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Success Factors for Quality in Product Development

A case study from automotive product development

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ABSTRACT

Background: Today's fast-paced product development cycles and increasing complexity of automotive products require new processes, methods and tools to manage product development organizations. Besides that, reduced cost and higher product quality calls for increased product development effectiveness and efficiency since product development stands for significant part of the quality costs. This implies a need for holistic approach by sharing and creating new knowledge and faster problem solving in projects.

Purpose: The aim of this thesis is to examine the factors that affect product quality, development cost and development time in automotive product development organizations. This thesis reviews existing literature in fields of quality management, lean product development and knowledge management with special focus on the factors that affect product quality, cost and development times. Three factors that affect product quality, cost and time are identified as:

- Cross functional teams
- Knowledge Integration
- Knowledge Flexibility

Method: A qualitative research case study is performed at a major automotive manufacturer in Sweden. Semi structured interviews are used to collect as much information as possible from respondents at two automotive product development companies. Collected data is analyzed using pattern matching techniques where the theoretical model is tested against the observed or actual model. Member checking and peer reviews are used to further enhance the credibility of this study.

Main findings: The outcome of this study is that product quality can be improved by using the cross-functional teams, work force with knowledge in multiple fields and by integrating previous product knowledge during the product development. Knowledge creation and sharing are fundamental in innovative product development. As such organizations need to develop processes to facilitate knowledge sharing and knowledge creation. Information integration may not be effective during innovative product development due to the lack of previous product knowledge. Both cross functional teams and knowledge integration appears to have strong influence on product quality and development cost. However, knowledge flexibility is not fully supported for development of innovative products. It appears that both generalists and specialists are needed to not end up in quality issues or loss of innovations. Project leaders with skills in more than one field will improve correct and timely decision making as well as integrating different views in cross functional teams which will lead to improved product quality and lower development cost and time.

Keywords: Product Development, Lean, Cross functional, Design Defects, Knowledge Management

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Abbreviations

CAE	Computer Aided Engineering
COPQ	Cost of Poor Quality
CFT	Cross Functional Team
DSM	Design System Matrix
ECU	Electronic Control Unit
GM	General Motors
JIT	Just In Time
PAF	Prevention, Appraisal, Failure
RBV	Resource Based View
TQM	Total Quality Management

1. INTRODUCTION

Automotive market is characterized by demand for quality products at lower prices, fulfilling legislation demands, reduced time to market and cost saving pressures. To withstand the pressure and be profitable in this competitive environment companies must be able to improve on all fronts as product development, production processes, dealership and services, relation with supplier etc. Organizations need to develop agility to innovate, design, and introduce new products to the market quickly (Krishnan & Ulrich, 2001). It requires new capabilities to solve problems effectively, avoid repetitive kind of issues in projects to convert efforts into products fulfilling customer's requirement.

Being first in the market has several strategic and operational advantages as charging premium price, brand image, controlling a large market share and enjoying the bottom line profit. Being first in the market is equivalent to being innovative, effective and efficient in order to design and produce good quality products at low cost.

Project success is measured in terms of how well a project meets time schedule, budgetary constraints and performance or product quality requirements (Steyn, 2011). A study on IT projects show that around 45% of IT projects runs over budget, 7% over time while delivering 56% less value than predicted (Bloch, Blumberg, & Laartz, 2012). If a project meets problems at end stage project manager may need to compromise quality due to the fact that both time for product release is close and that no more cost are possible to take on by the project. Figure 1 illustrates the relationship between quality, cost and time. If the product quality needs to be improved, the amount of time and resources need also to be increased so that the triangle still have a stable base to stand on (Tonnquist, 2010).

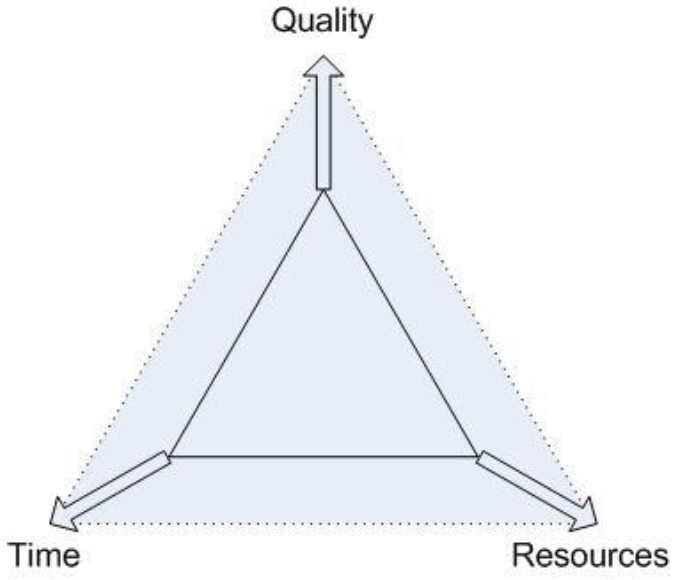

Figure 1:Resources, quality and time (Tonnquist, 2010)

Compromizing product quality in development stage may become very expensive for a company once product is launched. Cost of poor quality in the manufacturing industry lies between 5 to 25% of sales (Bell, McBride, & Wilson, 1994) and service industries expenditure are even higher, of the order of 30-40%. Up to 95% of these costs are the failure and appraisal costs and mere 5% are the prevention costs (Bell, McBride, & Wilson, 1994; Vincent, Omachonu & Suthummanon, 2004). In product development, major parts of the cost are related to product design. Product design stands for more than 40% of quality costs (Alard & Schönsleben, 2009). Even though product development stands for only 5% of the product cost but it influences manufacturing costs of the order of 75% and quality costs by 80%. Once the product has left design stage the cost to fix these problems gets multiplied due to added soft costs, warranty costs and product related costs as requirement of new tooling. Therefore detection of the quality problems in the development process and especially in the beginning of development process is very important.

Learning by doing and proactive investments in quality improvements have seen more effective than reactive investment in quality improvement (Ittner, Nagar, & Rajan, 2001). Proactive resource investment to shift the identification and problem solving earlier in product development in order to reduce the development time and cost is also suggested by Fujimoto & Thomke (2000). Furthermore, an increase in appraisal and prevention costs results in reduced failure cost; consequently, the level of quality increases and productivity improves (Carr & Ponoemon, 1994).

Business process improvement has been the most important tool for quality improvement in automotive industry. There are two types of process improvements: BPR (Business process re-engineering) and continual process improvement which is the idea behind total quality management (Pearson, 2002). Processes improvement helps to reduce non-productive activities, achieve better quality which leads to product cost reduction. Continual improvements of manufacturing processes have been successfully used by Toyota to reduce lead time, reduce inventories, improved quality and higher employee involvement and satisfaction. This process improvement has later been called Just-In-Time (JIT) system (Ohno, 1988). Manufacturing literature indicates further that the firms successful with implementing lean in manufacturing have also been successful in their new product development processes (Meybodi, 2005).

Importance of product development teams, their key skills and their interaction processes are studied by Madhavan & Grover (1998). Knowledge sharing, creation and integration of knowledge in process found to be important factors that affect team effectiveness. Besides that the team leaders with knowledge in multiple fields and knowledge about the interactions with other group's expertise found to be important for the overall team effectiveness. Besides team characteristics, project requirements have been found to be the second important criteria in project success (Bloch, Blumberg, & Laartz, 2012). Fujimoto and Thomke (2000) proposes project to project knowledge transfer and rapid problem solving by utilizing the existing knowledge which will help to detect the problems early in a project.

Since product development is a complex process with many interwoven parameter that requires interlinking of different management theories. Early problem identification, utilizing the teams to create and share knowledge, knowledge flexibility together with an efficient product development process are factors that will be investigated in this thesis. Effect on product development efficiency and effectiveness by implementation of these factors in product development process will also be discussed in this thesis.

1.1 Problem Description

Increased focus on cost reduction (Aberdeen Group, 2007) and quality (Eisenstein, 2005) in automotive sector compared to other industries exerts extra pressure on automotive companies to increase product development efficiency and effectiveness. Origin of most of the attributes of product quality as reliability, durability and performance lies in product development. Improved quality during product development is major challenge and possibility since 40% of the quality issues belong to product development (You, Alard, Schönsleben, & Zhu, 2009).

Higher perceived quality will lead to higher customer's retention (Kotler, 1994; Harari, 1992), lower marketing costs and will enable company to charge premium prices. If the quality is not satisfactory company may need to run price reduction campaign reducing profits or earnings per vehicle. According to Eisenstein (2005), lower perceived product quality was behind the loss of 2300 USD per vehicle for GM compare to 1600 USD earnings per vehicle for Nissan.

One way to increase product quality during development is to find issues both in technology choices and product requirements during early development stages (Bloch, Blumberg, & Laartz, 2012). The earlier an issue is found on a product the cheaper it is to solve. On the other hand the knowledge gap in beginning of a project is large which decreases along with product development iterations. The knowledge gap will be even larger in case of innovative products because organization is seeking development knowledge in such cases. So it becomes crucial to focus on earlier problem solving and integration of lesson leraned to reduce knowledge gap in beginning of projects.

If the quality problem are not detected during earlier development phase these may requires more efforts from the engineers to fix issues right before the product launch gate. As a consequence the future projects suffer when resources needed to work on those projects are in "fire-fighting" mode to solve problems from current projects. If the upcoming projects don't get sufficient resources, issues will be found at end stage which again ends up in a fire-fighting mode. It is a downward spiral that decreases the productivity and companies often fails to meet the customer's expectation and product quality (Black & Repenning, 2001; Aggeri & Segrestin, 2007).

Major parts of the cost of poor quality are the failure and appraisal costs (Bell, McBride, & Wilson, 1994; Vincent, Omachonu & Suthummanon, 2004). That means companies have to act reactively to solve the problems after customers complains. Many customers may find complaining expensive and instead switch suppliers upon receiving low quality products (Kotler, 1994; Harari, 1992). Therefore it is important for the companies to work proactively to ensure quality. Various studies show as well that returns on proactive investments in quality are higher than reactive investments in quality (Ittner, Nagar, & Rajan, 2001)

There has been extensive work done in individual areas as product development, development teams, knowledge integration and knowledge flexibility but not specifically identifying the relationship between them in an automotive product development organization. More research, therefore, is required towards this area, to understand the practical applications of management theories that will lead to improved product quality based on proven theoretical details. The aim of this thesis is thus, to do a research study on the importance and relationship of cross functionality, knowledge integration and skill development in a product development organization with focus on product quality improvement.

1.2 Research Question

The purpose of this thesis is to explore qualitative operational factors that affect product quality, cost and time in a product development organization and to explore the origin and possible solution for organizational issues.

As mentioned above the product cost reduction, product quality improvement and shorter development times are the main strategic objectives of the automotive companies. Product quality can have long term implications on customer retention, product price, product volumes and operational margins (Thomson, 2006 ; Vincent, Omachonu, & Suthummanon, 2004; Akerlof, 1970; Bell, McBride, & Wilson, 1994).

Literature in product development (Eppinger, Whitney, Smith, & Gebala, 1994; Aggeri & Segrestin, 2007; Bloch, Blumberg, & Laartz, 2012; Aw, 2005; Black & Repenning, 2001; Brown & Eiesenhardt, 1995), Lean product development (Olsson & Hansen, 2011; Oppenheim, 2004; Wang & Wang, 2012; Cook & Rogowski, 1996), quality (Giakatis & Rooney, 2000; Ittner, Nagar, & Rajan, 2001; Pearson D. J., 2002; Thomson, 2006)and strategy (Barney, 1991; Eppinger, Whitney, Smith, & Gebala, 1994; Kleinscmidt, Cooper, & Edgett, 2004; Ribeiro, 2012; Wernerfeldt, 1984; Willis & Jurkus, 2001) has provided insight into some typical mistakes that are repeated all the time in product development organizations. The main causes of these mistakes lies generally in missing information, reinventing solutions, inability to transfer lesson learned from failures (Madhavan & Grover, 1998; Fujimoto & Thomke, 2000), individual approach instead of team approach (Sethi, 2000; Fredericks, 2005), knowledge gap (Jiangnan, Zhiqiang, & ChuangLing, 2014), the existing knowledge is not shared or the lack of awareness about the consequences of product design on final quality (Liker & Franz, 2006).

The next obvious question is how to avoid these mistakes. To answer that, this thesis starts with exploring the interaction and complexity of the automotive product development. Even though the objective is to improve product quality by increasing efficiency and effectiveness of the resources working in product development but in order to understand the complexity of the subject there is a need to explore different field as: project management, project teams, lean product development, cost of poor quality, knowledge creation and sharing in organizations as well as the product development processes.

Detailed literature review led to three important factors that have significant effect on product development effectiveness and efficiency. These factors are cross functional teams (Sethi, 2000; Fredericks, 2005; O'Neil, 2007; Fujimoto & Clark, 1991), knowledge flexibility (Olsson & Hansen, 2011; Olsson, 2006; Kaeter, 1993; Dalton 1998; Hoyt, J. & Matuszek, T., 2001) and knowledge integration (Aw, 2005; Fujimoto & Clark, 1991; Fujimoto & Thomke, 2000; Madhavan & Grover, 1998).

Hence, cross functional teams together with integration of information and previous knowledge and resources with knowledge in multiple field are seen as primary factor that positively influence product development efficiency and effectiveness (Bloch, Blumberg, & Laartz, 2012;Pearson D. J., 2002).

The research question investigated in this thesis is:
How cross functional teams, knowledge flexibility and knowledge integration affect product quality and development cost and time in an automotive product development organization?

1.3 Thesis Contribution

Different management theories provide answers to individual organizational problems, e.g. knowledge management (Nonaka, Toyama, & Konno, 2000; Madhavan & Grover, 1998), information management (Aggeri & Segrestin, 2007;Song, Souder, & Dyer, 1997) or cross functional teams (Sethi, 2000) where product quality, product development time and cost require understanding of interaction among different fields while keeping a manageable number of variables. First contribution of this thesis is that it explores the significance and the interactions of factors related to knowledge management and knowledge dissemination in an automotive product development organization.

Besides that this thesis contributes to understand:

- How product quality and cost can be improved by integrating existing knowledge in a product development organization.
- How the implementation of these factors can be done successfully in existing product development processes.

- How inclusion of the cost of poor quality in product cost calculations will help to design and develop quality products.
- How product development time can be reduced by using the knowledge of cross-functional teams.
- What are the strengths and weaknesses of the cross functional teams.
- How knowledge flexibility will affect product development efficiency and effectiveness.

To sum up we can say that this thesis identify viable solutions to many of management problems existing in automotive product organizations.

1.4 Delimitation of Study

Focus of this thesis is on product development organization excluding important functions as sales, marketing and procurement or manufacturing. Another assumption in this work is that the information between team members in a cross functional team flows without any hinder and all team member's shares knowledge honestly without keeping back any information they have (O'Neil & Adya, 2007).

Successful use of cross functional teams may require strategies to improve emotional, cognitive, motivational and increasing behavioral competencies (DuBrin, 2010) which are not been discussed in this thesis. The thesis does not try to find the answer: if product and previous failure information is made available whether people will use it or not. Focus of this thesis is more on to understand if there is a need for information and knowledge integration in organization and the second how this can be made available by process modification.

The propositions in this thesis are validated with empirical data collected from only two automotive product developments companies with global operations. Six out of seven interviewees are from same company; hence we assume internal validity of the study is good. However more data from companies with both local and global operations needs to be collected to ensure credibility of this study.

2. Literature Review

Before we starts investigating the factors that affect quality, it is important to understand what "cost of quality" or more correctly "what the cost of poor quality" is? This chapter starts with defining cost of poor quality in general terms and ways it is measured and then continue with identification of the factors that affect product quality and the factors that will lead to improved product quality. This chapter will also introduce automotive products, automotive product development organizations as well as strategies used by companies to reduce the lead times and costs. Litterature study is summarized in the theoretical framework section which ends with presenting a conceptual model.

