiesa & Frattini, 2007).

3) Setting standards or references which they can compare measures against it (Nixon, 1998). Chiesa and Frattini (2007) proposed two ways for setting references: (a) Future objectives: standards are defined as vision for future which firm is aiming to achieve in long-term or short-term. It helps firm to compare its performance with its objective. (b) Bench marking: company should monitor performance of industry or competitors. It requires a thorough analysis in past and present situation in order to set standards for its own processes.

Based on these theories from empirical results performance measurement structure and processes in both firms will be analyzed. A Co performance measurement control performance of teams and projects and program by using indicators such as comparison of actual results with planned one and strategic indicators. The Chief project managers are responsible to control performance of teams. In addition documentation process manager control strategic indicator which are reflecting on overall project and programs and report it to vice-president of product development and steering committee. If there is an issue in processes data will be analysis and process manager will take responsibility for corrective action in collaboration with project managers. Each dimension will be controlled regularly. In project level every team run weekly meeting to control their performance and analyze it, every two weeks they review their meeting and control progress of corrective actions. They have another meeting every 4 weeks which they can share their problems with all sections and work cross-functionally. Steering committee has meeting typically every three months in order to control progress of projects. A Co has set standard for its performance as company vision for 2010-2012: "product renewal and internal efficiency". This vision has been in translated into product development process in company A as 20% lead time reduction in 2010.

B Co measures performance with indicators which reflect on performance in team and project level by comparison between actual results and planned one. Project managers are responsible for controlling these dimensions and should report it to the head of R&D unit and steering committee. In this level if there is a problem project manager is responsible for corrective action and reporting it directly to steering committee. The processes have been controlled constantly and visualization of processes helps to facilitate control effect of each corrective

action for all team members and managers. Project managers usually meet weekly with head of R&D unit and report in standing meeting to head of R&D units and other project managers. Steering committee usually has meeting every three months for controlling processes. B Co didn't set any reference and standard for improvement which seems necessary for performance improvement.

Table 15- Performance measurement processes and structure

Process and structure	Control object	controller	involvement of people	frequency of control	setting standards
A Co	Team, Project and Program	Vice-president, steering committee, Process manager, Chief project manager	Team, manager, manager, committee	Project Process Steering Weekly, Monthly, quarterly	2010-2012 vision
B Co	Team and Project	steering committee, Project manager,	Team, manager, committee	Project Steering Weekly, Quarterly	No standard

6-Conclusion:

The following chapter starts by answering the research question and discussing the specific contribution to body of knowledge in both areas of lean product development and performance measurement in product development. Subsequently, practical managerial implication will be addresses. The chapter will be concluded with future research proposals.

Objectives and contribution:

Lean product development (LPD) has been introduced as a concept which is able to improve Product development processes and firm's competitive advantages. The concept has been argued that has potential to reduce time to market of new product with higher quality and manufacturability (Karlsson & Ahlström, 1996).. Performance Measurement system is a key factor in evaluating processes and effect of new concepts or changes on process efficiency. There is an old saying "If you want to manage it, you have to measure it" (Driva, Pawar, & Menon, 2000). Managing and measuring performance in product development has been seen as a mean to ensuring survival of business by increasing quality, reducing time and cost (Driva et al. 2000). Identifying right metrics and measuring performance of Product development processes play a key role in success of Lean Product development. Consequently the main objective of this explorative research is to address research question:

"How companies measure performance in lean product development?"

Starting point of this research was about defining lean product development In order to identify target firms. Definitions have been categorized as process oriented and outcome oriented. Since there is lack of clear definition about lean product development, the methods and practices which can lead to a lean and efficient product development have been considered as well. These methods and Practices have been summarized in table 1 are: Customer focus, Front End loaded, Concurrent engineering, Cross functional teams, Control the right parameter (performance measurement), Effective portfolio management, Modern stage-gate processes, Heavy weight structure and Visualization.

The study shows the lean product development definition and perception in each firm is unique and based on their current situation. Uniqueness refers to the issue that Companies need to identify their abilities and weaknesses in order to be able improve processes. It can be dependent to what practices and tools have been already implemented in processes without titling it LPD. Or what are internal capabilities and experiences that firm acquire in business in order to deal with weaknesses and wastes in processes. Therefore a gap analysis is essential in order to identify the current situation and the path toward target. The success of such an analysis is dependent on commitment of employees. Commitment can be enhanced by involving them in processes and asking their perception since they are the end user of new

strategies and processes. On the other word a customer focus approach will create loyalty and commitment between employees for process improvement.

