

Product Development

The theory and its applicability in practice

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Abstract

This paper is a qualitative research to understand how well the theoretical methods of product development are applied in practice. A comparison between the theory and methods the companies are using is done in order to get an insight of the current situation. *Value analysis, Quality Function Deployment, Failure Mode and Effects Analysis, Design for Assembly, and Modular Function Deployment* that is brought up in this thesis are all well-known methods in the theory which assist companies to achieve a higher degree and effectiveness with their development. These methods answer fundamental problems that may occur in every company, and touches on areas such as the economical perspectives and customer related inquiries. It also finds solutions on uncertainties that might arise during product development.

After interviewing ABB, Scania and Atlas Copco, we learned that some of the theoretical methods were in fact utilized to a certain degree. However, there are instances where the enterprises establish their own principles to rationalize product development. After a thorough comparison made between the methods used by the companies and the theory, we discovered many similarities between them. The foundations of these methods are very much based on the existing theories.

We concluded that even though the theoretical methods aren't applicable to all situations, the fundamentals are widely accepted and the philosophies behind them are commonly applied in companies' own methods. The theory does not only act as a backbone for effective product development but also serves as an important tool for further method customization suitable to the uniqueness of each enterprise. Lack of knowledge in the actual theories can therefore undermine the companies' capability in achieving efficient methods which ultimately will only disfavor themselves in terms of time and money.

Companies spend a lot of time to discover methods to facilitate their development processes. They can instead collaborate with academic institutes and universities to exchange information since theories already exist out there that are able to answer and solve most the companies' current situation and their requirements. However, there are occasions in real life circumstances where things doesn't necessary go as smooth as depicted in literatures and theories. Therefore a balance between practice and theory where they complement each other will yield the optimal outcome.

Acknowledgment

This paper is about product development, we want to investigate which methods and principles are used in practice and how consistent it is with the theory. In order to obtain information about methods used in practice, we had to visit some companies within this industry, thus we would like to thank Mats Holmin at Atlas Copco who greatly helped us by providing information about the structure and development strategy of his company. We would also like to thank Simon Algesten at Scania, Peter Boman at ABB, George Fodor at ABB, and Fredrik Norlund at ABB for the same reasons. It would not be possible to write this paper without their support.

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1. Introduction

This section introduces the basic framework of this thesis, starting with giving an overview of principles for product development following with stating the purpose of the thesis. We will describe the questions needed to be answered in order to achieve the end result along with noting some limitations that will be encountered throughout the whole work.

1.1 Overview and History

In today's society we learn how products shall be developed with the best possible methods in order to adapt to the customer requirements with minimal error. This should also be conducted from an economic point of view to manufacture and assemble in a way that is beneficial for both the company and the consumers. Students in universities and colleges learn about general methods and principles like Quality Function Deployment (QFD), Failure Modes and Effects Analysis (FMEA), Modular Function Deployment (MFD), etc. But how useful are these methods in the real industrial situations and how could/are they applied in the different industries?

1.2 Purpose

The purpose of this thesis is to understand how well the theoretical methods of product development are applied in practice, and also to compare the theory taught and the principles used in industry in order to deem if the theories are useful in practice.

1.3 Research Questions

Some questions were formulated to serve as a parameter towards an understanding of the situation as well as a guide line to steer us in the correct path throughout the thesis.

1. Do companies make use of theoretical methods and what is the reason for their decision?
2. What are the differences and similarities between theory and practice and why do they arise?
3. Based on the previous issues, how applicable is the theory in practice?

1.4 Delimitations

There exist certain limits that we will encounter when progressing on this paper. There are some apparent factors that people will bump into that usually play a big part in determining the level of content, degree of proficiency and outcome of a thesis. For our case, among those is the allotted time, difficulty in contact with interviewees, and limitation on the size, which will all shape the end result of the work.

There are limits in what we can include in the theoretical part of this paper. We have handpicked among the many, the principles and methods concerning product development that we deem are vastly used and known to people both between and outside the border of the industry realm.

In the chapter, *Theoretical Principles*, where we describe the methods for product development existing in theory, there is a small section about *benchmarking* that has been broken out from the *Quality Function Deployment (QFD)* heading. This is because benchmarking has received a lot of attention in many sources about QFD due to its importance, thus the reason for giving it an own segment.

Due to the constrained time frame, we assume that the people we have interviewed represent their department or company, and their word is also absolutely consistent on behalf of the company. This is for a fact not entirely true due to no one is fully unbiased, and has complete and accurate knowledge about everything of their company. Nevertheless these are the assumptions we have to make due to the circumstances.

We have chosen three different industrial companies for this paper, ABB, Atlas Copco and Scania. Although they do not represent the whole industry world, we believe that they will enable us to receive a clearer picture in comprehending how majority of the industry operates.

ABB and Atlas Copco are large companies with many departments and areas of expertise, thus methods and structure within the company can greatly vary. It needs to however, be noted that we were looking at the Force Measurement department of ABB and Tools department for Atlas Copco to retain the consistency of this paper. Hence, whenever ABB and Atlas Copco are mentioned throughout this thesis, we are referring to those departments unless otherwise stated.