2.1 Quality and Product Positioning

The strength of product positioning or its relative benefit has a major effect on the rate of market growth. Stronger benefit advantage and affordable price lead to higher customer value creation and faster rate of market entry (Best, 2009). Besides that, product quality is an important product force which has strong effect on market penetration strategies and can also be used as non-price strategy. Non-price strategy is when competitors wouldn't lower prices in fear of price war and instead focus on promotions or lift up other benefit as high product quality. If two companies are selling comparable products, customers will chose the product with better quality if the price doesn't differs.

Quality in economists view is something valuable in products that customer want to own and can pay higher price for. Risk of not having uniform quality levels may confuse customers and may deteriorate brand image. According to Akerlof (1970) with an even distributed product quality there is a smaller risk for the customer to purchase a lemon (bad quality car or truck). If the quality is uneven, let's say there are some good quality cars and some not so good the price that the customer is willing to pay will be reduced due to the fact that customer will not be able to say what the quality will be on their specific product. It will also lower the price on the important second hand market when rumors about bad quality will be spread. The second hand market as we know is important for the owner when this will be the start capital for purchasing the next vehicle.

2.1.1 Cost of Producing Faulty Products

Estimated quality cost in the manufacturing industry lies between 5 and 25 percent of sales and service industries expenditure are of the order of 30-40 percent of operating costs. Up to 95% of these costs are the failure and appraisal costs (Bell, McBride, & Wilson, 1994; Vincent, Omachonu & Suthummanon, 2004).

Poor product quality costs both in term of return on investment and indirectly in the form of lost customers. So the question is besides various studies points in the

direction that firms can charge higher prices for good quality why are firms not opting for the increased quality? One of the reasons according to Shetty (2001) could be lacking data concerning cost related to poor quality and a perception that there are few opportunities by which quality could improve productivity. Improving quality is often regarded as an activity which will increase cost. But, improving quality means among other things, making less faulty products, fulfilling customer demands with the same amount of effort or cost which means lower unit cost.

Cost of poor quality estimation typically excludes positive revenue effects of quality as the opportunity cost of lost sales because of poor quality as well as the future revenue effects when higher quality products and services increase customer satisfaction. Customer retention is another parameter that usually is not counted within the cost of poor quality. According to Kotler (1994) and Harari (1992) many customers find complaining expensive and instead switch suppliers upon receiving low quality products.

Ittner (2001) presents, using detailed data on defect rates and quality costs that quality improvement is highly dependent upon the proactive investment and autonomous learning by doing than reactive investment in quality. Another important reflection they made is that the cumulative investment on quality has greater impact on current period defect rates than prevention expenditures in the current year. This shows the significance of accumulated knowledge and awareness about quality than to work on quality during a single project or when a customer failure is detected.

2.1.2 Product Design and Quality Cost

Product development is a potential source of competitive advantage for all firms (Brown & Eiesenhardt, 1995). It has also significant importance for the organic growth of a company and seen as critical mean, by which organizations can adapt, diversify and reinvent to match the evolving market and technical solutions. Developing new products bear high costs, so organizations are seeking for new ways to improve the product development efficiency and effectiveness.

Literature indicates as shown in Figure 2, that up to 40% of quality costs can be traced back to product design (You, Alard, Schönsleben, & Zhu, 2009). Even though product design and development may account for only 5% of the product cost but it has a central influence of the order of 75% on manufacturing costs and up to 80% of product quality (You, Alard, Schönsleben, & Zhu, 2009). Hence quality of the product design has high impact on the overall product quality.

According to Brown and Eisenhardt (1995), product development can be organized into three streams as rational plan, communication web and

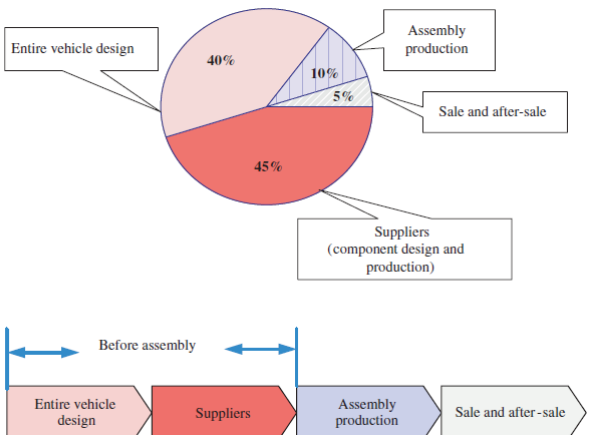

Figure 2: Total quality control in automotive production (You, Alard, Schönsleben, & Zhu, 2009)

disciplined problem solving where focus is on different aspects of product development. Rational plan focus is on very broad range of determinants of final product financial performance, communication web focus is on the narrow effects of communication on project performance and problem solving on the other hand focuses on development teams, suppliers and the development process. In order to succeed with product development, presence of gate keeper, effective external and internal communication and effective problem solving strategies are the requirements for high performing project teams (Brown & Eiesenhardt, 1995).

2.1.3 Quality Cost Model

Cost of poor quality (COPQ), are generally classified into four categories: prevention, appraisal, internal failure and external failures. Prevention and appraisal costs are collectively called conformance quality costs. These are the one that most companies would like to work with. Conformance quality costs reflect the cost of achieving certain level of quality.

Feigenbaum (1956) categorized quality related costs into four main categories: Prevention, appraisal, internal failure and external failure (P.A.F). The prevention appraisal failure model based on the cost categorization is one of the common approaches to identify and allocate quality related cost.

Prevention Costs: These are the cost aiming to reduce the possibility that an external or internal failure will occur. Typical examples of prevention costs are supplier quality assurance, design verification and quality planning.

Appraisal Cost: These are the costs to ascertain the conformance of a product to conformance, e.g. material used in testing and inspections.

Internal Failure Costs: These costs occur when a product fails to meet requirements. Such failures are identifies before the product is delivered to customer. Typical examples of these costs are: rework, scrap and delay in project.

External Failure Costs: These are the costs that occur when the failure is detected by customer. Typical examples are warranty costs, lost sales, product recall costs and customer dis-satisfaction that lead to future lost sales.

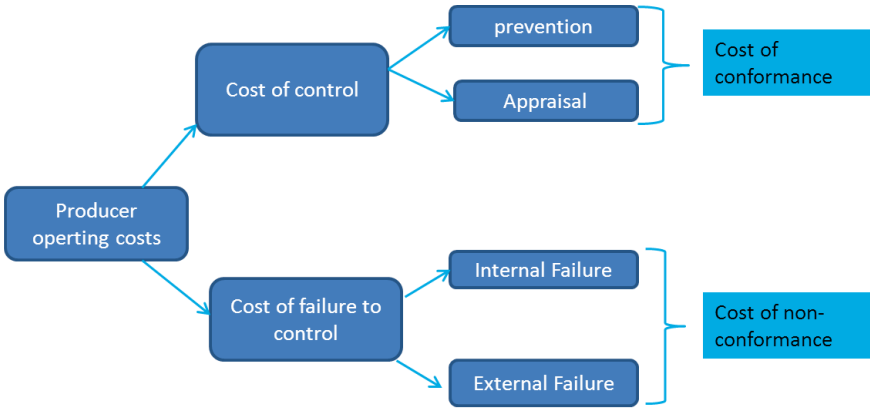

Figure 3: Cost categories according to PAF and Crosby's model (Giakatis & Rooney, 2000)

The main benefit of PAF model is that the quality related costs can be viewed at organization level and management can use as a strategic tool to process improvement. However this model does not show where the fault is and lacks efficiency to give direction how the quality or product development process should be modified (Giakatis & Rooney, 2000).

The PAF model and the Crosby's model are quite similar as shown in Figure 3. Crosby defines cost of quality as the sum of price of conformance and non-conformance. The price of conformance is the cost involved to make certain that things are done right the first time which is actually the cost of prevention and appraisal. Cost of non–conformance is actually the cost of internal and external failure. Joseph Juran went one step further to add even the tangible cost of losing customers due to poor quality (Klefsjö, 2001). The base line of the three different philosophies related to quality management is to minimize the cost of poor quality and to do things right the first time.

Giakatis and Roonney (2000) recommend use of a hybrid model. They recommends use of PAF model to identify the quality costs at macro levels and a process oriented quality cost model as IDEF0 to identify the quality costs at micro level. The process cost model focuses on process rather than products (Thomson, 2006) and is suggested as preferred model in total quality literature. It facilitates the collection and analysis of quality cost related direct and indirect functions in an organization.

2.2 Automotive Products

The automotive product can be classified into two types; market pull and market push products. Market pull are the products that are developed to satisfy a customer demand, e.g. improved fuel saving, high quality and reliability or compliance with new legislation demand. Market push products are those that a company can launch with added technology or features that can differentiate a company from other competitors in the market. During the last years many companies are gaining significant revenues from market push products as soft

products. Benefits are increased profits from existing product lines and increased customer retention rate.

2.2.1 Product Development Process

Product development is a combination of different processes which is multi-dimensional with strong links and dependencies between organization functions as marketing, engineering, finance, logistic, operations, after-market and service.

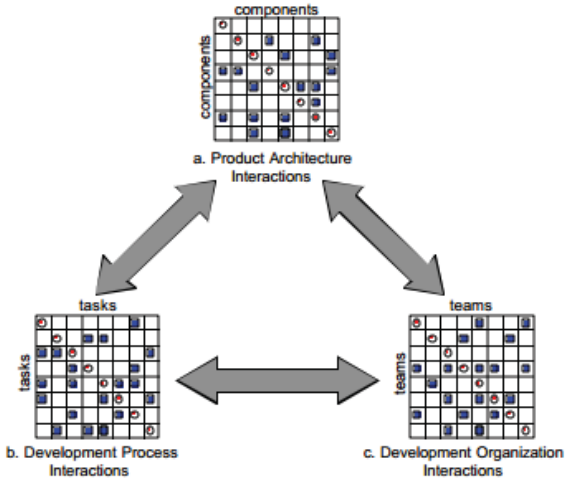

Figure 4: Product development interactions (Eppinger, Whitney, Smith, & Gebala, 1994)

The product architecture defines the product in the primary functional systems and the arrangement of how these systems work as a complete unit. The product architecture includes the system, subsystem and parts as well as the integration and interaction of these. This part is of high importance for the organization as well as product quality as it will impact a number of important attributes such as standardization or commonality of components.

Product Development is normally accomplished as a project with multi-functional project team. What kind of task to carry out and how these tasks are carried out are part of the development process and the development organization interactions. These tasks can belong to different functional group in the organizations which requires intensive communication between different groups.

Involvement of complete organization requires some rules in order to streamline individual activities. These rules are called a process or product development process as shown in figure 5. Product development process can be seen as a complex process which brings all facets of a business operation from product idea, product planning, product development, verification, manufacturing to launching the product into the market.

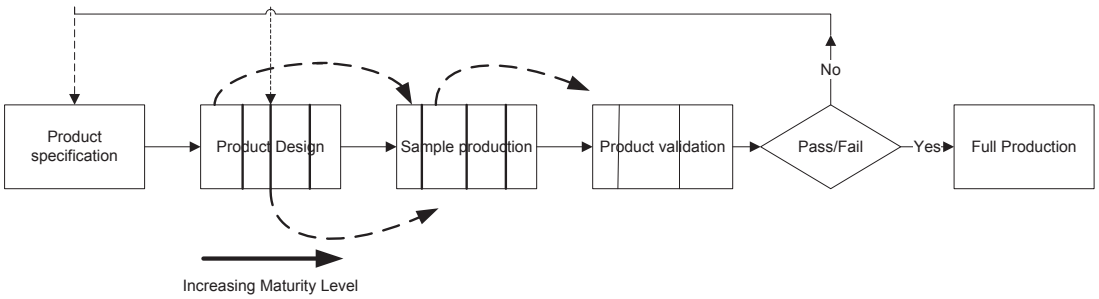

Figure 5: Traditional product development process (Aw, 2005).

2.2.2 Product Development Time and Cost

In today competitive automotive market only quality and competitive prices are not sufficient to stay ahead of competition. To sustain the competitiveness in the market, organizations must develop competitiveness to innovate, design and introduce new products to market quickly and efficiently. Increased market introduction rates also shrinks the window of opportunities to recoup the investments and bring revenue which exerts extra pressure on companies to bring products to market as fast as possible and off course with high effectiveness. Table 1 shows a comparison of a number of automotive product development goals to other industries. Decrease in product cost, product development costs and decreased product life cycles times are more important for automotive companies compared to other industries in general.

"A lot of emphasis" on:	All Respondents	Automotive
Increase product revenue	82%	67%
Decrease product cost	60%	67%
Decrease product development cost	36%	46%
Increase value of intellectual property	36%	41%
Decrease corporate risk	36%	37%
Decrease product lifecycle cost	29%	35%

Source: Aberdeen Group, December 2007

Table 1: Product development goals (Aberdeen Group, 2007)

2.2.3 Innovative Products and Quality

Innovation is important for the survival of a company otherwise new technology can make an industry obsolete (DuBrin, 2010). On the otherhand standardization of process has always been seen as important to gain higher efficiency and effectiveness (Taylor, 1911; Ohno, 1988). Standardized processes can't be effectively used on innovative products since companies are generally missing process and procedure to develop or manufacture this kind of products.

If the technologies used in innovative product are unknown both for the production facilities and development team it can create disturbances in the quality. Innovative products, therefore can disrupt the continuously quality improvement as in a mature product which makes quality securing work more difficult.

Integrating information or by sharing information, ideas, product knowledge to other parts of the organization the quality and innovativeness can be improved (DuBrin, 2010). Different parts of the organization have possibilities to get both different inputs and views about the product that should be developed. By not having information integration different commodities can pull the project in different directions with different focus areas and the end product quality may not be as expected.

Quality strategies	Innovativeness Strategies
Exploitation of existing certainities	Exploration of new possibilities
Standardization using best practice guidelines	Deviating from standards, experimenting with prototypes
Improving quality is important but not enough	Innovation is must for early follower

Table 2: Process requirements with focus on innovation or quality

2.3 Lean Product Development

The core idea of Lean is to maximize customer value by elimination of waste. The overall framework of Lean is to "*do right things*" as well as "*do things right*" (Hugh, 2005). Originally, lean was regarded to be relevant to the manufacturing where focus is on waste reduction in material supply, components production, delivery of products and information flows.

The just-in-time (JIT) production system has received considerable attention and been behind the success of automotive companies as Toyota. Major benefits of JIT as inventory reduction, quality improvement, waste reduction and quick delivery are well known (Cook & Rogowski, 1996). Through the successful implementation of JIT methodology companies have dominated their competitors not only in lower price and better quality but also in the areas of innovation, design and fast new product development (Blackburn, 1991; Fujimoto & Clark, 1991).

Meybodi (2005) demonstrates that there are similarities between JIT (which is a generic form of lean) and parallel or concurrent product development. Main principle of lean as waste elimination and individual respect is fully valid in product development. Waste according to Oppenheim (2004) is defined as anything other than the minimum required for mission assurance. Waste elimination in manufacturing has been achieved by pull production system, flexible resources, short set-up times and small batches.

Looking on differences between manufacturing and the product development, one can say that information and knowledge flow in product development can be

compared to material flow in manufacturing. Material flow is easy to follow on factory floor since it is something physical where its movement can be easily measured and used to process improvement. On the other hand information and knowledge flow are quite difficult to locate since information can stay at different places at same time. Elimination of the waste that occurs during its transmission can be used for engineering process improvement.