Similarly both firms have addressed main objective of lean concept as identifying waste and eliminating it continuously. Their approach in defining LPD is processes oriented. They are seeking for processes which help them achieve to efficient processes. While A Co has a general view about waste, B Co main focus is on one kind of wastes (communication) and tools that can help them to achieve waste reduction. Therefore it seems definition of A Co from LPD similar to Liker and Morgan (2006) is more about what is the best way in order to identify the waste and eliminate it and as the result improve product development performance. While B Co focuses on tool (Visualization) which lead to efficient processes similar to Karlsson & Ahlström (1996) definition. But tool (visualization) B Co use under title of LPD is different than interrelated tools that Karlsson & Ahlström (1996) argued as a “coherent whole” with LPD title.

The empirical results show firms employ most of the practices which has been reviewed in literatures already in product development processes. These practices have been summarized in the following table. The study results are consistent with Karlsson & Ahlström (1996) argument that majority of large firms employ techniques that they considered in their definition of lean product development. At the same time firms are aware of difference between nature of production processes and product development. They have the ability to transform lean concept in manufacturing to Lean product development (for example by identifying communication and flow of information as a major waste instead of flow of material and material handling in production).

Table 16- practices and Techniques

	Case A	Case B
Tools and techniques:		
1-Customers Focus	√	√
2- Supplier Involvement	√	√
3- Concurrent engineering	X	X
4- Cross-Functional team	√	√
5- Control the Right Parameter	√	X
6- Effective Portfolio management	N/A	N/A
7- Modern stage-Gate Process	√	X
8-Heavyweight team structure	X	√
9- Modularization	√	√
10- Visualization	X	√

The results about performance measurement can be categorized in three categories of objective, dimension & indicators, structure and Processes:

Objective: the main findings from empirical studies shows that performance measurement system in product development helps to improve communication, support decision making , motivate employees and improve R&D performance. Introducing quantitative measures will help to create a common language through organization. Such a common language will improve the perception about processes and communication between different organizational levels. In addition when people can see the results of their effort as quantitative measures will be encouraged to continuously improve their performance. At the same time measurement helps managers to follow effect of their decisions and support their proposals and decision for next step. But firms are not aware of all benefits and objectives of performance measurement systems which have been argued in theories.

Dimension& Indicators: empirical findings are aligned with theories that companies consider efficiency of processes rather than effectiveness when it comes to performance measurement. A reason can be that it is difficult to assign an indicator to effectiveness of product development processes. Therefore firms prefer to measure the dimensions which are easier to measure such as cost, quality and time. They compare them with planned ones in order to evaluate performance of product development. Indicators are also assigned to mentioned efficiency dimensions of cost, quality and time. Implication and importance of each indicator is different and is dependent to firm’s strategy.

Table 17- Performance measurement dimensions in theory and Practice

Dimensions	Efficiency	Effectiveness
Theory	√	√
Practice	√	X

Structure and performance: the structure and processes are unique for each firm. Firms control performance on different levels and objectives. A Co control performance in level of program, project and team while B Co controls performance in level of project and team. The reason can be difference in scale of product development in companies. A Co with 2000 employee in product development is running several projects at the same time while B Co has only 50 employees in product development which create limitation in number of projects taking at the same time.

Project managers play an important role in controlling processes and reporting to the top managers. Top managers and steering committee are involved in performance measurement processes continuously. A Co by setting strategic indicator and reporting it to vice president of product development involve top managers in processes continuously. Similarly B Co head of R&D unit conduct weekly meetings with project managers in order to follow up the projects and visualize them. Also firms involve employees in different level of performance

measurement while performance has been controlled in regular basis. Meanwhile some firms fail to set a clear standard for performance of the firm but other firms have set clear vision or standard. Lack of such a standard can discourage people since the path and the goal is vague.

In conclusion, firms are aware of importance of performance measurement system and try to design suitable performance measurement system. As it has been argued the performance measurement systems are unique for each firm. On the other hand performance measurement systems in practice focus on efficiency of processes regarding cost, quality and time but not effectiveness. The main differences between two companies in processes are related to strategic indicators and setting standers. A Co involved all the level of organization and facilitates communication in more formal way by reporting strategic indicators to top managers and communicating them with all employees while the communication in B Co is more informal. Project managers report in standing meeting to the head of R&D unit and other project managers. It seems Size of companies and number employees play a vital role in design of performance measurement system. As much as the organization size increases, the need for formal processes is bigger.