This paper has been written and formulated to be understandable for graduate engineering students who studies production with similar knowledge and education level.

1.5 Method

Two types of methods will be given to literature studies and empirical studies due to the different approach needed in handling them.

1.5.1 Literature studies

The information attained for the theoretical parts are mainly from literatures, articles and academic papers concerning our area of studies. To enhance the variety of sources and to get a more direct input, we have been visiting some professors in the Production Engineering department at the Royal Institute of Technology (KTH). We have also been present on several lectures about our specific topic of product development. These were the method used to gather the information required for our literature studies.

1.5.2 Interviews

In order to understand which methods and principles are used for product development in practice, we had to interview companies with rather high proficiency in this area. To collect this information we choose to interview some managers in three different industries who are familiar with the topic pertained. The three companies were the experts in heavy truck industry Scania, pioneers at hand-held tools for industrial environment Atlas Copco, and the innovators in the force measurement industry ABB. We thought that these three companies pretty well represent the industry world, therefore they were chosen. We also only picked three companies due to lack of time in appointing more meetings.

We have provided a sheet of paper with the questions we were going to ask for the manger. However, we weren't strictly following that paper and rather held the interview in a more natural fashion by asking questions more freely. We believed that preforming the interviews in this way contributes to a more relaxed atmosphere. Apart from taking notes by hand, we also recorded the interview. The meetings with the managers were accompanied with a tour around their factory so

we could see how they produce and assemble some of their products as well as how the company functions internally.

After every interview, we wrote down what was mentioned in order to compare it with the questions that had been prepared. Then we organized the story and tried to extract the important points. The final thing is to put down the information in text and polish the story to make sure everything is understandable as well as letting somebody else proofreading the interview. Since we recorded our interview, we could always go back and listen to the whole thing, word by word, and reanalyze each part if something is misunderstood.

When conducting a research there are two main methods that can be used, the qualitative method and the quantitative method. For this paper, we have been using the qualitative method. The aim of a qualitative research is a complete detailed description. It involves analysis of data such as interviews, pictures or objects; and interviews are the source we are focusing on for this paper.

2. Theoretical Principles

In this chapter, we have collected some widely used and well-known theoretical methods that are used for product development. We have portrayed the methods of Value Analysis, Quality Function Deployment, Failure Mode and Effects Analysis, Design for Assembly and Modular Function Deployment in a descriptive manner in the following passages.

2.1 Value Analysis (VA)

After the World War II, intensive developments of new technologies were required. Even questions about new quality assurance and assertion started to arise, gaining a new interpretation, as well as attaining more attention around the world. In the 1950s people began to study and see that both the quality and cost efficiency could already be influenced during the construction phase of a product. The value of a product became defined as the relation between performance and cost. These ideas were elaborated by Lawrence D.Miles and he created the method called Value Analysis (Johannesson et al. 2004).

The purpose of this method is to discover the cheapest manufacturing method for a product and at the same time trying to find the best alternative which can keep the same functionalities for the lowest price. During this analysis similar question as the following are asked:

- What is the main function of the product?
- How much does it cost?
- Which alternative solutions exist?
- How much will the cost be for the alternative solution?

When those questions are answered comes the time to choose the alternative with the lowest cost that simultaneously keeps the same functions of the product. Another important advantage with the VA method is that it enables traceability that didn't exist before, in other words everything that is done gets documented and becomes easy to retrace (Johannesson et al. 2004).

2.2 Quality Function Deployment (QFD)

Manufactured products primary has the purpose to please and satisfy the customer and market. Therefore everything that is produced should be adapted after the customer and market needs. Thus, it is essential for the manufacturing to be able to translate from customer needs to a more measureable and technical parameters. (Asif, 2012)

QFD is an instrument that does this translation. QFD was introduced in Japan by Dr. Yoji Akao (1966). He stated that QFD is *“a method to transform user demands into design quality, to deploy the functions forming quality, and to deploy methods for achieving the design quality into subsystems and component parts, and ultimately to specific elements of the manufacturing process.”*

The car industry is an example of where the method is put into good use. With the help of QFD they could find the best components of a car to modify, such as the *car doors*, wind shield or rear-view mirror, after the needs of their client. This method is more beneficial for products that need further development and less suitable for completely new products.

The House of Quality for Enterprise Product Development Processes is a technique and tool based on QFD. It is a matrix that apart from showing the customer requirements and quantified construction specifications also includes a competitor analysis (benchmarking) where the company can see its strengths and weaknesses compared to its rivals (Johannesson et al. 2004). The matrix comprise of four points of interest:

- Market survey – to find the customers' need, demand and expectation
- Benchmarking – to find the strengths and weaknesses compared to the competitors
- Identify its own priorities for development
- Translate the customer demands to quantitative specifications for construction and manufacturing

Figure 1 is an example of how a House of Quality matrix can look like. Note that the four points of interest previously mentioned is distributed into nine different sections of the matrix below.