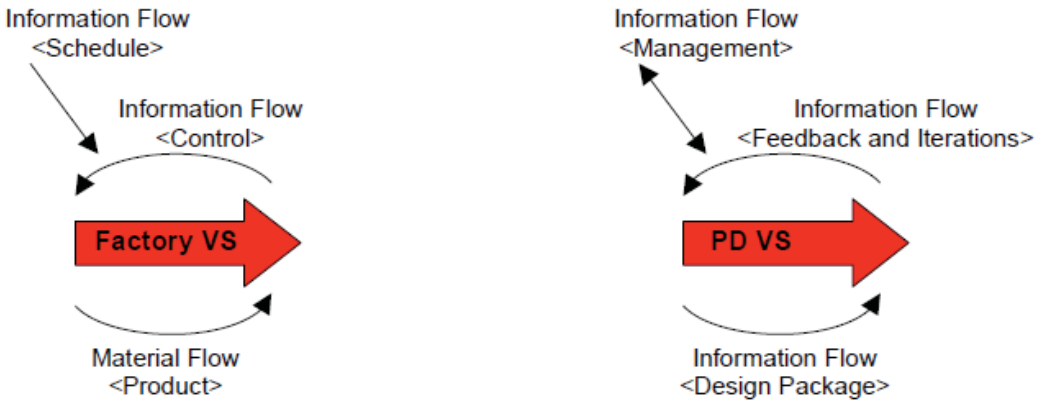

Figure 6: Analogies value stream in product development and factory (Hugh, 2005)

Comparing further product development to manufacturing one can say transportation in product development can be hand-off and reformatting the input and output information. This kind of waste occurs quite often in international as well as de-centralized organizations where standardized procedures or working method are not used or are not available. This may not be an issue in small localized firms.

Other defects in product development can be creation of defective information which can't be verified until later stage or until next activity is performed. Most companies produces huge amount of information from field, customer experience as well as product development knowledge but usefulness of this information is limited if information is not available at right time, right place and in right format.

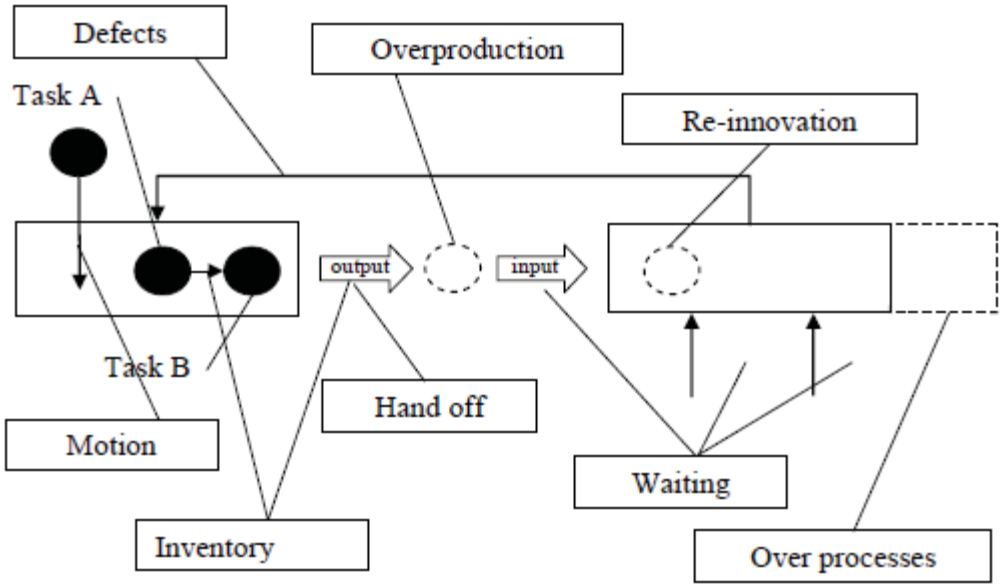

Figure 7: Waste in product development (Wang & Wang, 2012)

Solution to some of waste activities in product development according to Meybodi (2005) and Wang & Wang (2012) are flow of small pieces of information, cross-functional teams, parallel information flow in organization and human resources with broader knowledge base or knowledge flexibility which could lead to higher product development performance and productivity.

2.4 Knowledge Based View Theory

According to Resource based view theory (RBV) A firm can earn sustained above normal returns on investment if and only if the firm have superior firm specific resources (superior resources are valuable, rare, imperfectly mobile, inimitable and no-substitutable) and capabilities. This theory emphasizes properties of firm resources and in particular distinguishes between tangible (peoples, machinery, capital) and in-tangible or knowledge-based resources (Rodan & Galunic, 1998). Knowledge based resources are the capabilities and ways in which the tangible resources are converted into desired outputs, i.e. employee's knowledge, experiences and skills, organizational procedures and actions.

In knowledge base theory which can be seen as extension of Resource Based View (RBV), attention is shifted from tangible to differentiation of intangible resources. According to this theory the Intangible assets may be more important from a strategic point of view, since they bring together the requirements necessary for producing sustainable advantage: to be valuable, rare and difficult to imitate and replace by competitors (Barney, 1991).

A firm's stock of knowledge (tacit or explicit) is a strategic resource and an important determinant of its competitive success (Nonaka &Toyama, 2003). High stock of qualified human capital with advanced technical skills, know-how in R&D projects, and risk taking propensity increases the probability of a firm to carry out

innovative activities (Song, 1997). Therefore, a firm working with innovative products should not only be able to create knowledge within their boundaries, but they must also expose themselves to external environments to receive new ideas that in combination with in-house knowledge can innovate new ideas and products. This will also encourage innovative behavior and to check own technological developments against those of competitors.

2.4.1 Knowledge Gap in Product Development

Knowledge gap is defined as the knowledge which a firm currently lacks but has been identified critically important for its survival and growth and hence needed to be filled (Haider, 2003). Further there are four kinds of knowledge gaps that can arise in an organization: product development, manufacturing, selling and management (Vos, Keizer, & Halman, 1998). In this thesis only the knowledge gap in product development will be considered.

There are two contradictory forces acting in product development (Olsson & Hansen, 2011). One is input to production processes and the other input to decision process. Production processes may seek early decision and decision process typically strive to delay final commitments in order to keep options open.

Figure 8: Information to take decision

Knowledge gap lead to uncertainity in a project, which is described as the gap between the amount of information needed to perform an activity and the information processed by the organization at this time. This uncertainty can be reduced by by identifying the type and filling of knowledge gaps. Furthermore, there are three types of knowledge gaps in product development (Jiangnan, Zhiqiang, & ChuangLing, 2014) as

1. Containing type: in this type of knowledge gap can be filled through knowledge adjusting or self-learning based on current knowledge.
2. Intersection type: In this type of knowledge gap a part of the knowledge needed is available or possessed by the organization. However this is not sufficient to meet the need.
3. Separation Type: In this type of knowledge gap there is no knowledge available in the firm. Hence the firm will need to acquire the knowledge from outside.

The knowledge gap reduction of first two types can be effectively done by using the already available information from previous project, market or other parts of organization butcompany need to buy knowledge externally to fill the separation type of knowledge gap.

2.4.2 Knowledge Conversion in organization: Sharing and Creation

There are four different "modes" of knowledge conversion: (1) tacit knowledge to tacit knowledge, (2) explicit knowledge to explicit knowledge, (3) tacit knowledge to explicit (4) explicit knowledge to tacit knowledge (Nonaka, Byosiere, Borucki, & Konnot, 1994). The first mode of knowledge conversion is through interaction between individuals as apprentices work with mentors, learn craftsmanship by observation, imitation, and practice and in organization on job training are some typical examples. This process of creating tacit knowledge through shared experience is called "socialization". The second mode of knowledge conversion involves the use of social processes to combine different bodies of explicit knowledge held by individuals in an organization. Individuals exchange and combine knowledge through such exchange mechanisms as meetings and other form of conversations. The reconfiguration of existing information through some form of sorting, adding, and categorizing of explicit knowledge can lead to new knowledge. This process of creating explicit knowledge from explicit knowledge is referred to as "combination" (Nonaka, Byosiere, Borucki, & Konnot, 1994).

Third and fourth mode of knowledge conversion involves both explicit and tacit knowledge. These conversion modes capture the idea that tacit and explicit knowledge are complementary and can expand over time through a process of mutual interaction. This interaction involves two different operations. One is the conversion of tacit knowledge into explicit knowledge, which is called "externalization" and the other is the conversion of explicit knowledge into tacit knowledge, which is called "internalization" or "learning".

Organizations are using different ways to collect and make available tacit knowledge within organization. Some companies uses knowledge documentation to collect the tacit knowledge and make available these documents for the employee. Japanese firms have used on-work training where the knowledge is spread within groups and method is called learn-by-doing. Learn-by-doing can be an effective method but may due to cultural backgrounds have not been used in western companies (Nonaka & Toyama, 2003). Western companies has relied more on spreading this knowledge through documentation instead.

Since the tacit knowledge is difficult to codify it could also be difficult to detect and get documented. Nonaka and Takeuchi (1995) proposes alternative means to transfer tacit knowledge as socialization, job rotation as moving peoples possessing tacit knowledge to different areas in the organization. Socialization and combination of people possessing tacit knowledge in the organization could be beneficial for innovation and will ensure higher effectiveness of knowledge transfer (Nonaka & Toyama, 2003).

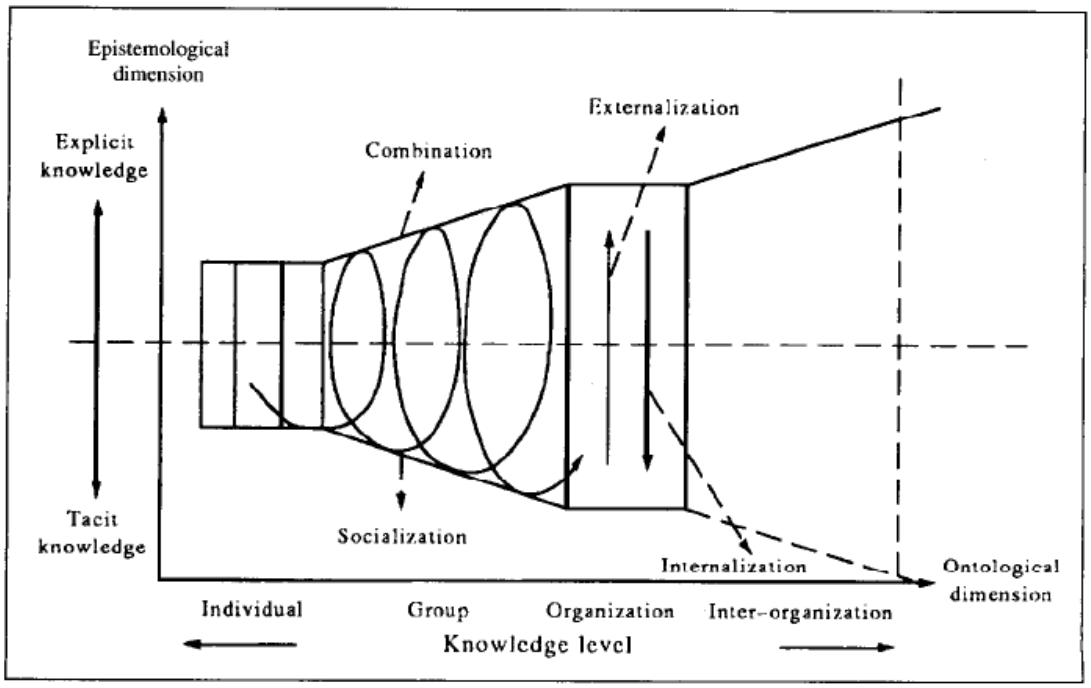

Figure 9: Knowledge creation spiral (Nonaka, Byosiere, Borucki, & Konnot, 1994)

2.5 Front-End In Product Development

Cost, time and quality as mentioned previously are important parameters to project success. Market competition, shortening product development life cycles and legislation requirements forces automotive companies to convert new technologies into new products as fast as possible. So the companies are looking for different strategies to reduce development costs, shorten the product development times while keeping the focus on quality requirements.

Generally product development in automotive companies is taking place in project form, as shown in Figure 10. Time before a project enters development stage is called "*front end of innovation*". Front end is regarded as most troublesome phase of the innovation process but also with lot of opportunities to improve the overall innovation performance of the company (Kleinscmidt, Cooper, & Edgett, 2004; Thomke & Fujimoto, 2000; Martinsuo & Poskela, 2009). According to (Kleinscmidt, Cooper, & Edgett, 2004), only 24% of the best performing companies (based on investigation of 105 product development US companies) executed well the front end of projects.

What are the possible causes or why companies not execute well the front end activities? One of major cause identified by (Kleinscmidt, Cooper, & Edgett, 2004) is that the line organization management becomes involved just after the development process starts (Kleinscmidt, Cooper, & Edgett, 2004; Martinsuo & Poskela, 2009). Line organizations are not involved could be due to not having sufficient resources (Repenning & Black, 2001) in the front-end but consequence of this will be less control over the technological solution chosen in the front-end.

Where wrong technological choice made in this phase may require higher number of resources during project life.

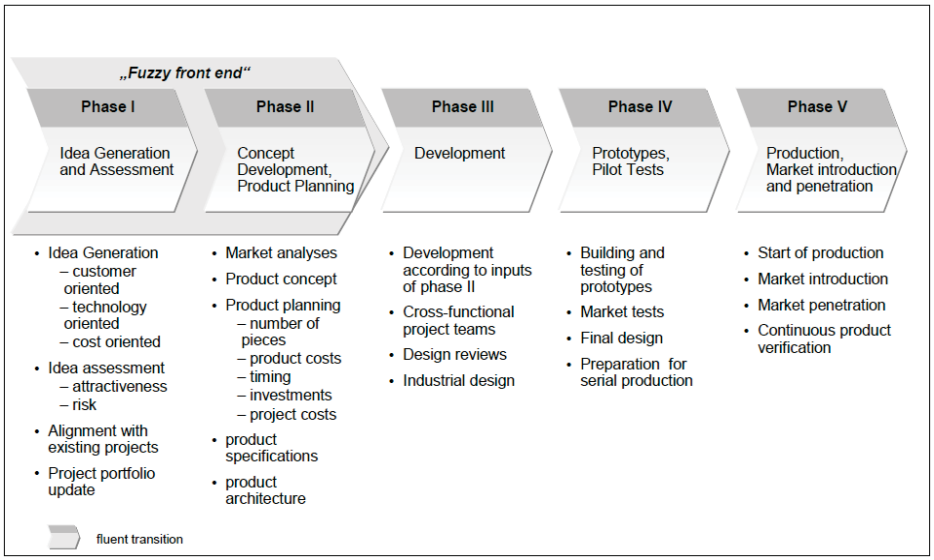

Figure 10: Product development cycle (Varworn & Cornelius, 2001)

2.5.1 Front Loading Strategy

Product development can be seen as disciplined problem solving iterative process with each problem-solving process consisting of design, build, run and analysis activities. To speed up the development process it is important to find and solve the problem as early in project life as possible. This will also lead to lower project costs since costs of the solution to problem found in beginning of project are much lower than the one found at later stage.

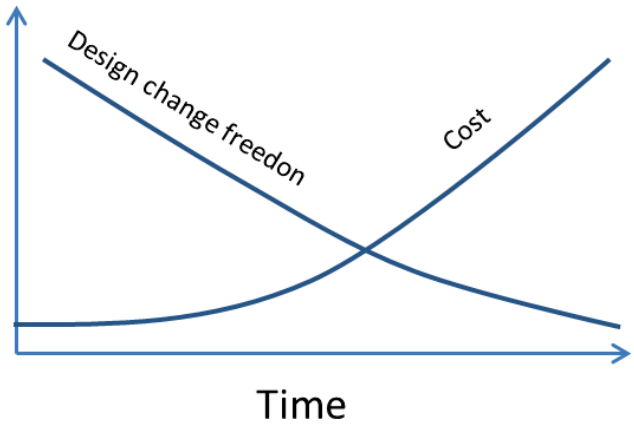

Figure 11: Cost and design change relation in product development.

2.5.2 Simulation Role as Front Loading Strategy

Simulations are an effective approach to rapid problem solving. Simulations tools ability to have several iterations in short time compared to any physical build

reduces number of variants and uncertainty in project. Instead of creating physical prototypes and tests simulation tools can be used to verify the requirements at a fraction of cost and time compared to build prototypes for testing. One good example is crash prototyping in automobile sector.

In automotive industry crashes are important to understand how the impact will be on a car or truck during collision. But by replacing some of the actual crashes and using simulations instead can lowers the cost and time for development of new products. By making small changes in the design the engineers can simulate the behavior and make corrections to the actual product. Fujimoto & Thomke (2000) argue that the innovativeness can be higher when there is a possibility to test the novel ideas at a cheap price without performing actual tests on real prototypes.