Managerial Implication:

Based on findings of research the managerial recommendations will be addressed in four categories:

- 1- Need for definition: in order to improve understanding about lean product development in organization, firms should arrange meetings with employees and argue different aspects of concept. These discussions should lead to a clear definition of lean product developments and processes in order to achieve to LPD. Such a meeting and definition will increase commitment of people to processes since they feel an important role in design of them.
- 2- Setting goals: any process improvement require pre-defined goals and targets. Identifying ideal situation will helps firms to compare their current situation with target and evaluate performance improvement continuously. Lack of an objective can lead to confusion and failure. The goals can be defined in term of performance dimensions. The dimensions are in term of efficiency and effectiveness. The objective can refer to both or one of them. For example A Co vision is 20% lead time reduction in product development processes. A well-defined performance measurement system will moderate continuous improvement positively.
- 3- Design of performance measurement: firms should consider all aspect of performance measurement system in addition to objectives. By identifying measured dimension and assigning suitable indicators to each dimension. Designing structure and processes which for each phase responsibility of employees is clear. Also all employees are

involved in processes and able to follow performance. In the design of PM system the control objects should be clarified and an indicator should be assigned to performance of each object. The person or unit which responsible for controlling each object and indicator should be highlighted.

- 4- The crucial role of project manager: Project manager has a crucial role in performance measurement systems. Since project managers are intermediary between different levels of organization success of system is dependent in project manager capabilities. Project managers should be able to establish communication with all parties and analyze the feedback correctly. In addition a heavy-weight structure that project manager has more control over resources and can increase commitment of project team seem more suitable. Such a structure will reduce levels of communication and will facilitate flow of information.

Further studies:

This research has had an explorative nature since the researches in area of lean product development and performance measurement systems in Lean product developments are in the beginning of developing theories.

Since this paper has been conducted based on one interview in each firm with a senior manager an in-depth case study is needed. In-depth case study can help to analyze theories and findings of previous research in one or more cases and evaluate effect of them on performance improvement. As a consequence it should lead to design of an integrated performance measurement system in lean product development environment with help of employees in all level of organization.

In the next step based on current studies hypothesis regarding effect of performance measurement systems and performance improvement can be generated. From theories can be concluded that a well-defined performance measurement system has a positive relationship with performance improvement in product development processes. This statement by considering dimensions of performance, control variables can be tested on sample of firms in different industries. Moderating factor which can influence this relationship should be studied in the next step.

As it has been concluded firms measure efficiency rather than effectiveness in their processes. Designing suitable performance measurement system which can assign measurable indicators to effectiveness of product development processes seems essential in performance measure in LPD. Therefore a future study can focus on how to measure effectiveness and what indicators can be used in order to measure effectiveness of processes.

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8-Appendices:

Appendix 1: A synthesis of suggestions from the literature about the PMS designs

(Chiesa, Frattini, Lazzarotti, & Manzini, 2007).