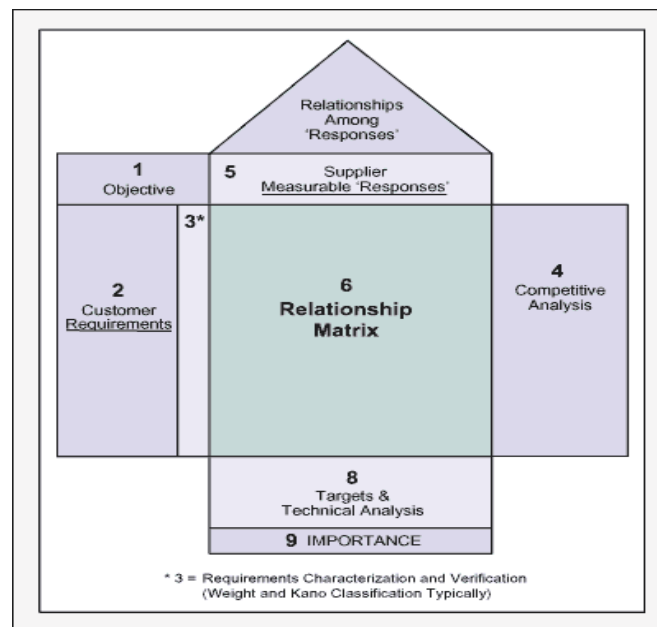


Figure 1: Basic QFD "House of Quality" (David L. Hallowell)

However, there are several difficulties in the application of some parameters. Among them includes interpreting the customer voice, defining correlations between the quality demanded and quality characteristics (Carnevali et al. 2008). This method is therefore more of a foundation and support for discussion and documentation within product development than a stone set rule to follow (Johannesson et al. 2004).

Figure 2 is an example of the house of quality matrix for car doors that was mentioned in an earlier paragraph of this chapter.

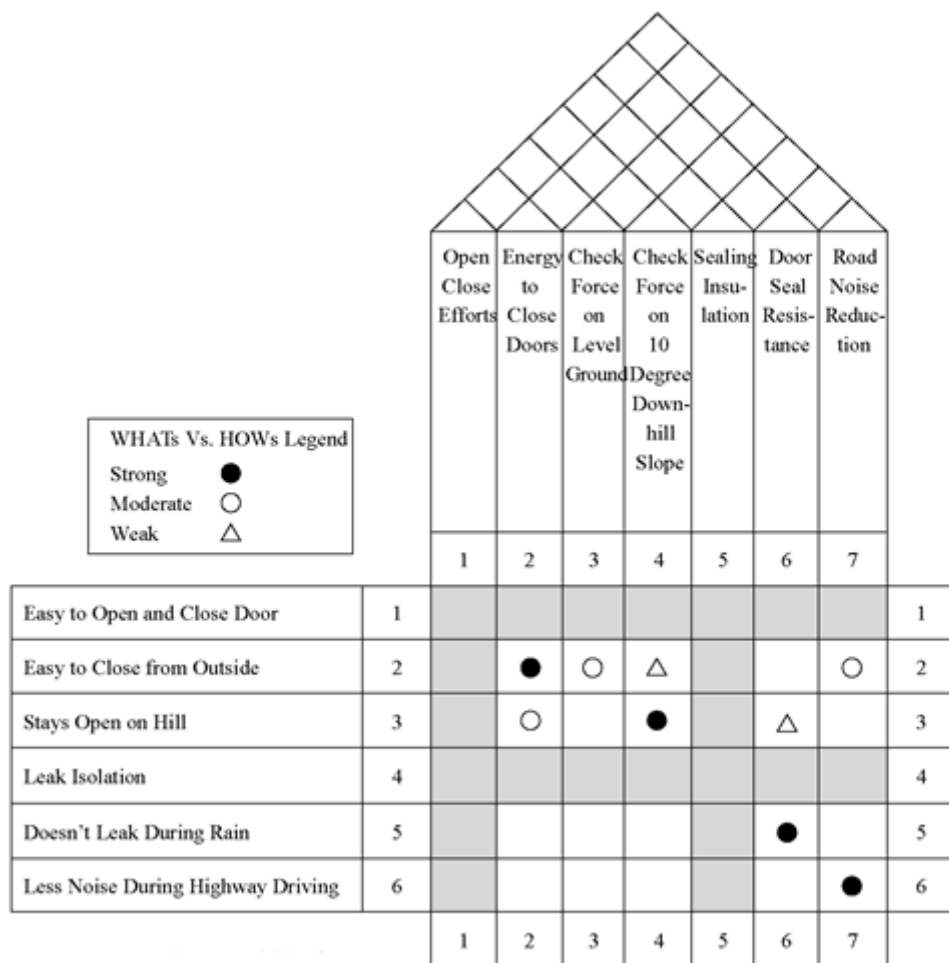


Figure 2: House of Quality Matrix for Doors (Biren Prasad, 1998)

It can be concluded that with the support of the QFD method we can find out the customer demands and wishes, and translate this to a more technical and measurable parameter. From the parameters it is possible to find the requirements to meet the customer needs. Another advantage of QFD is enabling traceability for the solution of product development due to the fact that everything is neatly documented.