Time saving by using simulation tools instead of physical prototypes is shown in Figure 12. Development time can be squeezed significantly if the simulation tools are used first to study most of the interactions and then make a physical test to verify the simulations results. This time earned can either be used to come up with new ideas that can improve the quality further or shorten the project time and cost.

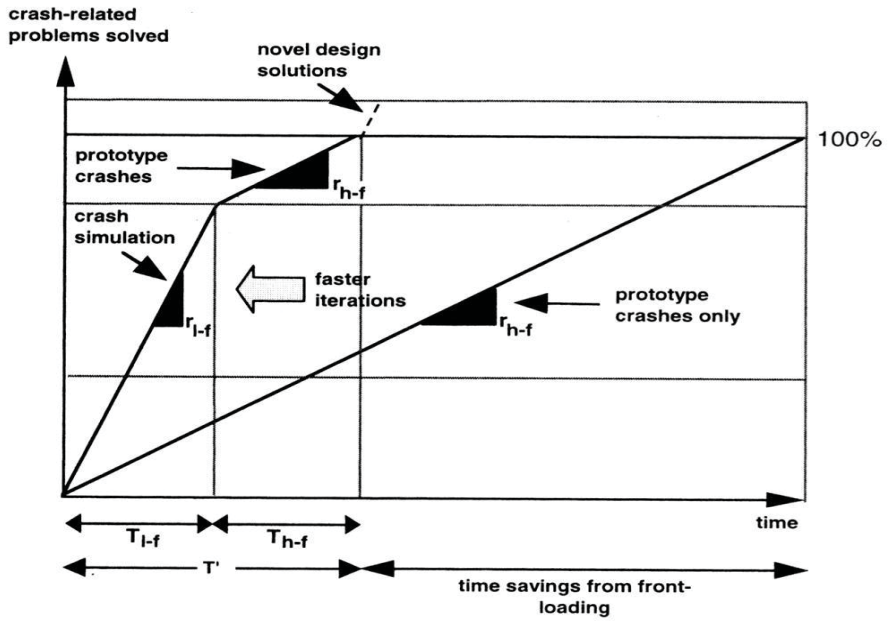

Figure 12: Front-Loading problem solving using simulation tools (Fujimoto & Thomke, 2000).

There are some limitation using simulation approach depending upon the type of problem. (Aggeri & Segrestin, 2007) proposed to split the general product development problems into four categories depending upon the type of problem and the possible solutioin strategy the require. Simulation according to Aggari & Segrestin (2007) can be succefully used for the cases when the underlying problem is not related to innovative products. Solution to the problems related to innovative product are asking for collective learning process or conitnual exchange of knowledge between experts.

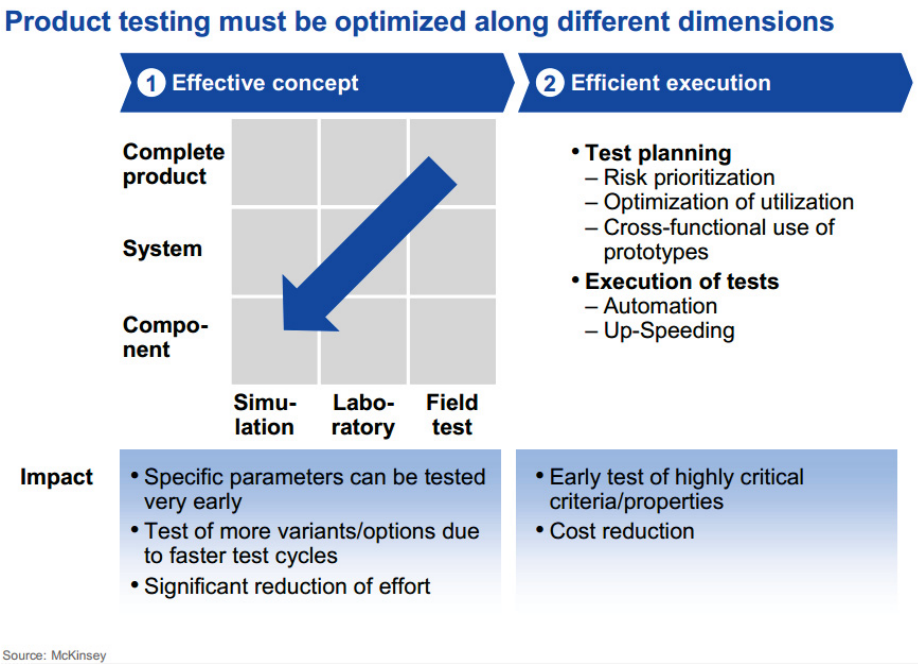

Figure 13: Simulation roles to reduce development time (McKinsey, 2010)

2.5.3 Innovative Products and Front-Loading

When a new product is created from scratch or heavily reworked the main problem for the organization will be the lack of knowledge about it and what consequences the early decision will have for effect. During the early phases of the project the concepts are chosen, budget created and the work is planned. But it is lack of knowledge is the greatest at this stage. By implementing a front load strategy in this type of project, it is not certain that the full effect will be achieved.

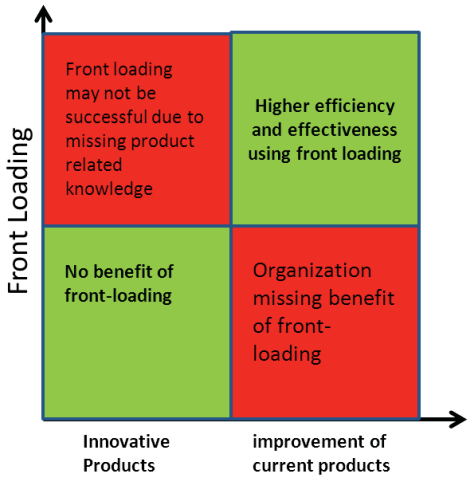

Figure 14: When to use frontloading

The design problems and issues might not be discovered due to missing previous information about the problems that may occur. But if the product is in a rather steady state and the organization is mature it will have knowledge from earlier projects and development that can be used together with a frontload strategy to find issues earlier and reduce resource wastage and time (Aggeri & Segrestin, 2007). The innovative project should be used to teach the organization the product so that the knowledge can be reused later and the management should be responsible for finding gaps in the knowledge during the process.

2.6 Theoretical Framework

Product development is a complex process with multiple interactions among suppliers, manufacturing, sales, purchasing, verification and product design and development. Literature in the field of quality management, group psychology, operational management and innovation, as discussed above, indicates that the effectiveness of the product development strongly influenced by knowledge creation, knowledge sharing and knowledge dissemination, knowledge gap, time and cost pressure and the type of products: innovative or mature. Furthermore, these product quality influencing factors are influenced by organizational factors as cross functional teams, knowledge sharing strategies and operational strategy to infuse existing knowledge back into the product development process. Building effective teams together with information integration and project requirements has been seen as primary factor that positively influence project success (Bloch, Blumberg, & Laartz, 2012;Pearson D. J., 2002).

New product development (NPD) as mentioned in above sections is a complex process with inherent uncertainty. Uncertainty arises due to the intangible and complex nature of the process (Fredericks, 2005). As uncertainty increases, functional expertise, divergent knowledge, skills, and abilities are required to resolve challenges. Success in reducing uncertainty will depend upon communication, information sharing and involvement among team members (Gupta, Raj, & Wilemon, 1987). Focus of the team members in such a team is on creating common understanding by carefully attending, one another's perspectives, freely questioning and challenging these perspectives and underlying perceptions (Sethi, 2000). The knowledge diversity in such a team will help team to discover superior ideas to find solution to customer needs (Sethi, 2000; Fujimoto & Clark, 1991). Diverse knowledge from different areas of product development development will lead to faster communication and create consistency in decision making regarding the product.

Innovative products ask more for collective learning process or conitnual exchange of knowledge between experts than incremental improved products (Aggeri & Segrestin, 2007). Organizations needs to use different product development strategies based on the product type, innovative or mature products as shown in Table 2. Innovative products require more generative learning which is more akin to reorientation to deep structure, thought and processes. The Existence of diverse knowledge base in cross functional teams will affect innovative product development in a positive way by filling the knowledge gap or by increased rate of learning new competencies (Brombacher, Sander, Sonnemans, & Rouvroye, 2005; Sethi, 2000; Fujimoto & Clark, 1991).

Product design is of fundamental importance for product quality and cost. Even though product design and development may account for only 5% of the product cost but it has a central influence of the order of 75% on manufacturing costs and up to 80% of product quality (You, Alard, Schönsleben, & Zhu, 2009). Early involvement of cross functional team with diverse knowledge will help to

understand project requirements, increased chances of improved communication and coordination that can even mitigate the effect of innovation, project cost and time (Sethi, 2000).

There are some limitations of the cross functional teams. Individual with expertise from different functional areas have generally different ideas about a product. Without proper information integration, these individual will generally pull the project in own preferred direction which may adversely affect product quality (Fujimoto & Clark, 1991). Project will run smoother when team members understand each other's responsibilities and share information (Fredericks, 2005).

Some automotive companies have dominated their competitors not only in lower price and better quality but also in the areas of innovation, design and fast new product development with implementation of lean manufacturing to eliminate waste (Blackburn, 1991; Fujimoto & Clark, 1991). Waste elimination in manufacturing has been achieved by pull production system, flexible resources, short set-up times and small batches. Product development according to Meybodi(2005) and Wang & Wang(2012) has similarities as moving small pieces of information, cross-functional teams, parallel information flow in organization and human resources with broader knowledge base or knowledge flexibility. Concurrent engineering which largely is about parallel problem solving in cross-functional team environment has been seens as an effective process to shorten lead times and to avoid late design changes (Fujimoto & Thomke, 2000). Fujimoto & Thomke (2000) proposes two approaches project-to-project knowledge transfer and rapid problem solving to enhance efficiency of the product development. Supplier integration or involvement in the design phase may also lead to reduced cost of and number of design changes (Aggeri & Segrestin, 2007).

Flexibility in product, related processes and resource knowledge are essential to achieve a lean product development organization (Olsson, 2006; Olsson & Hansen, 2011; Kaeter, 1993). Many automotive companies have achieved increased manufacturing flexibility by adopting platform strategy which allow production of different products on same line, reduce cost and lead times and increase rate of re-use of components. By doing this also the workforce have been transformed into a higher flexible workforce by broaden their skills to be able to cope with their new work environment.

This transformation is also possible to do within product development where the engineers learns more skills within development and are able to take on a broader variety of tasks and this leads to higher responsiveness in an organization. According to Kaeter (1993) this will lead to higher productivity, flexibility, quality and morale. Dalton (1998) showed that on one specific company, Ralcorp could show improvements in overall output, defects, yield and downtime by 30 to 40% by implementing multi-skilled and flexible workforce. One way of creating a flexible workforce is to implement job rotation. Job rotation will support development of

informal communication channels, coordinate the flow of work across boundaries and support socialization within the organization (Hoyt & Matuszek, 2001).

However, concerns are also raised to that the organization fosters generalists and not specialist and that this can have an impact on high-tech organizations where complex problem solving is needed. It can also have a negative impact on the career goals for employees that strive for a career as a technical specialist instead of generalist (Hoyt & Matuszek, 2001).

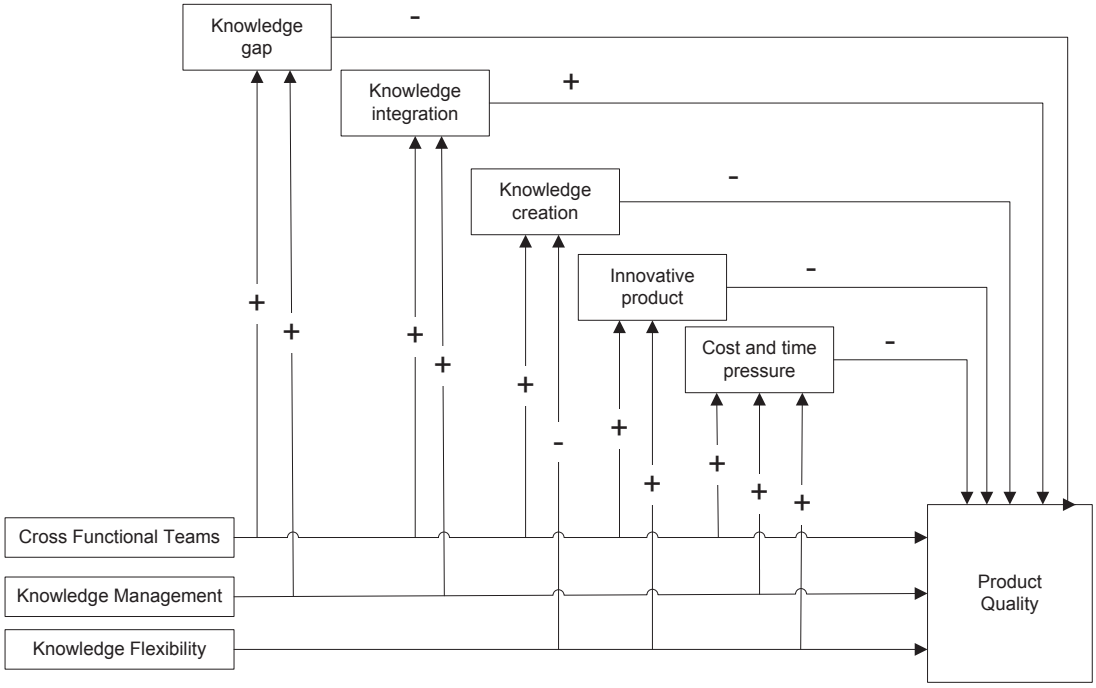

Figure 15: Conceptual Model.

A conceptual model based on literature review is shown in Figure 15. Five main factors that affect product quality are defined. Furthermore, literature studies led to identification of three factors namely: cross functional teams, knowledge integration and knowledge flexibility which can reduce the adverse effect of five product quality affecting factors. Plus and minus signs are if the factor has a positive or negative effect on the influenced parameter as:
Knowledge gap have negative influence on the product quality. Cross functional teams and knowledge integration have a positive effect to decrease knowledge gap. Product quality will be affected in a negative way if product development is missing knowledge or knowledge creation is required. Both cross functional teams and knowledge management will influence positively the knowledge creation process hence will lead to improved quality. On the other hand knowledge flexibility or shallow knowledge in many fields will not help knowledge creation process since knowledge creation process needs expertise knowledge.

3. Methodology

According to Yin (2009), a case studies research form supports deeper and detailed investigation when it is necessary to answer questions as “how” and “why” a certain outcome is more evident. This research form goes deeper, can take into account large number of parameters and is good for contemporary events than any other research form. This chapter will introduce reader to the research methodology used in this thesis. Chapter starts with research philosophy, research approach, research method and ends with introducing the research questions and data collection. So the chapter layout is based upon the logical procedure recommended by Yin (2009) as plan, design, prepare, collect, analyze and share.

3.1 Why Qualitative Research

Qualitative research is characterized by its aim to understand underlying reasons, motivations and collect in-depth information of some aspect of social life (Yin 2009). Qualitative methods aim more to understand the experience, attitude and perception in terms of “what”, “why” and “how” rather than “how many” or “how much” which is generally in focus for the quantitative research methods.

Research subject in this thesis looks for indicators of product development efficiency and effectiveness and concentrates on suggesting possible improvements while producing new insights and knowledge. Qualitative research is suitable when as in this case research questions concerned more with the process than outcome (Rubin & Rubin, 2012; Yin, 2009; Ghauri & Grönhaug, 2002). Other benefit of qualitative research is to look at the participants in natural settings and allow the researchers to bring in own experiences and deep understanding in the subject (Rubin & Rubin, 2012). Own experiences together with feeling, perceptions and ideas of the participants provides evidence in qualitative studies.

So the focus in this thesis is to understand cause, why and how “cross-functional teams”, “knowledge flexibility” and “information integration” affect quality and cost in product development and why implementation of these factors in the beginning of a project will improve the product development process. So the outcomes of this thesis are not expected in the form of “how much” percent product quality will increase by implementing e.g. information integration in projects but to get understanding of why and how these factors affect quality.