Suggestions	References
The basic constitutive elements of a PMS for NPD are: (i) dimensions of performance and related indicators; (ii) structure of the system, i.e., the set of controlled objects whose performance are measured (e.g., individual, functional unit); and (iii) process aspects to be defined for a proper working of the system, i.e., norms to measure performance against, timing and frequency of the measurement, role and tasks of people involved in the system implementation.	Kaplan & Norton, 1992; Kerssens-van Drongelen & Cook, 1997; Kerssens-van Drongelen & Bilderbeek, 1999; Driva et al., 1999; Bremser & Barsky, 2004; Godener & Soderquist, 2004
The design of the PMS constitutive elements should be coherent with the “NPD environment” in which the system is going to be used. This “NPD environment” is basically defined in terms of: (i) critical objectives of the NPD project; (ii) organizational and managerial practices adopted for the NPD process; and (iii) characteristics of the NPD tasks that are going to be internally undertaken.	Kerssens-van Drongelen & Cook, 1997; Frattini et al., 2006
The characteristics of the “NPD environment” depend on a set of higher-level variables e.g., (i) company’s business strategy; (ii) competitive context [i.e., rules of competition and competitive pressures]; (iii) environmental features [i.e., macro-economic factors, institutional norms, and social and cultural characteristics]. Therefore, these variables indirectly influence the PMS constitutive elements design.	Loch & Tapper, 2002; Sandstrom & Toivanen, 2002; Nixon, 1998; Kerssens-van Drongelen & Cook, 1997
The PMS objectives (e.g., motivating people, supporting decision making, fostering communication) are driven not only by the goals of the NPD project, but also by the adopted management style and the nature of development tasks.	Goold & Campbell, 1987; Frattini et al., 2006
The dimensions of performance traditionally considered in a PMS for NPD projects relate to time, costs, and quality. Moreover, they are generally further disaggregated in order to be actually measured. Economic and financial metrics should be used as well as quantitative nonfinancial and qualitative measures.	Soderquist & Godener, 2004; Driva et al., 2000; Loch & Tapper 2002; Sandstrom & Toivanen, 2002; Pawar & Driva, 1999
The elements of the performance measurement system should evolve over time coherently with the progress of the NPD process.	Nixon, 1998
Risk and uncertainty must be considered during the PMS definition.	Davila, 2000
An appropriate definition of the norms [i.e., standards to measure performance against] is necessary to ensure that the measurement system provides useful indications capable of eventually correcting the courses of action. Scenario analysis can be a useful tool for an accurate standard definition.	Burch, 1994; Merchant, 1998
Constraints in human and financial resources available for the implementation and actual use of the PMS influence the design of the achievable objectives and the other constitutive elements.	Kerssens-van Drongelen & Cook, 1997; Frattini et al., 2006

Appendix 2: Interview Questions

Introductory:

A1) what is your position in this company?

A2) how long have you been in this position?

In the case that the respondent is relatively new to the company or newly assigned to the position the following questions are helpful:

A3) what was your previous position?

A4) how long have you been employed at this company?

The General Information about the Industry & the Company

B1) is your position specifically related to any product of the company? Can you explain about the relation?

B2) what are the main markets of the company?

B3) what are the main competitors of the company?

B4) in your opinion what are the main market priorities that companies have to obtain in order to be competitive in the market? To what extents do you believe your company possesses them?

Product Development Nature and Product Development Procedure

C1) how long does it take for a product to enter into the market from the very concept?

If the interviewee answers partially or thoroughly to all the questions below, the

R&D nature of the company and industry might reveal in terms of resource consumption, capital intensity and product life cycle:

C2) how much money does your company spends on R&D activities annually?

C3) how many R&D units does the company possess?

C4) how many employees does company employed in R&D units?

C5) how often do you introduce new product to the market?

C6) can you briefly explain the product development procedure?

In the case that the explanation would not be sufficient the following sub-questions

Can be helpful:

C7) how does a development project legitimize to commence?

C8) how many steps does a project have?

C9) who is responsible to evaluate and control the project?

C10) how do you evaluate a project during development phases?

C11) what are the criteria for project evaluation?

The following questions help to understand the team structure:

C12) do you form any project teams for the product development projects?

C13) how many people are involved in the development projects?

C14) what type of capabilities and technicalities do you seek in the individuals to be assigned in the development projects?

C15) what departments are involved in the development projects?

Lean Product Development

E1) can you define lean product development?

E2) how long have you been implementing LPD in your organization?

E3) why do you start practicing LPD in your organization?

E4) how do you learn about LPD? Have your company planned any trainees or workshops for the employees to learn about LPD?

E5) in your opinion, what are the main challenges, barriers and benefits of implementing LPD?

If the answer is not consistent the following sub-questions are helpful:

E51) is there any change in the evaluation process? Evaluation criteria?

E52) is there any change in the project team structure?

E53) is there any change in the development procedure?

E6) do you think that LPD has helped product development process to improve? If yes, can you explain?

If the answer to the above question is no:

E6.1) what are your reasons on not having a satisfactory results out of LPD implementation?

The role of question E61 is to know whether the interviewee perceives LPD as useless practice, or believes that the implementation of LPD is not successful.

Performance measurement and Indicators

F1) How many stage-gates you use in the R&D process

F2) what are important indicators for controlling performance of product development process?

F3) what is the process for controlling these performances?

F3.1) what is correction process?

F3.2) how managers reacts to these signals?

F4) Do you have any vision for improvement of these KPIs?

F5) how implementing lean product development improved the R&D performance (which indicators have changed)

F6) Do you have any special tool for identifying wastes?