2.2.1 Benchmarking

Benchmarking is the process of comparing one's business processes to best practices from other organizations and companies. This can be within the same industry but also with other businesses in order to continuously make improvements from what has previously been accomplished (Ax et al. 2010). Benchmarking can be done on basically any area, from the functionality of the products to logistics within transportation. The direction and focus of benchmarking can also vary depending on which results are desired.

There are three benchmarking methods that will be mentioned. The first one can be categorized as “internal benchmarking” where you benchmark internally within the same company or underlying companies, and can be done between the departments as well. The second one, “competition oriented benchmarking” is where you compare your own company to other companies that are within the same market or has their attention directed towards the same customer groups. This method is seen to be more effective than the internal method. The third version of benchmarking is called “function targeted benchmarking” or just “general benchmarking.” This method is externally radiated, similar to the “competition oriented benchmarking”. The difference is that you don't necessary study the companies within the same business or industry but instead companies that have exceeded in performance within any known areas. The focus is put on functioning, manufacturing, administration and marketing. This is because it doesn't matter which business these areas are belonged to since they are rather general and possible to apply for most business niches (Ax et al. 2010).

2.3 Failure Mode and Effects Analysis (FMEA)

The FMEA method is based on subjective and relative evaluations of imperfections and errors that can appear on a product and the consequences that can arise from it. This method is centered on errors that have a chance to appear on the component level and how it eventually can affect the whole system. The FMEA identifies all the possible errors that can occur. The three factors that this method brings forward are the *probability of error*, *degree of severity*, and *probability to discover or not discover the error*. By working with subjectively rough estimates, this method can already be used on early stages of the development of the product. An important part of this analysis is to prioritize the biggest errors and problems which can arise, and then later in turn amend the problem. The FMEA is used within two areas. The first one and also the more common one is called *design-FMEA*. It means to run an analysis during the construction works. The second one called *process-FMEA* is used during the processing of a product.

The three factors that were previously mentioned are extracted with relative scales and can look similar as below:

- Probability of error
 - 1 = Very small probability that the error occurs
 - 4 = There is a certain probability that the error occurs
 - 10 = High probability that the error occurs
- Degree of severity
 - 1 = negligible influence on the product and the user won't notice
 - 4-6 = quite serious influence and the user will notice the error
 - 10 = Very serious consequences and dangerous for the user
- Probability to not discover the error
 - 1 = the error will quite easily be discovered
 - 4-6 = the error might be discovered

After all these factors are accounted for, the Risk Priority Number (RPN) is calculated. The RPN is calculated through multiplication of the three factors, and will become a number between 1 and 1000. The FMEA method brings forward the basic data for prioritizing the errors that needs to be addressed. After the RPNs are established for the different types of errors, suggestions of how to remedy the errors with the highest RPN are then made, and new RPNs are again extracted from that (Johannesson et al. 2004). All this information is documented in the FMEA table. An example of how a FMEA table can look like can be seen in figure 3 below:

2.4 Design for Assembly (DFA)

Design for Assembly is often used to obtain a higher degree of product adaptation. As the name of the method states, the components are designed in such a way which makes assembling as easy as possible. This is usually done during the manufacturing and development of a product.

The way of DFA was very much accentuated and developed during the end of the 1980s in USA. Many variants of this method have been branched from the original. Some examples of it are: Design for Manufacturing, Design for Injection Molding, Design for Quality, Design for Service, Design for Environment and so on. New methods based on DFA have also been developed by companies that want to adapt to their own assembly procedures. For instance *Hitachi* has established a new system called Producibility Evaluation Method (PEM), as well as *Sony* and *Sharp* have been developing their own assembly adaptation methods (Johannesson et al. 2004).

The first thing that is done during DFA is to evaluate the most profitable assembly method from a cost perspective and at the same time take the production volume, flexibility and the time between readjustments into consideration. There are three major assembly methods that exist. The “*automatic assembly*” is used during large volume production (million products/year). “*Robot assembly*” is used when a higher requirement of flexibility on a product is needed. The final one “*manual assembly*” is most suited for when the volume quantity is small enough or when the assembling is too advanced for robots (Johannesson et al. 2004).

2.4.1 Design for Automatic Assembly (DFA2)

Design for Automatic Assembly is commonly categorized as an under category of DFA. DFA2 is DFA but directed towards automatic assembly. The equipment for manual and automatic assembly does vary a lot. Manual assembly is the use of human capabilities with or without the aid of the sophisticated jigs, fixtures and power tools to perform the assembly task (Redford 1983). A human has capacity and traits in flexibility of movements, power, speed, and has good sense of touch and sight which makes certain operations only possible or more suitable for the human being compared to robots (this fact is reserved for change in the future). The machines on the other hand exceed humans in terms of steadier quality because of its repeatability, and it can work without the need for breaks (Eskilander, 2001).

Maffei (2012) states that “DFA2 should be put into use early for product development, preferably already during the design phase until the finished product in order to minimize and eliminate future changes.” Notably products which are suited for automatic assembly can also be assembled manually (Eskilander, 2001). Apart from finding the best method, issues concerning the environment should also be considered during this process. Before actually introducing the final solution, it also has to be economically viable (Maffei, 2012).