3.2 Research Philosophy

Research philosophies differ on the goal to research and how this goal should be accomplished (Rubin & Rubin, 2012). There are two type of research paradigm in literature to verify theoretical propositions namely positivism and naturalism. Positivist claims that there is single objective reality that can be measured without bias using standardized instruments. Naturalists on the other hand claim that reality

exists but it can't be measured directly but perceived by different peoples in different ways. Perception of what reality is can be dependent of cultural background, knowledge and prior experiences. We can say that positivism stands for objectivity, predictability, controllability and measurability focusing more on quantitative research methods. On the other hand naturalism emphasizes more on understanding, interpretation and meaning out of a process focusing on qualitative research methods.

The factors affecting product quality and related cost to achieve that quality level are perceived differently by different person in the same organization. A person working at lower hierarchical level may see information integration most important since he or she is directly impacted of the available information. On the other hand person working in projects may see cross-functional teams as important parameters to fill knowledge gaps, improve quality and reduce development cost. However almost everyone in a company will be aware of the fact that quality should be improved while cost has to be decreased in order to be competitive. Since the realities are multiple, the variables are interwoven or difficult to separate and causes from effects are difficult to distinguish, we believe a naturalist approach will be most suitable. A naturalist approach will help us to understand in depth the effect of cross-functional teams, knowledge flexibility and information integration on product development.

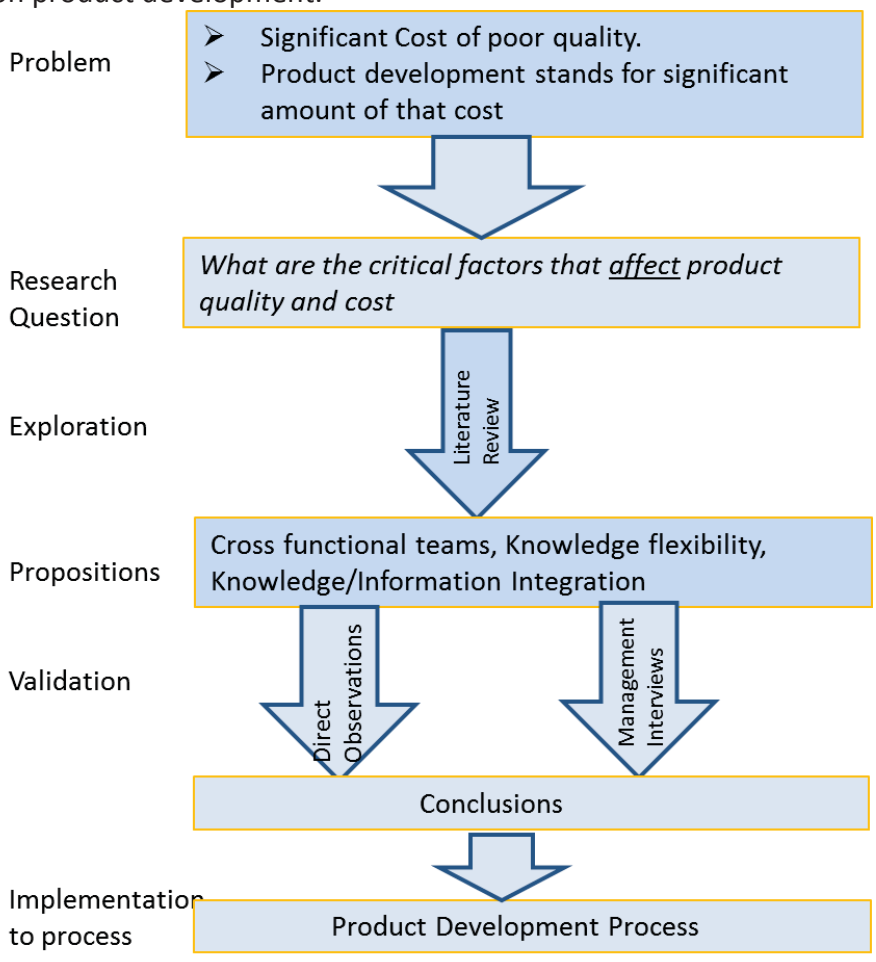

Figure 16: Thesis Approach

3.3 Research Approach

Another important parameter to carry out research in social life sciences is research method of reasoning (Hyde, 2000). There are two broad types of research methods of reasoning: deductive or inductive. The main difference between them is that the deductive approach starts with developing a hypothesis based on existing theory and then testing the hypothesis through observations. This is also termed as top-down approach where conclusions are drawn from the available facts in relation to theoretical models. The inductive approach on the other hand starts with a set of observations which moves towards more abstract generalizations and ideas.

The research approach in this thesis is based upon the deductive approach. The abstractions and hypothesis in this thesis are developed from the existing theories in the field of quality, strategy, knowledge management and resource based view. Three important factors are identified as cross functional team, knowledge flexibility and information integrations which can significantly affect the product development. Another reason why an inductive approach cannot be used is the lack of data from product development organizations. Even if data existed it will be mostly for internal use because this subject touches the product development processes and strategies which is generally confidential information.

3.4 Research Design

According to Yin (2009) the case study method is the preferred strategy when "how or "why" questions are being posed and when the investigator has little control over events. Case study method can in fact be used in all type of research designs as exploratory, descriptive or explanatory (Yin, 2009; Ghauri and Grönhaug, 2002). The research design depends upon the research questions and the research objectives.

Exploratory research design is used when it is important to understand a problem in depth. Initially it will starts with a broader formulation and problem view gets smaller as progress is made. Descriptive research is designed to provide systematic and accurate description of a social phenomenon. This kind of research is usually directed toward understanding question as “what” where researcher starts with collecting data and then develop a hypotheses. Explanatory research starts to understand possible cause of a social phenomenon that means researcher develop a hypothesis before collecting data where research try to explain how parts of a phenomenon are related to each other (Saunders, Lewis, & Thornhill, 2009).

Main objective of this thesis is to understand what are the key parameters that affect product quality in product development organization and the second “how” or “why” implementation of these will lead to improvements. Therefore an exploratory approach will be most suitable for this case. One way to find support for

this kind of explorative study is to interview experts in the field and people involved in company's strategy formulation (Ghauri & Grönhaug, 2002;Rubin & Rubin, 2012).

Research strategy in this thesis is based upon naturalist paradigm, qualitative research, deductive reasoning method and exploratory research design. Interviewing the experts in area and participant observation will be most suitable to verify the theoretical propositions.

3.5 Content Validity and Reliability

Reliability and validity questions in qualitative research are assocoiated with how reliable and valid the researcher's data collection and analysis are. Reliability can be seen as a quality concept to create understanding for the conducted research that it is credible and that the findings in the research have consistency, applicability and dependability (Stenbacka, 2001) ; Golafshani, 2003). Validity is the trustworthiness of the research which can be tested and verified leading to the generalization of the result. Internal validity refers to the approximate validity with which we infer that a relationship between two variables is causal. External validity refers to the approximate validity with which we can infer that the presumed causal relationship can be generalized across different types of persons, settings, and times.

Choice of research methods that ensure that the data recording is accurate and the interpretations of data are empirical and logical is important to increasing reliability and validity in qualitative research studies (Morse, Barrett, Mayan, Olson, & Spiers, 2002). Collecting data from different sources which is also called data triangulation is a method to ensure validity of qualitative research (Yin, 2009). The validity of this research is ensured by data triangulation using different data sources as in-depth literature review, semi structured interviews at two automotive companies and direct observations. To ensure efficient and effective saturation of data, participants that have deep knowledge of research topic were chosen for the interviews (Morse, Barrett, Mayan, Olson, & Spiers, 2002). To further improve the credibility of this study both member checking and peer reviews are used. Three participants were contacted to check if the outcomes stated in the thesis matches with what has been said. Besides that all interviews were recorded on mobile phone.

3.6 Data Collection

According to Yin (2009), multiple data gathering techniques can be used to ensure validity of a case study. Multiple sources of data can increase the validity of a study. The finding of the case study will likely to be more convincing and accurate if it is based on different sources of information. Data sources according to Yin (2009) can be documents, archival records, survey, direct observations, and open-ended, structured or focused interviews. Experts' interviews and direct observations have been the main sources of data to ensure validity of this cases study.

3.6.1 Interviews

Following the systematic replication logic as proposed by Yin (2009) participants from management, project manager and team leader positions from two different companies were chosen to conduct interviews. In general interviews resemble to some extent the everyday conversations people have but they can be focused (to a greater or lesser extent) depending upon the researcher's needs for data. Interviews are called focused when one is following a set of pre-defined questions in relation to the research questions.

In this thesis interviews are performed in a semi-structured way. This form of interview lets participants to explore even other ideas however focus is always on the subject under discussion. Participants were informed about the subject in advanced. Most of the interview took 45 minutes to one hour.

The focus of selecting interview participants was to achieve maximum depth and richness of the data to address the research questions. Individual engineers are not involved with the strategies or process modification so the focus was more to interview individual who are aware of the field as lean, knowledge management processes, strategy and quality. However, open-ended conversations with some of the engineers besides interviewees have given important insight into problems like missing product or market information. For this study total 7 interviewees from two different companies with global operations and from different organizational levels were selected as shown in Table 3. A list of question is prepared to assist conducting interviews successfully. These questions were sent through Emails to participants prior to meeting so that participant is prepared to discuss the subject in depth.

Organizational Position	Product development experience
Department Manager	Over 35 years. Group manager, project manager
Requirement Manager	27 years. Group manager
Senior advisor	36 years, department manager, group manager
Senior quality advisor	35 years, group manager, project lead
Project Manager Quality	25 years, project lead
Technical specialist Verification	23 years, Verification, Software development, Project lead
Process Manager	15 years, Process development, Software development

Table 3: Interview participants

The interview participants are from two automotive companies with different roles within the companies. All participants have long experience from management and project leadership roles. To get depth into the study employee from quality department, line, requirement writing, project management and verification in order to study this subject in depth.

3.6.2 Direct Observations

Direct observation as a source of empirical evidence can contribute to the development of a strong case study (Yin, 2009; Jack, 2008). Direct observation provides an additional opportunity for researchers to interact with participants and participate in activities. Direct observation may involve activities as meeting observations, side-walk activities, factory work or open-ended conversation.

Some of benefits of direct observations are that they provide insight into the taken-for-granted aspects of everyday activities that may go un-reported by participants. This gives the researcher direct experience of the phenomena being studied, and creates an opportunity to see and hear what is happening in a social setting rather than focusing solely on narrative descriptions of participants (Silva, 2004). Authors of this thesis have long experience from automotive product development which helps to explore the subject in depth. Authors have been involved in quality revisions as well as involved in product development to solve the quality issues. This role gave opportunity to understand the limitation that product development engineers faces.

3.7 Analysis Method

Data analysis according to Yin (2009) consists of examining, categorizing, tabulating or recombining the evidence to address the initial propositions of a study. Data analysis according to Glesne (1999) involves organizing what one has seen, heard and read in order to make a sense of what one has learned. There are five different analysis techniques: pattern matching, explanation building, time series analysis, logic-models and cross-case synthesis Yin (2009). The first four techniques can be used to analyze both single and multiple case studies while the last one can only be used for multiple case studies.

Pattern matching logic is one of the most desirable validation techniques in case study research Yin (2009). The analysis method is useful for both descriptive and explanatory researches where a predicted pattern is matched with an empirical pattern. The expected pattern in this research is drawn from existing literature and is compared to the pattern from the collected interviews response and direct observations.

Analysis process requires sorting data in order to filter it and discard irrelevant data, select the one relevant to study and display in right format, create explanations, and look for patterns that validate the propositions. Data in this research is sorted and displayed in tables sorted related to three factors that according to in-depth literature review has significant effects on product quality.

Interviews are conducted at two companies with global operations working in automotive field. Product development methods and procedures used at these companies are similar. Hence, we can consider this thesis as a single case study. Six

out of seven interviews were recorded and notes were taken during all interviews. Data from the interviews was added to Microsoft Excel work sheet which was further rearranged into categories answering the questions related to the variables from the conceptual model. All the important pieces of original interview data are presented in this report.

3.8 Ethical Considerations

We endeavor to ensure through this research to treat with respect all participants and information they have provided. We preserve all confidentiality and anonymity as the aim of this research is only for education purposes. We intended to be honest and open through this whole exercise of collecting data and during interaction with the participants by explaining aim of this research and the way the information they provide will be used.

4. Empirical Findings

This Chapter will present the empirical data gathered from the semi structured interviews. Chapter will start with presenting information about the companies and choice of interview participants.

4.1 Case Study Company A

The first company chosen for this case study is Volvo Group Truck Technology which is part of the Volvo Corporation. Volvo Group Trucks Technology's responsibilities within Volvo group are:

- Product Planning
- Project & Range Management
- Complete Vehicle
- Volvo Group Advanced Technology & Research
- Volvo Group Powertrain Engineering
- Vehicle Engineering
- Volvo Group Purchasing

Volvo is a multinational automotive manufacturing company headquartered in Gothenburg, Sweden. Volvo was established in 1915 as a subsidiary of the Swedish ball bearing company SKF. In 1924, Assar Gabrielsson, a SKF sales manager and engineer Gustaf Larson decided to start construction of cars. The first car left the factory in 1927 (Volvo Group, 2013) which can be seen as beginning of what Volvo is today. The first truck is then manufactured in 1928 and this is today one of the main products. Principal activities today are production, distribution and sales of trucks, buses and construction equipment.

Figure 17: Volvo Group Operations (Volvo AB, 2014)

Over the years, Volvo has bought several other companies to have a full range of commercial automotive products. In 1999 Volvo sold manufacturing and development of cars to Ford and becomes a company focused only on the diesel engine and its applications. Volvo portfolio today consists of brands like MACK trucks, Renault trucks, Nissan Diesel, Eicher trucks, Volvo buses, Volvo construction equipment and Volvo Penta on the marine applications side. Volvo expected truck sales for 2013 are 250000 (Volvo Group, 2012).

Quality, safety and environmental care are Volvo's three core values. Volvo quality focus is expressed as "Our *goal is to exceed their expectations. With a customer focus based on everyone's commitment and participation, combined with a process culture, our aim is to be number one in customer satisfaction. This is based on a culture in which all employees are responsive and aware of what must be accomplished to be the best business partner"* (Volvo AB, 2014)

Today the Volvo group employs around 115 000 people and have production facilities in 18 countries (Volvo Group, 2013). Product development together with purchasing and product planning employ currently around 10000 persons.

4.2 Case Study Company B

The second company chosen in the case study is Cummins Turbo Technology. The company was founded in 1919 by Clessie Cummins. Demand of diesel engines rose dramatically during World War II and by 1956 company had sales over $100 million. The company continued to grow, and by 1967 Cummins comprised approximately half of the U.S. heavy-duty diesel engine market. Increase in demand and robust sales in the '50s and '60s prompted Cummins to expand its operation internationally. The company opened its first overseas plant in Scotland in 1956, and by 1970 it had created a sales and service network of 2,500 dealers in 98 countries.

Cummins expanded its product line with the introduction of midrange engines (via joint venture) in the early 1980s. Company has joint ventures with large truck makers in key markets as Dongfeng in China, Comatsu and Tata in India. Cummins has today four business segments: Engine, Power generation, Distribution and Components. The Engine Business is the largest of the four segments, designing and manufacturing both diesel and natural gas-powered engines for on-highway and off-highway

Cummins Component Business Unit consists of Emission Solutions, Filtration (Fleet guard), Fuel Systems, and Turbo Technologies (Holset). With regards to Turbo Technologies, Cummins designs and manufactures turbocharger and related products, on a global scale, for diesel engines above 3 liters. Cummins Turbo Technologies was incorporated in 1952 as Holset in Huddersfield, UK and later purchased by Cummins in 1973 which was renamed to Cummins Turbo Technologies in 2006. CTT is leader in turbocharger design and development.

Company has long experience in this fields and supply turbo charger to commercial diesel and gas-derivative engines.

CTT employs around 2000 employees globally with sales of over $1billion per annum. CTT has headquarters and Technical Centre in Huddersfield, UK but is a global company having established sites in Brazil, China, India, The Netherlands and the USA.