2.5 Modular Function Deployment (MFD)

As competition from every corner holds a tighter grip on companies and harder requirements are put on the prices and quality, it has become imperative to take as much advantage as possible on the

resources that exist. In order to combat this, the companies try to expand their market share through extending their offers and supplies with the help of presenting a larger variation and higher quality of their existing product range and at the same time trying to decrease the manufacturing cost per unit (Johannesson et al. 2004).

A good solution to this is to design the products in such a way that the components for the main product can be included in various combinations. Also that the components can be mixed and matched in a variety of configurations depending on what functions the product want to have. This means that with a limited number of components a company can achieve great variation in the production for different products of the similar series. In other words, by picking and choosing among an array of compatible components, the consumer can move freely around a large area of the product space (Langlois et al. 1991). This is the strategy of modular function deployment, in addition, it grants economic benefits in the development, production and service. The positive advantage and effect with the interchangeable “modules” are (Johannesson et al. 2004):

- The time for development decreases
- Less risk, especially when you want to develop a product with new functions
- Less lead time during the manufacturing process
- Higher quality
- Less article number to administer

A systematic method that has been developed for the MFD consists of five parts. The method largely based on the forth mentioned QFD and DFA. The five parts are the following (Johannesson et al. 2004):

1. QFD for the control of customers’ need and benchmarking to know the competitive situation
2. Part function based generation of technical part solutions
3. Identification of possible modules with the Module Indication Matrix (MIM)
4. Examination and evaluation of the suggested modular division/classification
5. Component construction of muddles with DFM and DFA methods

Along with the advancement of technology come parts and components that need to be replaced and reconstructed. The MFD makes the whole process easier due to the interchangeable modules. Less effort is needed on meeting the customer requirements because it will be easier to combine and produce what the customer wants with MFD.

2.6 Earlier Studies

Previous research about product development has shown that there exists a gap between the theories produced by researchers from what is used in practice. The reason for that is the lack of knowledge among practitioners and companies about these theoretical product development methods. This results in differences in practice. Although the companies are aware about the importance of the theoretical methods, there is much to be gained if the link between theory and practice could be closer and stronger (Ledwith et al., 2011).

3. Methods that are used in today's industry

In this chapter, companies from three different industries have been studied, and the methods they use in order to develop their products have also been described. The three companies that we presented are Atlas Copco Tools, Scania and ABB – Force Measurement.

3.1 Atlas Copco Tools

Atlas Copco is a globally renowned Swedish industrial enterprise that was founded 1873 under the name Atlas Limited (Atlas Copco, 2009a). The name was changed into Atlas Copco during 1956 after the acquisition of the Belgian company Airpic Engineering NV (Atlas Copco, 2009b). The main products of Atlas Copco Tools are hand-held tools for industrial environments such as cordless screwdriver, impact wrench, drill, grinder, and riveting hammer. 97% of their sales come from customers outside Sweden, and their biggest market is China. The products they sell are not suited for private customers due to the high prices. Atlas Copco focuses very much on the quality of their products, hence the price. The customers are very well aware of this fact, but it is due to the high quality their trust is gained and their products get sold. The philosophy that skims throughout the company is that they need to be better than their competitors in terms of both performance and durability, which is the main reason why they are having higher prices than overall in this market, as stated by Holmin (2012), Mechanical Manager at Atlas Copco. Their main competitors today are Bosch in Germany, Cooper in USA and some other companies in Japan.

There is always a trade-off for every company when it comes to responsiveness and effectiveness (Chopra et al. 2010). What would be optimal is to be at the front of the *efficiency-responsiveness curve* (see figure 4) where it is most profitable for all the companies. One cannot have high effectiveness and at the same time provide high service and responsiveness. There is in other words a trade-off between these two alternatives. Every company has its own layouts where they decide on how to structure their company and what they should focus on. They also have their own strategy on how to reach their goal (Porter, 1996). There are some companies that focus on providing their customers with smaller range of products but using a lower price to attract them, while other companies go with the opposite strategy and put their stakes on better customer oriented service and quality to a higher price (Chopra et al. 2010). Atlas Copco in our case is the latter one with expensive high quality tools. Their strategic position is heavily directed towards the responsiveness axis on the responsiveness-efficiency curve.

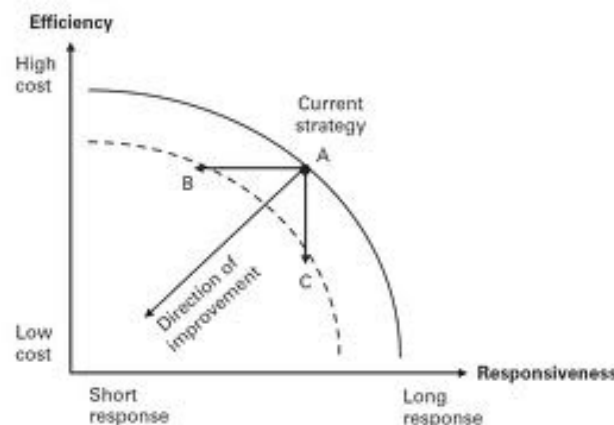


Figure 4: Efficiency-Responsiveness Curve (Dr. David Simchi-Levi, 2011)

3.1.1 Profitability calculations and the view of Value Analysis

Profitability calculations are always made at the start of each project in order to find the cost for developing a new product. The number of units that will be sold, the price of the product and etc. are the common questions asked. With these factors taken into consideration they will calculate a *net present value (NVP)*. The Value Analysis (VA) is about to identify the alternative that gives the most profitable product but at the same time keeps all the intended functions. Atlas Copco is not using the VA method but an own strategy instead. They try to maintain the performance of the product and see it as a more important factor than the price. They believe that by providing a product with high and solid performance, the customers would willingly pay more for it. There are times when Atlas Copco is willing to lower some functions of a product in order to decrease the price. These events are considered when Atlas Copco starts a new project, thus adjusting some functions for some customers are usually not a major problem. Atlas Copco is doing their best in bringing forth the ideal solutions and products simultaneously as they compromises the trade-offs between the price and function. (Holmin, 2012).

3.1.2 Development with customer as focus

Atlas Copco got teams of marketer and technicians who visit their customers to get an update on what they need and demand. With the new information the technicians lists new ideas on products that can be developed and suggestions on projects that can be started. The projects are then analyzed and ranked in terms of the economic standpoint and viability. Therefore before starting a new project, a lot of thorough and strategic thoughts need to be put into it (Holmin, 2012).

The QFD method and the house of quality matrix are not being used by Atlas Copco. They instead have a similar way of thinking when letting technicians and engineers to do the research and find the requirements of the customers. Based on the gathered information, they can then determine the next step to take. Although this method is not called QFD, their approach and process is very identical to it. They call it *product planning* (Holmin, 2012) where they collect the information gathered from the customers into an excel file in order to find the cost and optimal solution. The excel filing they do is similar to the house of quality matrix used in QFD.

Benchmarking is quite heavily focused on in QFD and Atlas Copco does the same. Atlas Copco put emphasis on external benchmarking (*competition oriented benchmarking*) that was mentioned in the chapter *Theoretical Principles* (see 2.2.1). Since Atlas Copco stresses the importance of being better than their competitors in terms of both durability and performance, knowledge about the rival's products is therefore essential. There are times when they buy their competitors' products to analyze, disassemble and investigate its functions. There are certain risks along with external benchmarking since disputes and hostility can occur between the companies. Despite that, external benchmarking is popular due to its effectiveness but needs to be handled with care. Atlas Copco does a lot of cross-examining of products but is not limited to it in their benchmarking. Competitors are doing the same thing as them. This is known and done by both parts and cannot be avoided.

3.1.3 Error Analysis – *Risk analysis a more appropriate method than FMEA*

The FMEA principle requires a lot of work and is very time consuming. Atlas Copco has been trying to use the FMEA method but realized that it doesn't work well for them. There are situations where customers require FMEA to be used. Due to Atlas Copco is very customer oriented, they have implemented it afterwards to meet their needs. The reason to why Atlas Copco doesn't think the

FMEA is applicable for them is because they have too many details and components for one product. To make a FMEA analysis on each component will require too much work and time (Stamatis, 2003). Holmin (2012) noted that they instead implemented something called *risk analysis*. The risk analysis is about looking at the biggest risk factors a project has and is done from the very start of a project. Some examples of risk factors are when the production line is being overburdened which can result in a delayed project, or technical solutions that doesn't work the way they are intended to. The risk analysis is done by the project leaders and team members where they together discuss about the possibility and type of risks that can occur in the project.

3.1.4 Assembly

When Atlas Copco designs for assembly, they involve production engineers and technicians at an early stage of the projects for product development. The engineers are present to see how the drawing of a product is made, how the assembly will look like and when the prototype will be made. They will also be present when the initial product is assembled in the lab etc. In this way, they can comment and point out how to improve the design of the product in order to make the assembly phase easier before they start mass-producing the product (Holmin, 2012). There are traces of DFA that can be seen, but Atlas Copco is not exactly moving along the theoretical path.

Not much emphasis was put on the importance of assembly 10 years ago. The production was not integrated with development. The development department used to send their drawings to the production, and the production blindly assembled the product without any extra thought put on it. However, assembly has received great significance along the years and Atlas Copco is continuously improving it.

DFA2, design for automatic assembly is not used in Atlas Copco because most of their products are made manually due to the smaller volumes that are demanded at each given time. Hence, it is more profitable with manual assembly instead of buying expensive machines to do the work.

3.1.5 Modular System – Future method of product development

The modular system has lately become more interesting for many companies in which it simplifies assembly, and contributes to more variations and customer specific products. Atlas Copco is one those companies that has started put modularization into good use, for instance a tool where the gear could be switched to change the rotation speed. Atlas Copco got many products where each product series often includes modular system,.There is a constant increase in products which uses the modular system. MFD not only gives a larger range of variation to the customers but at the same time eases the production for the company. People will surely be seeing more modularized tooled from Atlas Copco in the future (Holmin, 2012).