4.3 Empirical data: Interview

In this section, empirical data collected from semi structured interviews will be presented. In order to get a broader organization view, the selected sample of interviewees is representative for organization regarding product development, quality and processes. The focus of selecting interview participants was to achieve maximum depth and richness of the data to address the research questions. Individual engineers are not involved with the strategies or process modification so the focus was more to interview individual who are aware of the field as lean, product quality, management processes and involved in company's strategy formulation. However, open-ended conversations with some of the engineers besides interviewees have given important insight into problems like missing product or market information.

For this study total 7 interviewees from different organizational levels were selected as shown in Table 3. Semi structured Interviews were carried out individually at participant offices but one interview was carried out per telephone. All interviews were organized around a set of predetermined questions (Appendix A) but the interviewees also got the possibility to give their personal view about the questions. Interview was recorded with permission and notes were taken during each interview. Effort was made not to influence the interview by putting contradicting questions, neither based on theory or own experience.

	Q1:Do your team or group faces or have faced time, cost and quality issues. What were the reasons behind this in your opinion?	Q2: How will teams with multi-disciplinary knowledge, e.g. of product design, sales and quality, affect product quality?	Q3: How will cross functional teams affect knowledge sharing and knowledge creation?	Q4: How will utilization of cross functional teams in beginning of projects affect product quality?	Q5: What in your opinion could be drawbacks or hinderance to use cross functional teams?
Interviewee 1	Yes, main reason has been * Focus on delivery than quality * More local focus. Broader focus missing * Requirements not clearly defined, understood * Project not front loaded with correct resources * Knowledge of final customers use, especially after guarantee period * Knowledge of solution missing	* Cross function team contributes to better technology system development which leads to better Quality and feature. * Improved requirements understanding. Define concepts and design review. This will give right base for correct solution and right prerequisites for quality * Probability of choosing correct solution is high * Will lead to better quality since solution gone through multimple view.	* will increase rate of knowledge sharing which leads to shorter lead time and results in better quality. * Effective problem solving when people with different knowledge bases coexists in team, i.e. developer can communicate directly to manufacturing if component will be suitable or not. * Alternatives approaches can be discussed before effort being put to design.	* Will help to review concepts early in projects * This affects all areas, better quality and shorter lead time. Both better quality and shorter lead time results in lower cost.	* Communication is important otherwise risk of im-balance and distortion * may not effective if the products are innovative due to long lead times to decision and too much discussion if required knowledge doesn't exists
Interviewee 2	* Pre-requisites not understood correctly * Knowledge from past, customer, technical solution knowledge * Lack of knowledge to understand problems * Project leader not able to integrate different views * Developer not understood answer to "Why" a certain technical solution was used. * Lack of communication between development teams courage to convey message * Component solution knowledge is not managed in a usefull way	* interaction with multiples views refines one's own understanding * Product development needs broader and deep knowledge * Will lead to better quality if communication and integration of ideas works well * Teams with broader knowledge base, open communication, open-mindedness, individual respect will lead to better quality * Team can help to understand what needs to be done	* infomral contacts with teams members will help for better understanding * Diversity of knowledge, cultural and ethical will be beneficial * How that should be done may needs deep indivdual knowledge * Walk and go leadership is good for sharing and knowledge creation	* Better understanding and interpretation of requirements * Help to choose better technical solutions	lead times may be longer what product quality will sure be better * Communication and individual respect will be fundamental * Good team leadership respecting and integrating individual views
Interviewee 3	* lack of experience in development team * deep knowledge to understand problem * Bristande professionalism * Knowledge of previous experiences lacks	* teams with mutual respect will help to solve the problem * Communication is the "art of the impossible" * informal contact is more important than meeting during formal meetings * Pulling information through informal network is far more productive. Team member and leadership with participative leadership will better pull information from organization	* knowledge, ethnical diversity is good for development and leadership to integrate different views * Knowledge breadth, depth, communication and loyalty are important	* will always help understanding pre-requisites * Resources with correct knowledge base can be identified * Correct technology solution can be chosen in cenceptual phase	* Can not see any drawbacks of using CFT. * Cross functional teams fails if team leader leadership
Interviewee 4	* Missing knowledge about customer use and in-correct translation of the customer requirements into product requirements * Time and cost pressure lead to risk taking. * Development methods not updated for recent requirements * Problem is more related to development method not in product development process	* Cross functional teams will lead to improved quality since it makes multiples views readily available * Individual designer will benefit from team knowledge which ultimately lead to less cost and shorter development time. * knowledge diversity is good for both product development and to develop products that final customer want.	Development engineer, casting expert,material expert and manufacturing experts need close collaboration so that the designed parts is castable, and have correct material properties, is withing tolerance in order to avoid surprises at manufacturing.	* knowledge diversity will help develop products that final customer want.	* Good leadership is pre-requisite to get a cross functional team to function, for decision making otherwise risk of too much discussion can be result. * Communication is key to success of such teams. Different cultural backgrounds and employement rules can hinder work of such teams. * Personal agenda and defensive position of individual in such teams can make work difficult.
Interviewee 5	* Requirements not clearly understood * Time and cost pressure * Human resource management. Resources with correct knowledge base are not deployed * lacking communication between customers and developers	* CFT will imrove quality and development time if correct resorces and correct communication channel exists * Will help to improve project requirements * Group knowledge levels is always larger than individual * Not possible to drive development with some kind of cross-functionality involved. * Resources with multiple field knowledge are difficult to find and expensive to keep	* Whole phenomena of CFT is to share knowledge * Can bridge the gap to functional teams since members usually belong to these times * Will help to understand Interaction of different systems * Help to understand limitation of a method or system	* Uncertainity is high in beginning of projects. CFT will help to decrease the uncertainity. * Less development iterations required due to better understanding of requirements	* CFT will not be effective without proper commnication. * Time consuming without proper decision making. * Team leader needs to be good on integrating different views.
Interviewee 6	* Yes * In projects the PM usually locks time and cost and by this quality will suffer. When quality issues arise it will lead to increase time and cost to fix them anyway.	* There is a risk with cross functional teams and that there will be alot of stakeholders. * We need to keep it within the development organization and have one person taking a outside perspective as customer or sales organization.	* By implementing cross functional teams knowledge sharing will improve. People will understand why we need to do things. * Also knowledge creation will improve due to that we will create and maintain knowledge.	* If done the right way it will decrease the leadtime but everyone needs to be working in the same direction. * It will create less interfaces to outside stakeholder.	* Risk that the team misses dead angels when they have been working together for a long time. The team can be to like in their thinking.
Interviewee 7	* Yes * Usually this is due to scope and vision.	* It can lead to great creativity and progress if the roles are cleared out.	* In an ideal world it is vital with cross functional teams. * Risk of a lot of handshake meetings.	* If done right it will increase the quality.	* Risk that the boundaries and responsibilities are not clear in the beginning of project. It will lead to many meetings and lost time. If this is not cleared it will lead to that persons will fight for their organizations need and not the best for the project. * The saving of one recent major project was to cut the cross functional teams and add a strong PM that had mandate to take decision. This shortened the leadtime to decision and by this the project was saved.

Table 4: Interview responses, Cross functional teams

	Q1: How can knowledge integration in front end of development projects (improvement/innovative) affects quality?	Q2: How will knowledge integration impact knowledge gap in product development?	Q3: How does your group/team work or should work with knowledge integration? Are there any hinders to accomplish that?
Interviewee 1	* Knowledge integration is absolute right step to find correct mix to achieve goals without big risks * The knowledge integration is pre-requisites to meet this complex development process. * Knowledge is a fundamental of quality; of course it is desired to have right knowledge in front instead of solving quality issues afterwards, product maintenance. * Knowledge integration is in big complex innovation/development is absolute right step to find correct mix to achieve goals without big risks	* Product development has become extremely complex by time due to high focus on customer feature, meeting complex legal requirements and shorter lead time. The knowledge integration is pre-requisites to meet this complex development process. * Individuals can not master the requirements of this complex process * Solution to many problems can be found if the avaialble knowledge from previous projects, markets, sales and involved indivduals could be integrated	* keep guidelines updated with latest knowledge * Consult colleagues * always take a look through solved problems
Interviewee 2	* knowledge integration will help for both innovative and improvement products, i.e. Knowledge of product use is important for both type of products	* You can't expect change without understanding knowledge about how product are used * Quality problem apears when customer demands aren't properly translated into requirements * if the knowledge/information is made available in easy to use way it will surely decrease knowledge gaps * make the avaibale information attractive, that individual want to use it.	Management duty to help make information attractive in form of: -internal education -demand on individual groups that available knowledge is used and documented * knowledge should be integrated by writing/updating guidelines, job training and with help of teams * Encourage individuals to document their experience and share with help of modern technology as inter company personal sites and discussion forum *my experience is that its long way to go before a satisfactory level of knowledge/information is achieved
Interviewee 3	* project history, what was good and why something didn't work help to tackle future problems * you can't develop a product without knowledge of how it going to be used * Best practices should be shared * available knowledge can be used in front of projects to translate requirements * Use the best practices guidelines from previous projects * automotive product are more or less carry over with very small part innovation. Previous knowledge/information can solve many of the problems	If knowledge from previous project/customers/previous quality was available in a useful and easy to understand way, it should have solved many of the quality issues. * knowledge management will help technical understanding in depth from different angles.	* Hidden agenda may lead to the fact that available knowledge is not properly utilized *Both management and individual are responsible to utilize the available knowledge * Individual performance factors on knowledge sharing * personal prestige and personal interests may hinders use of available knowledge
Interviewee 4	* Knowledge integration is to learn from your mistakes and keep improving development methods * Product planning and product attribute leadership need to integrate the final customer knowledge in project conceptual phase. This will reduce need for risk taking *Effective use of information technology will be useful for knowledge sharing integration in product development. * Product use knowledge is imporatnt for development	* will help totranslate requirements into actions * technical knowhow will help designer to understand many issues that may be detected later in project otherwise. * make project aware of the risks * help to find the suitable solution to problems	* Knowledge integration is to learn from your mistakes and keep improving development methods * Management to provide structure to share and make use of available knowledge * Tacit knowledge is better integrated by job rotation * correct person in correct role is required in order to succeed with knowledge management.
Interviewee 5	* Important decisions are made in beginning of projects. * Need to information from previous project, market and devlopment is highly needed in this phase * Proper methods can be chosen without loosing time	* absolutely knowledge availability will decrease knowledge gap * organization will be better equipped to understand problems	* Communicate why certain decision was made. * update development guidelines * write down why certain method was used * what arre the advantages or disdvantages of certain methods * encourage communication at every step * always respect individual and their opinion
Interviewee 6	* It will lead to better quality. * Developers will not make the same misstake twice. * Also in innovative projects it is good to use old data even if the new solutions will not be the same.	* Will decrease the knowledge gap if it is easy to search and use the data. If not it will delay the project and tie up resources that tries to use the data.	* Processes are built to document and capture knowledge. * It is a lack of deployment and education on how it should be used. * It is also a cost of current projects when they need to document but cannot use the results, it will only be used in later projects.
Interviewee 7	* The reuse of information is fundamental and the organization needs to make sure that it is available. * Today there is a lack of information between commodities. Every commodety creates their own but does not connect it to other and gets no feedback on it.	* If well structured it will lower the gap.	* Different departments creates their own system no link between them. There is no common tool.

Table 5: Interview response, knowledge and information integration

	How can knowledge flexibility/expertise affect project quality?	What is your opinion about knowledge flexibility effect on: - Improvement products - Innovative products	How can knowledge flexibility be good for filling knowledge gaps during projects?	Will knowledge flexibility of project leaders with multi-disciplinary qualification improve product quality and Why?
Interviewee 1	* flexibility is the ability to restructure knowledge in multiple ways depending on the changing situational demands (i.e. difficulty or complexity of the situation) *will help to understand system interaction	* Product development is extremely complex with high technical complexity. It is more or less impossible to find team which covers the breadth of the project. Knowledge flexibility is an enabler to make this team/projects successful	sure. One can understand interaction better with knowledge from multiple field. A designer with manufacturing and casting knowledge will be able to design better product which is easy to assemble and cast.	Product development is extremely complex with high technical complexity. It is more or less impossible to find team which covers the bred of the project. Knowledge flexibility is an enabler to make this team/projects successful
Interviewee 2	* An optimal mix of expertise and generalist is required. You can't develop products if you don't know how to do it. * Product quality can be better optimized (otherwise risk of sub-optimizing concepts and solutions) if knowledge of different fields available at development time *Knowledge expertise is needed to	Knowledge flexibility will improve quality more of innovative products than improvement products.	Absolute. * knowledge flexibility will be helpfull to help to fill knowledge gaps * translate pre-requisites to doable tasks.	* Product quality can be better optimized (otherwise risk of sub-optimizing concepts and solutions) if knowledge of different fields available at development time * Multi-discipline knowledge of project leaders will be beneficial since he/she will integrate different ideas and opinion about a solution
Interviewee 3	* product development is alwaysmult-displinary. One can't optimize by only expertise. *Flexibility needed to know "what to do" and expertise to answer "how to do" *Quality will improve drastically if developer have knowledge in multiple fields.	* will lead to shorter development time and lower cost * Innovative product may need more knowledge in depth, hence may impact quality in a negative way.	Will lead to simplify and visualize tasks	* multiple field or system knowledge is important for quality * Individual with broad knowleddge base and retrospective experience will improve project quality *knowledge flexibility with participative leadership will benefit
Interviewee 4	* Technical knowledge and know-how is fundamental for part och individual system quality. * But complete system will require people (or so called system integrators)with knowledge of other systems as well in order to produce a optimized product*. * A combination of technical experts and generalist is required both for innovative or normal products.	A combination of technical experts and generalist is required both for innovative or normal products.		project leader with broad knowledge base and may be less deep knowledge of one area will be beneficial. * Project leadership is to assess risks, knowledge management is right knowledge at right place.
Interviewee 5	* we ar eworking with advanced innovative products. * Expertise is very important for us. * However flexibility will help to match the products to different environment	* Flexibility will be effective for improvement products * Optimal mix of flexibility and expertise will improve product quality	Yes to some extent. But resources of this kind are difficult to find who have knowledge in different fields. * Proper human resources strategies can help to develop * Flexibility of inter-related fields as design, material and manufacturing could be beneficial for quality	* Sure. Project leader is information integrator. Skilled in communication and technology will be beneficial for quality, cost and time. * With knowledge in multiples fields makes decision makeing accurate and timely.
Interviewee 6	* The importance is the balance between knowledge flexibility and expertice. * If the mix is right it will lead to improved quality.	* There is no different between those two. Generalists can handle them both.	* It is good with a overview but also expert knowledge is needed.	* The PM handles all aspects of the project and development. He/she needs to have a wide knowledge if the project should succeed.
Interviewee 7	* If there is no good flow of information it can solve the knowledge gap but at the same time it can lower the expert knowledge.	*It is usable in improvement projects but more valuable in innovative when there is lack of reusable data and lessons learned.		* The PM needs to have a broad knowledge of both the development process and what is expected from the outside world.

Table 6: Interview response, Flexibility

5. ANALYSIS AND DISCUSSIONS

The purpose of this research is to study the factors that can influence product quality and strategies that an organization may utilize to improve product quality. The theory chapter provided the framework and has therefore built a foundation and conceptual fundamentals on which these two important aspects can be related. It is important to underscore the importance of effective resources utilization to produce quality products at low cost and less time which ultimately lead to larger market share and can prove an edge over competitors in cost sensitive automotive market.

Literature studies indicate that knowledge gap, need of knowledge creation and sharing, innovative products and time/cost pressure are important factors that adversely affect product quality. Hence, assumption is that product development strategies that reduce the adverse effect of these factors will improve the product quality. Furthermore literature studies show that cross functional teams, knowledge information integration and knowledge flexibility of resources will help to reduce the adverse effect of above factors and hence will lead to improved product quality. The conceptual model (Figure 15) will be validated using empirical data collected through semi structured interview and direct observations.

The interviews were recorded and from this, the results are filtered down to match the three proposals for improvements and presented in the tables in section 4.3. To be able to do a deeper analysis these results are filtered down one more time, discarding irrelevant data and duplicates. The interview answers are concluded for thesis propositions; Cross functional teams, Knowledge integration and Knowledge flexibility. Data is further sorted for each affected factor; knowledge gap, knowledge sharing, knowledge creation, innovation products and time and cost pressure. These tables are presented in each of the analysis areas below. Both answers that supports and rejects the proposals of this thesis are presented.

5.1 Cross Functional Teams

The conceptual base for the hypotheses in this thesis is drawn from the literature in quality management, group psychology and innovation. This literature suggests that outcomes of the cross functional team should be dependent of the team composition of skills and group psychology that team members are able to share their knowledge and help each other to find solutions (Fujimoto & Clark, 1991; Nonaka, Toyama, & Konno, 2000 ; Sethi, 2000). So the pattern that will be matched is that team with diverse knowledge, efficient communication and mutual respect between team members will lead to better product quality. Cross functional team will lower the knowledge gap, help to create and share knowledge, and choose optimal solution earlier in projects that will consequently lead to lower development cost and development time. In sections below cross functional teams effect on knowledge gap, knowledge sharing and creation as well as the effect on development time and cost are discussed.

5.1.1 Knowledge Gap

Knowledge gap is defined as type of knowledge which a firm currently lacks but has been identified critically important for its survival and growth and hence needed to be filled (Haider, 2003). Further three types of knowledge gaps as containing, intersection and separation are identified in product development (Jiangnan, Zhiqiang, & ChuangLing, 2014). For the first two types of knowledge gaps, the needed knowledge exists within the company and in case of separation type of knowledge gaps the firm need to acquire the needed knowledge externally.

The interview responses, Table 7: Interview response Cross functional teams effect on knowledge gap , show that cross functional teams are effective to fill knowledge gaps of the first and the second type. Main reasons behind are the broader knowledge base of the team compared to individuals, effective problem solving and possibility of concept reviews by using simulations tools etc. As the knowledge gaps tend to be big in beginning of projects, use of cross functionality will benefit to reduce the knowledge gap. Other factor that may affect knowledge gap is innovation. Existing or previous knowledge in case of innovative products is usually missing. In such cases as indicated in literature (Sethi, 2002), cross functional teams are effective means to reduce effect of innovation on quality by accelerating the process of knowledge creation and increased product understanding. Since automotive products are innovative to small extent, cross functional teams are mostly effective for automotive products.

If the knowledge gap is of type separation, means company need to get required knowledge externally, cross functional teams may not be very effective. Respondent from the software field indicate missing knowledge and previous development experience as main reason behind quality problems which clearly indicate knowledge gap possible to be filled with knowledge existing in the company.

How cross functional teams help to fill knowledge gap
❖ help to integrate existing knowledge by, e.g. simulation to reduce the knowledge gap ❖ Diversity of knowledge will be helpful to understand complex problems
❖ Improve requirement understanding
❖ Higher probability of choosing right solutions
❖ Effective problem solving and early concept review
❖ Solution has gone through multiple views
❖ Team with broader knowledge base will increase understanding
❖ Can decide or help to prioritize the activities ❖ May not be effective for innovative products due to long lead times and too much discussion if needed knowledge doesn't exists

Table 7: Interview response Cross functional teams effect on knowledge gap

5.1.2 Knowledge Creation and Knowledge Sharing

Theories within organization theory (Nonaka, Byosiere, Borucki, & Konnot, 1994) and quality (Pruett & Thomas, 1996) suggests that product development success is highly determined by the creation of knowledge at the individual and organizational level. Organization need to integrate the four knowledge conversion processes "socialization, externalization, combination, and internalization "into the product development (Nonaka & Toyama, 2003).

The theoretical pattern is that cross functional teams will lead to knowledge conversion in the organization by internal discussions and convert tacit knowledge into explicit knowledge by having meaningful dialogue and use of sophisticated metaphors. Interview respondents indicates that (Table 8) cross functional team are effective to convert the tacit knowledge into explicit knowledge by integration, synthesis and dissemination of existing knowledge. Furthermore the explicit knowledge in the organization may be converted into tacit knowledge by personal experience where knowledge is acquired from real world experiences and through experimentation and simulation. The central theme of the organizational knowledge conversion model to maintain dynamic between the four modes of knowledge conversion (Nonaka & Toyama, 2003) can be achieved by implementing cross functionality in projects.

Cross functional teams will help on both building of tacit and explicit knowledge and on the interchange between these two aspects of knowledge through internal discussions and externalization (Nonaka, Byosiere, Borucki, & Konnot, 1994). Metaphors, analogies, and dialogue are considered important to convert tacit knowledge into explicit, i.e. process for externalization. Communication is seen as fundamental for knowledge conversion process both by the respondents and in literature. According to Brown & Duguid (1999) knowledge sharing becomes difficult when knowledge to be exchanged between different communities since sharing of tacit knowledge occurs through the establishment of shared understanding. In global organizations, there can be additional hindrances when inter-organizational boundaries, different educational and cultural backgrounds are involved. Hence, establishment of shared understanding is important in global organizations.

Knowledge diversity, depth and breadth are seen important from respondents reflections to understand problems on complete products. Knowledge diversity if used and communicated properly can lead to better quality. But this will require active participation from management and leadership to integrate different views where communications barriers may exists due to cultures, technical backgrounds and personalities. Cross functional teams may face with opportunistic behavior by the team members. Mitigation of such behavior calls for arrangements that will

motivate the members to behave in an acceptable manner to ensure the welfare of all the team members rather than just few individuals.

❖ Will increase rate of knowledge sharing which leads to shorter lead time and results in better quality. ❖ Effective problem solving when people with different knowledge bases coexists in team, i.e. developer can communicate directly to manufacturing if component will be suitable or not. ❖ Alternatives approaches can be discussed before effort being put to design.
❖ Informal contacts with teams members will help for better understanding ❖ Diversity of knowledge, cultural and ethnical will be beneficial ❖ Walk and go leadership is good for sharing and knowledge creation
❖ knowledge, ethnical diversity is good for development and leadership to integrate different views ❖ Effective if Knowledge breadth, depth, communication and loyalty exists
❖ Development engineer, casting expert, material expert and manufacturing experts need close collaboration so that the designed parts is castable, and have correct material properties, is within tolerance in order to avoid surprises at manufacturing.
❖ Whole phenomena of CFT is to share knowledge ❖ Can bridge the gap to functional teams since members usually belong to these times ❖ Will help to understand Interaction of different systems ❖ Help to understand limitation of a method or system
❖ By implementing cross functional teams knowledge sharing will improve. People will understand why we need to do things. ❖ Knowledge creation will improve which will lead to maintain and knowledge creation
❖ Cross functional teams are ideal for development ❖ Will lead to requirement understanding which is dependent of knowledge sharing

Table 8:Interview response: Cross functional team effect on knowledge creation and sharing

5.1.3 Time and Cost Pressure

Improper product design stands for more than 40% of quality costs (You, Alard, Schönsleben, & Zhu, 2009). One cannot mitigate the adverse effect of wrong design on manufacturing costs (Liker & Franz, 2006). There are three apparent trade-offs involved in product development; quality and product innovativeness, knowledge level in the cross functional team and time and cost pressure on the team.

Cross functional teams are effective to reduce uncertainty in projects by choosing right solutions, planning the activities, refining the available knowledge and improve understanding of the technological concepts (Sethi, 2000 ; Haider, 2003) as well pulling the information from the functional organization. Hence, theoretical pattern is that cross functional team will reduce the adverse effect of time and cost pressures on quality.

Empirical data indicates that many of the design failures start from the wrong choice of technical solutions. This choice in general depends upon not fully understanding, translating and verifying the customers' requirements in beginning of projects. Which leads to creation of defective information which can't be verified until later stage or until next activity is performed. Most companies produces huge amount of information from field, customer experience as well as product

development knowledge but usefulness of this information is limited. Literature (Sethi, 2002) as well as interview respondent supports that cross functional teams will improve the use of this information to improve the project requirements and help to choose better solution which will lead to less time and better quality.

As mentioned previously the knowledge gap is bigger in the beginning of project and effect of this knowledge gap becomes higher on coming development stages. Front loading with resources and available information in front of project will lead to higher effectiveness to fill knowledge gaps and choice of technical solutions is supported by participants as well as litterature(Fujimoto, 1991; Aggari & Segrestin, 2007; Repenning, 2001). Use of more simulations in front of projects to improve product will lead to reduced development time and higher product quality.

❖ Will help to review concepts early in projects ❖ This affects all areas, better quality and shorter lead time. Both better quality and shorter lead time results in lower cost.
❖ Better understanding and interpretation of requirements ❖ Help to choose better technical solutions
❖ will always help understanding pre-requisites ❖ Resources with correct knowledge base can be identified ❖ Correct technology solution can be chosen in conceptual phase
❖ Knowledge diversity will help develop products that final customer want.
❖ Uncertainty is high in beginning of projects. CFT will help to decrease the uncertainty. ❖ Less development iterations required due to better understanding of requirements
❖ If done the right way it will decrease the lead time but everyone needs to be working in the same direction. ❖ It will create fewer interfaces to outside stakeholder.
❖ If done right it will increase the quality, decrease cost and shorten lead times

Table 9: Interview response: Cross functional team effect on time and cost.

5.1.4 Innovative Products

Five out of seven respondent support that cross functional teams are important for both improvement and innovative projects while two participant indicates that cross functional teams may not be effective in case of innovative products or if products are new to company. One respondent fears that "*If the required knowledge doesn't exist it can lead only to long discussions without conclusions. Outcome may be long lead times to decision and too much discussion if required knowledge doesn't exist*".

Since majority of projects in automotive are of continual improvement nature with few technological innovations, cross functional teams are seen as mostly effective in automotive product development. An experienced product development engineers quote about the repetitiveness of problems as "*Similar problem appears all the*

times. We work on them, solve them and write reports but usually forget to mention how the problem was tackled, since problem solving tactic is quite personal and difficult to express in written language or in reports". Hence the quality is not always due to innovation of products instead due to in-effective problem solving methods and inability to transfer know-how of tackling such problems.

5.1.5 Effectiveness of Cross Functional Teams

Interview response agrees to literature that effectiveness of cross functional teams will depend upon the knowledge integrator role present in the team, open communication, individual respect and freedom to express one's own ideas (Sethi, 2002). Individual respect, openness and transparency are mentioned by all the interviewee as important factor for cross functionality. Personal agenda or personal interests of individual may affect effectiveness of cross functional teams negatively. Hence willingness of the individual to share and contribute to improve product quality is prerequisite of team functioning (O'Neil & Adya, 2007).

❖ Communication is important otherwise risk of imbalance and distortion ❖ may not effective if the products are innovative due to long lead times to decision and too much discussion if required knowledge doesn't exists
❖ lead times may be longer what product quality will sure be better ❖ Communication and individual respect will be fundamental ❖ Good team leadership respecting and integrating individual views
❖ Cannot see any drawbacks of using CFT. Cross functional teams fails if team leader leadership are lacking.
❖ Good leadership is pre-requisite to get a cross functional team to function, for decision making otherwise risk of too much discussion can be result. ❖ Communication is key to success of such teams. ❖ Different cultural backgrounds and employment rules can hinder work of such teams. ❖ Personal agenda and defensive position of individual in such teams can make work difficult.
❖ CFT will not be effective without proper communication. ❖ Time consuming without proper decision making. ❖ Team leader needs to be good on integrating different views.
❖ Risk that the team misses dead angels when they have been working together for a long time. The team can be to like in their thinking.
❖ Risk that the boundaries and responsibilities are not clear in the beginning of project. It will lead to many meetings and lost time. If this is not cleared it will lead to that persons will fight for their organizations need and not the best for the project. ❖ The saving of one recent major project was to cut the cross functional teams and add a strong PM that had mandate to take decision. This shortened the leadtime to decision and by this the project was saved.

Table 10: Interview response: how to improve effectiveness of cross functional teams.

All participants see importance of cross functional teams. However communication, strong leadership as information integrator will be required for decision making in such teams. Requirement setting phase in projects is seen most important for the success of projects in literature (Kleinscmidt, Cooper, & Edgett, 2004) as well as respondents. Involvement of line organization earlier in projects will improve

product quality and will positively affect product development time and cost. If line organization is not involved it will have consequences on the choice of chosen solutions which may require higher number of resources during project life.

5.2 Knowledge Integration

The proposed conceptual model states that knowledge gap in beginning of projects and that development cost and time will decrease by implementing knowledge integration into the organization. All the interviews points into the same direction, that if knowledge is reused from previous project it will lead to a product development with lower risk.

Knowledge Gap	Cost and development time	Knowledge Integration in front end
❖ Important decisions are made in the beginning of projects.	❖ Project history, what was good and why something didn't work help to tackle future problems.	❖ Knowledge integration is prerequisite to meet this complex development process
❖ You cannot develop a product without knowledge of how it is going to be used.	❖ It will lead to better quality.	❖ Knowledge integration will help both innovative and improvements projects.
❖ Technical knowhow will help designers to understand many issues that may be detected later in projects.	❖ Developers will not make the same mistake twice.	❖ Best practices should be shared
❖ Will make projects aware of risks.	❖ Help to find suitable solutions to problems.	❖ The re-use of information is fundamental.
❖ Today there is a lack of information between commodities.		❖ Quality problem appears when customer demands are not properly translated to requirements.
❖ Different departments create their own information and no link between them.		❖ Available knowledge can be used in front of projects to translate requirements.
❖ If well-structured it will lower the gap.		

Table 11: Interview response: Knowledge/information effect on quality

5.2.1 Knowledge Gap and Knowledge Integration

The knowledge gap is at the highest level in the beginning of projects. It is also here that the biggest decisions is taken on how the product will be developed and what techniques and technologies that will be used. By having the knowledge from previous projects available in newly started projects, there should be a decreased risk of failing or having severe quality issues at the end can be avoided. This is especially valuable in a project with a front end approach, when a larger part of the development is done early in the project and in the end there should only be minor corrections. It can be seen in the light of Olsson & Hansen (2011) where there is on one side production process that need early decisions on how to proceed in the

production and on the other side a development decision process asks for decision as late as possible or when there is sufficient information available. By using knowledge integration it is possible to take decisions earlier due to the fact that more information is available and the production process can start their work.

As seen in the interviews there is already work ongoing in the company to catch and reuse knowledge from projects and employees. This is either done through a process that documents the knowledge for later use or by creating guidelines on how a problem should be tackled based on previous knowledge. It is important to mention here, that created data should be in easy to use format. One problem highlighted in interviews is, that there is no common system between different departments where guidelines or knowledge is shared and reused combined with other commodities knowledge. Knowledge does not spread through the organization and persons working on other departments do not understand why other are taking decisions as they do. These issues are partly solved by one of main proposals in this thesis, cross functional teams. These teams are only temporary in a project and the knowledge still need to be captured for later use especially when it comes to maintenance of the product. Cross functional teams can also be the solution for spreading information that is not possible to codify in documentations (Nonaka & Toyama, 2003).

During interviews some concerns like the friendly usability of earlier captured knowledge came up. If a full organization is creating data for later use it will be lots of data that needs to be gone through in future projects to not make the same mistakes as earlier. If it is not easy to use it will tie up resources going through all documentation. By this there is a need to have it easy accessible and structured.

All interviews support that knowledge integration if correctly done and if the information is usable and user-friendly, it will decrease the knowledge gap in front end product development.

5.2.2 Development Cost and Time

By integrating previous knowledge in development there is a possibility to decrease the risks that will lead to longer lead time and higher cost of projects. By having the knowledge from all commodities like customer behavior and earlier issues already in the product planning phase it will make it easier to make the right decisions early in the projects and by this making sure that the customers get the product that they want to buy. Also by having the best practices and lessons learned available the developers will have the possibilities to use the proper methods of solving issues and understand the problems. In a project view it can be valuable with earlier captured knowledge when the project manager are able to predict issues that will occur and can plan in advance to have available resources to handle them. The responsibility to create this knowledge base, can be seen, as stated by Pruett & Thomas (1996) “manage knowledge is a management issue”. This means that management should create technical solutions and make this kind of information available, both quick and accurate. Besides that it should be within management responsibility to keep such knowledge base continually updated.