3.1.6 Environment

Constant examinations make sure that Atlas Copco keeps the requirement on the environmental specifications for each of their projects. Examples are verification on usage of forbidden materials or harm done to the environment during production. Each project includes certain environmental goals that should be met. The company has a major goal to reduce the carbon dioxide release with 20% by 2015. The environmental aspects are becoming more important within Atlas Copco. They even have an Eco-Designer that work specifically with environmental questions and improvement of that front.

The growing importance and focus to the environmental questions for Atlas Copco are not only because of problems such as *save the environment* or *reduce the release of dangerous gases*, but economical motives exist as well (Holmin, 2012). By decreasing the usage of energy, costs will also decrease. The main goal of a company is to generate money, everything that is being done in a company have the ultimate goal to increase the capital. Hence by answering to the environmental questions it can both contribute to a greener world and result in higher return at the same time.

3.2 Scania

Scania is a globally renowned company and is a leading manufacturer of heavy trucks, buses, truck engines as well as marine engines. In addition to these products, they also provide and sell a wide range of service-related products and financial services. Large proportion of the production takes place outside Stockholm in Södertälje, but is also existent in Europe and Latin America. The research and development department is also situated in Södertälje (scania, 2009).

Scania's largest market is the United Kingdom, Germany and Brazil. Service and after sales has been growing faster than production in today's market. Scania invest heavily in high quality, as a result their products are quite expensive. Furthermore, they also sell whole service package which includes guarantees, maintenance and buy back, which is attractive for the customer and creates a win-win situation. Scania has Volvo and Mercedes Benz as their main competitors.

3.2.1 Value Analysis – A question of fashion

Value analysis for Scania is a question of *fashion*. It is sometimes important and sometimes not, depending on the current trend. To make a decision of using value analysis depends a lot on if they have enough time to implement it. When the pressure is high on the development side, the company has to prioritize on other investments and projects than value analysis. They don't have time to look back to their already existing products in order to find a cheaper way to produce it.

3.2.2 Quality and Customer – Scania and Rivals

Scania does a lot of benchmarking exercises to get a good idea of how and what their competitors are doing. In Scania, the benchmarking style for the development and production department is different. The production department is very open, rival firms are able to make visits and Scania is also allowed to visit them. There is in general less secrecy in the production department, because even if their competitors discover any special or efficient way Scania works at, it will take time for them to readjust their own company to work in that way as well. After each visit, the whole procedure is documented in a report for later use. They will later on refer to the report when the time comes to analyze and study their competitors. Simon Algsten (2012) Product Engineer at Scania mentioned that an advantage from these visits, whether you go on visits or receiving other companies visits, there will be a lot of information exchange. This leads to better understanding of the competitors as well as their products. Thus this knowledge can be used to advance the enterprise. Mutual exchange of information hastens the improvements in technology.

There are *future groups* in Scania that are continuously trying to predict and analyze new requirements customers want, adapt to it and at the same time satisfy their demand. Traces of QFD can be seen in Scania's way of thinking, but they are not using the house of quality matrix. They acquire information about the customer needs from the *future groups* and adapt accordingly to their demands. Competitive analysis is done by benchmarking where the strengths and weaknesses are developed. These are all basic techniques that can be found in QFD.

3.2.3 Error Analysis – Focus on FMEA

Scania uses the FMEA method for making error analysis on their products and components. The method is divided into two areas, DFMEA and PFMEA which stands for Design-FMEA and Process-FMEA. The two types of FMEA was mentioned in the previous section (see 2.3), where error analysis is done during the design or process phase.

Design FMEA is done during the development of a product where a group of engineers and technicians analyze errors that could occur for the new product. Many of the problems that arise are usually due to tolerance faults which originate both internally and from the providers. When all the errors and faults are discovered, a point system will rank them in order to extract the most severe errors which need to be addressed first.

During the Process-FMEA, when the production department assumes that the product already passed the DFMEA phase and received the best possible design, the assemblers and engineers put their minds together to discover any risks that may emerge during the production phase. An example of Scania's PFMEA template is shown in figure 5.

P-FMEA REG NO:		Reason for P-FMEA				PARTICIPANTS:				DATE:		
MAIN GROUP and SUB GROUP / ARTICLE NO / MAIN COMPONENT Concerned:												
PROCESS												
Process Step/Function Processteg/ funktion	Failure mode Felsätt	Failure cause Felorsak	Failure effect - Line Feleffekt - Line	Failure effect Customer Feleffekt Kund	Control Styrning	O	S	D	R	Measure Åtgärd	Resp. Ansv.	Completion date Färdigdatum
1									0			
2									0			
3									0			
4									0			
5									0			
6									0			
7									0			
8									0			
9									0			
10									0			
11									0			
12									0			

Figure 5: Scania's P-FMEA Table (Scania, 2012)

Scania is a company that deals with a huge amount of components, it is therefore impossible to make FMEA tests on all existing ones. Scania tried it once, but it was too time consuming so they abandoned that idea. Scania has since then changed its approach. Instead of running FMEA on all the existing products, they will only do it every time a new product is developed (Algesten, 2012). In this way, all future products will eventually undergo a FMEA test, and the old products will be replaced by the new trialed products in due time.