The risk with late quality issues and an organization that goes into firefighting mode can partly be eliminated by introducing knowledge management and knowledge integration in early project phases. An organization that suffers of earlier quality issues that needs to be corrected, will be drained of resources (Black & Repenning, 2001). By having a database of earlier issues and knowledge in the organization it will be possible both to correct issues with less resources and having less problems introduced in the product due to the fact that these are already handled in the development phase.

Knowledge from earlier projects will be useful on innovative projects. Even though the solution will not be the same but presence of this knowledge will help developer to make the right decisions. This is quite contrary to statements in literature DuBrin(2010) that reuse of earlier data during innovative projects is inefficient.

5.3 Knowledge Flexibility

Cross training or cross understanding make people able to take on a broader variety of tasks and this leads to higher responsiveness, higher productivity, flexibility and morale (Kaeter, 1993; Dalton, 1998). A flexible workforce will support development of informal communication channels, coordinate the flow of work across boundaries and support socialization within the organization (Hoyt, J.; Matuszek, T., 2001). These factors are important both to share as well create knowledge (Nonaka, Byosiere, Borucki, & Konnot, 1994).

5.3.1 Knowledge Gap

Six out of seven respondents agree that knowledge flexibility will lead to better quality by filling knowledge gaps especially by understanding and simplifying the project requirements, interaction of individual system with rest of the system and better understanding of the complete system. Interview responses indicate that knowledge from multiples functions is a requirement in automotive field and people with this kind of knowledge will be able to fulfill complete product requirement by optimizing the complete product. However requirement of experts will be high if the products are innovative and expert knowledge together with overall product knowledge will lead to reduction in development times and improved quality.

Knowledge of the multiple fields is seen important by interview respondent to develop a optimized product. Interview reflection is quite similar to Madhaven and Grover (1998) that persons with T-shaped skills not only are expert in their field but also understands how their expertise field interacts with other functions. A person with T-shape skills has deep knowledge of one's system as well as the knowledge about the interactions with other systems. People with t-shaped skills have the ability to combine theoretical and practical knowledge and to sustain meaningful conversations with others (Madhavan & Grover, 1998). Peoples with such skills can

expand their competences across several functional branch areas, and thereby develop systemic thinking skills (Lee & Choi, 2003; Liker & Franz, 2006).

Knowledge flexibility of the project leaders is considered important for product development effectiveness. It is considered important for integration of different views, timely and appropriate decision making taking into account the overall performance of the product. Individual with broad knowledge base and retrospective experience will improve product quality. Broad knowledge base will be helpful to understand and verify the requirements and identify the knowledge gaps in beginning of projects.

5.3.2 Innovative Products

According to interview respondents quality will be positively affected by the presence of cross trained peoples in the organization. However when it comes to innovative products expertise is required to understand and explore the problems. Experts interact with several programs at a time and therefore have the opportunity to observe and learn from various product development projects which help them to find solution from depth and breadth. Hence t-shaped skills are seen effective to improve product quality where only cross trained peoples or generalist may not have required skills.

All respondent agrees on the importance of knowledge flexibility of project leaders. Information integrator role of the project leaders will help on timely decision making and information integration of information from different knowledge sources. This is quite similar to what Madhavan & Grover (1998) mentioned as team leaders with A-shaped skills (expertise in at least two disciplines) are more effective at knowledge development and integration tasks. A-shaped skills allow them to combine insights from multiple knowledge sources. Particularly in cross functional teams, leader with such skills will be better equipped to synthesize the different views and increases the richness of available knowledge. Besides that such team leaders can craft a unified vision by integrating and reconciling different ideas and views (Madhaven &Grover, 1998; Brown & Eiesenhardt, 1995).

T-shaped skills of the product development engineer and A-shaped skills of the project leaders are seen important to affect development of improvement as well as innovative products. Timely decision making and choice of solution that fits to customer demand will lead to shorter development times and lower cost.

Direct observation similar to interview responses and literature indicates importance of knowledge flexibility. "*Both generalists with good knowledge of other functions in the organization are needed but at the same time expert knowledge is needed to drive new innovations*". One other voice states that "*I think that deep knowledge of an area or system is what builds good solutions. However we need persons and structures that understands the impact on product level*". So from the results and the comments it can be seen that both generalists and expertise is

needed to have get good quality and low development costs in product development.

5.3.3 Time and Cost pressures

Lean product development literature indicates importance of flexibility in order to reduce waste (Olsson, 2006; Olsson & Hansen, 2011; Wang & Wang, 2012; Liker & Franz, 2006). Waste could be of many kinds as producing information or design that cannot be verified or are verified very late in projects, or choice of solution not fitting other systems properly, or producing huge amount information which is not in the correct or a usable format. Minimization of such activities will be beneficial to reduce the lead times and cost.

Respondent's answer to question if knowledge flexibility will affect time and cost pressures are listed in Table 12. Less number of development iterations due to broad and multiple field´s knowledge is mentioned as an important factor to reduce time and cost. When number of person can verify the accuracy of information, it will help to develop solution that most probably will be fulfilling requirement of complete system.

There could be concern as stated by Aggeri and Segrestin (2007) that experts could lose some of their expert knowledge if they are not in an environment of other experts within their field. If management wants to use knowledge flexibility in their development they also need to make sure that the experts continue to be this by letting them be deeper with their specific knowledge and not only contribute to the group. There can also be a need to invest in specific forums for the expert where they can develop and discuss ideas together with other experts within their areas.

Knowledge Gap	Information Integration	Innovative Products	Time and Cost
❖ Ability to restructure knowledge ❖ Knowledge from multiple fields will help to optimize	❖ Knowledge flexibility is important for project leaders to make efficient and timely decisions. ❖ Requirements from multiples fields can be combined	❖ No project in automotive is completely innovative. Flexibility will be good. ❖ However expertise is required to develop new solutions and understand technology in depth. ❖ One expert and four knowledge flexible person in project teams will optimal choice.	❖ Less number of iterations due to multiple field knowledge
❖ Will help to translate pre-requisites to doable tasks ❖ Interest is to get fully functional product, not if part of the complete product is over optimized and other part perform poorly.	❖ Product quality can be better optimized ❖ Multi-discipline knowledge of project leaders will be beneficial since he/she will integrate different ideas and opinion about a solution	❖ Knowledge expertise is needed to solve problems in depth. But complete product must work proper. ❖ An optimal mix of expertise and generalist is required. ❖ You can't develop products if you don't know how to do it. ❖ Knowledge flexibility will improve quality more of innovative products than improvement products.	❖ Requirement understanding ❖ Multiple fields knowledge leads to less number of development iterations
❖ Individual with broad knowledge base and retrospective experience will improve project quality	❖ multiple field or system knowledge is important for quality ❖ Knowledge flexibility with participative leadership will benefit	❖ Innovative product may need more knowledge in depth	❖ will lead to shorter development time and lower cost ❖ Will lead to simplify and visualize tasks
❖ Project leader with broad knowledge base and may be less deep knowledge of one area will be beneficial.	❖ Technical knowledge from multiple fields and know-how is fundamental for part och individual system quality. ❖ But complete system will require people (or so called system integrators)with knowledge of other systems as well in order to produce a optimized product.	❖ A combination of technical experts and generalist is required both for innovative or normal products.	❖ multiple field knowledge will accelerate problem solving
❖ However flexibility will help to match the products to different environment ❖ Yes to some extent. But resources of this kind are difficult to find who have knowledge in different fields. ❖ Knowledge of inter-related fields as design, material and manufacturing could be beneficial for quality	❖ Sure. Project leader is information integrator. Skilled in communication and technology will be beneficial for quality, cost and time.	❖ We are working with advanced innovative products. ❖ Expertise is very important for us. ❖ Flexibility will be effective for improvement products	❖ better choice of solutions ❖ Human resources strategies to develop Flexibility of inter-related fields as design, material and manufacturing could be beneficial for quality ❖ With knowledge in multiples fields makes decision making accurate and timely
❖ It is good with a overview	❖ The PM handles all aspects of the project and development. ❖ He/she needs to have a wide knowledge if the project should succeed.	❖ The importance is the balance between knowledge flexibility and expertise. ❖ Expert knowledge is needed.	
❖ If there is no good flow of information it can't solve the knowledge gap but at the same time it can lower the expert knowledge.	❖ The PM needs to have a broad knowledge of both the development process and what is expected from the outside world.	❖ It is usable in improvement projects but more valuable in innovative when there is lack of reusable data and lessons learned.	

Table 12: Interview response: knowledge flexibility

6. Conclusions and Future Recommendation

In this chapter we will link back empirical results to main question, if factors as cross functional teams, knowledge and information integration and knowledge flexibility lead to higher quality and lower product development cost? First section will conclude if empirical findings support thesis propositions that above mentioned factors and the second section will discuss what more need to be done in order to implement these findings into product development.

6.1 Conclusions

Final product quality can be improved by integrating efficiently cross functional teams, simulations, product development, product quality and failure experience from previous projects into the product development processes. Integrating this information in beginning of project will help to minimize risks of repeating mistakes, help project leader to mitigate risk and plan in advance, increase problem solving speed and identify the knowledge gaps and develop strategies to develop knowledge.

Recommendation is to actively promote the knowledge sharing ways in the form of knowledge and information management process in order to make information easy accessible to all within the organization. If there is no knowledge/information management process, retrieving information becomes personal contact dependent and does not flow without interruptions. One has to know where to get required information and whom to ask instead of access it easily from a database or similar. Organization may need some special processes to capture the knowledge which is not written down like product development experiences etc. Different approaches are needed depending on if the information can be coded or not. Special working routines like trainees working parallel with people bearing tacit knowledge may be necessary. Other solution to transfer tacit knowledge could be to let people bearing this kind of knowledge update methods, codes or operational routines. Job rotation can be another solution to reach higher information integration and flexibility.

Cross function teams are important to reduce product development time and increase quality. Higher efficiency of cross functional teams can be achieved if effectively used in the early phases of a project. However, there is a risk of losing expertise competence if the team members are placed outside their functional areas. This may affect innovation negatively and is needed to be handled by management in a secured manner (keep in touch with functional groups and have routines to get integrated back into groups after project is over). Cross functional teams will also lead to flexibility of knowledge, where the people have understanding of more areas of the product development than their own area and is important according to lean philosophy to pull information from functional groups. When having knowledge about many fields developers can develop

understanding about when, why and what outcomes are needed and expected from other teams. One of the main findings in this thesis regarding knowledge flexibility is that both generalists and specialists are needed for developing quality products. Specialists are needed to solve issues and drive innovation in an organization where generalists are needed to understand the impact on the complete system.

Implementation of the three identified factors will improve product quality and reduce product development time and cost. Not using the knowledge already available in an organization can lead to the fact that wrong conceptual techniques are chosen or requirement from other commodities are missed. Consequences will be expensive product and degraded quality due to detection of issues late in product development cycle. This thesis finds strong support for the use of frontloading but management needs to be aware of the risks when using it on innovative products. Front loading only with human resources without knowledge integration will not be effective to improve quality.

Successful implementations of these factors will require both management and individual involvement. New working routines will be required to promote cross functionality, knowledge flexibility or cross training of work force and information integration. Thesis finds strong support for cross functional teams and information integration to improve product quality and to reduce product development cost however knowledge flexibility is fully supported for improvement projects and expertise is required to develop innovative products.

Effectiveness of cross functional teams will depend upon the knowledge integrator role present in the team, open communication, openness and transparency, individual respect and freedom to express one's ideas. Project leaders or information integrator role with skills in more than one field will improve correct and timely decision making as well as integrating different views.

Opportunistic behavior of individual member in cross functional teams may affect effectiveness of cross functional teams negatively. Hence willingness of the individual to share and contribute to improve product quality is prerequisite of team functioning. Inter-organizational boundaries, different educational and cultural backgrounds hinder conversion from tacit to explicit knowledge. Hence, establishment of shared understanding is important in global organizations. New communication ways should be adopted by organization to create openess within organization. Use of information technology to share problems and possible solutions, should be encouraged.

By implementing the proposed solutions in product development it should be possible to move the "cost to failure of control" to "cost of control" (Giakatis & Rooney, 2000). By this the product development company will have better control of the risks and costs and will be able to man up earlier and avoid ending up in a firefighting mode.

Proposed updated product development process is shown in

Figure 18.

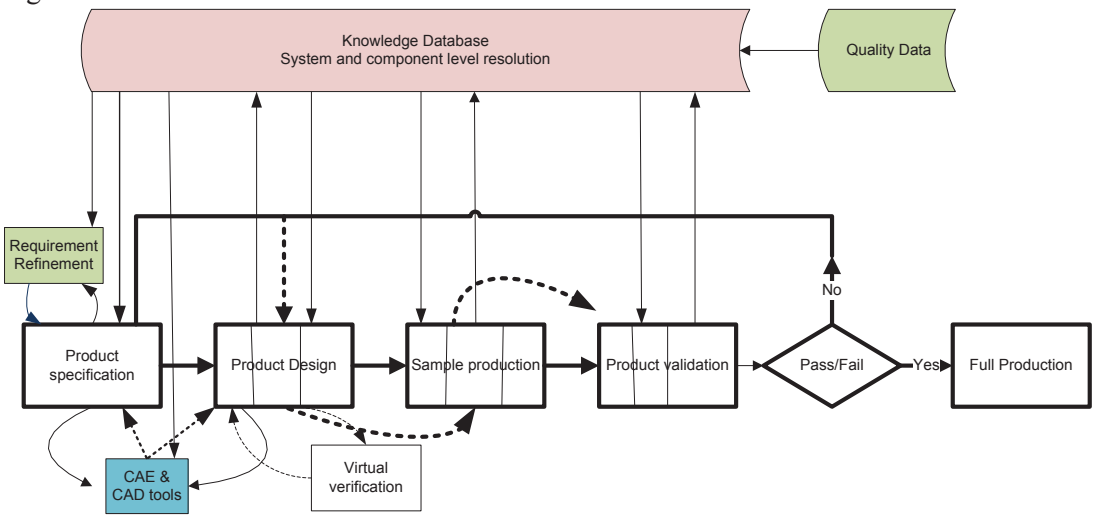

Figure 18: Proposed product development process.

6.2 Future Work and Developments

The main conclusions of this thesis is, in order to maintain quality, process improvements with focus on knowledge/information management, cross functional teams and front loading are needed. A database containing information about the known quality issues and problem solved during development can improve both the work and quality in the future projects. One of the main issues with this kind of database is how the data should be structured and presented to the users. If it is not well structured and presented it will be like the card game “go fish”, where the information is stored somewhere and one might get lucky if one can find the right one at the right timing. There is a need to take in consideration how to secure this kind of information. Internal use of this data can be very helpful but if the data ends up in public or at competitors it could be devastating to the company.

Information integration need in other businesses as medic care and manufacturing could be interesting for future studies. New strategy or process to promote knowledge sharing and quantify its effect on the project development could also be an interesting subject.

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Appendix A: Interview Questions

What is your current Role?
How long product development experience do you have?
Do your team or group faces or have faced time, cost and quality issues. What were the reasons behind this in your opinion?
How will teams with multi-disciplinary knowledge of product design, sales and quality lead to: - Quality - Development time - Development cost
How will cross functional teams effect: - knowledge sharing - knowledge creation
How will utilization of cross functional teams in beginning of projects affect product quality?
What in your opinion could be drawbacks of using cross functional teams?
How knowledge integration in front-end of improvement projects can (mature products), affect quality?
How can knowledge integration in front end of innovative projects, affect quality?
Will knowledge integration in general lead to improved quality and why?
How will knowledge integration impact knowledge gap in product development?
What could be the benefit of knowledge integration on development cost and time?
How does your group/team work with knowledge integration? Are there any hinders to accomplish that?
Can knowledge flexibility be good for filling knowledge gaps during projects?
How can knowledge flexibility affect: - Product Quality - Product development time - Product development cost
What is your opinion about knowledge flexibility effect on: - Improvement products - Innovative products
Will knowledge flexibility of project leaders with multi-disciplinary qualification improve product quality and Why?
How will knowledge expertise affect product development - Product Quality - Product development time - Product development cost

Table 13: Interview Questions