For the existing products, it will be more profitable to act on data and outcomes instead of a new FMEA analysis. For example it is better to act on the actual existing errors than making new estimates of the products again from the very beginning. Since when a product is available on the market there will be statistics on it.

Scania is a high quality oriented manufacturing company. If there are reoccurring problems with their products, it will be a heavy blow on Scania's reputation. A customer is prepared to pay for a truck at a higher price when they make an order from Scania because they feel reassured of their purchase and acknowledge their quality. For Scania to meet these expectations, their products needs to be as perfect as possible, therefore FMEA is an essential process and method for Scania to ensure their quality.

3.2.4 Assembly

Scania is using manual assembly to assemble most of their products. The reason is because they possess a wide array of different products and therefore becomes difficult to make good use of robots and machines. It requires a huge amount of time and effort to setup and program the robots to be useful and applicable for all the different product variants. However, Scania make use of semi-automatic assembly as it can facilitate and provide better accuracy for assembling. An example would be during the adjustment of a valve lash where the set screw and locking screw need to be fine-tuned, see figure 6. This procedure was fully automated but due to many stop times, delays and valves getting installed in the wrong direction, at least 1-2engineer was required to keep the machine running. This machine has therefore been replaced with a semi-automated machine. As of today the critical instances such as measurements are done with the machine and adjustment done by man.



Figure 6: Adjustment of Valve Lash (CPGNation, 2009)

When a factory is going to choose between manual or automatic assembly, the two important factors to take into account are number of variants and volume. Volvo Cars is using a more automatic workshop due to the lower number of variants and higher volume in production, while Scania has a lower volume and higher variants. Thus manual and semi-automatic is more favorable for the company (Algesten, 2012).

When it is time to determine how the assembly should precede, a product engineer who is the link between the *design* and the *line* will try to merge and enable the communication between these two groups in order to achieve a good assembly method. The assemblers are engaged with the project together with the designers during the design phase when the first sketches are made on the drawing desks. The assemblers can at this point give opinions and feedbacks about how the product should be designed in order to make the assembly phase as smooth as possible. They also come into

an agreement of how the assembly should be done. Scania has a long DFA checklist with many requirements before establishing an assembly method appropriate for the products.

3.2.5 Modular System – Veteran Scania

The basic idea of modular system is that there are a few bricks and building blocks which can be effectively combined with each other in different configurations which bring an assortment of functions but at the same time keeping variety of components low. It is practically impossible to combine all products with each other, but great variations can be achieved by the usage of modules (Algesten, 2012). Scania is still way ahead in the competition in terms of modularization compared to other companies. This is evaluated by comparing the number of variants and number of articles that Scania has over other companies.

Scania introduced the modular system under the 1940s and was one of the first companies in Sweden to make use of this method. They started with categorizing the different area of usage for trucks, like for driving in urban districts, long-distance, mining conditions, and lumber carriage. Technical stats and requirements were extracted for what was needed in each environment and conditions. Different specifications were needed depending on whether a truck is run on a highway or in mines. This marked the birth of the modular system for Scania and their customers could choose the trucks that were best optimized for their tasks. With the advantage of modularization, it helped Scania to keep their numbers of articles low, and contributed to the whole chain from purchase, transport, storage to assembly.

Even though modularization is a nice and convenient system, there are some limitations to it (Algesten, 2012). There are times when a simple product, in this case an engine, was at first thought to only use a few components but due to new rules and customers demand, it had to keep adding new components. For each new component added contributes to a larger pool of articles, and eventually unnecessary ones will be created in the process. This isn't wanted in modular system since it wants to keep the number of articles as low as possible.

3.2.6 Environment

Scania has a vision to take responsibility for the environment and communities they affect. There are certain legal requirements and terms which companies need to follow, and they may only sell their products when the requirements are met. However, Scania doesn't want to be more environmental than needed. For an environmental friendly product a big investment will only yield a small improvement. It will be both expensive and time consuming, resulting in increase of the product's price, which will in turn decrease the interest of customers. Thus every company tries to keep as close to the lowest limit of the regulations as possible. There is another perspective of the environmental aspect where environment and economy goes hand in hand, more environmentally friendly result in lowering the cost for the factory. Take test-running the engines as an example, less time on test-running an engine means less energy consumption which results in reduction in emission while saving money.

3.3 ABB – Force Measurement Department

“Elektriska Aktiebolaget” was founded 1883 in Stockholm, it manufactured electric illuminated equipment and dynamos. The company merged with the “Wenströms och Gramströms” electric power company and changed the name into “Allmänna Svenska Elektriska Aktiebolaget”, in short ASEA. In the 1980s ASEA was one of the companies with the greatest influence within the electric-industry. Again during 1987, ASEA merged with a company in Switzerland under the name BBC – Born Boveri et Cie, this marked the birth of ABB (ABB, 2011).

ABB manufactures products such as industrial robots, products and systems for power transmission, and process and industrial automation. China with incredible growth is ABB’s largest market. Compared to China, Sweden only makes a small portion of ABB’s revenue. ABB got many customers in both Europe and North America.

ABB’s main customers for their force measurement department are the rolling/milling and paper industry. They produce tools for measuring force and dimensions such as thickness, width, positions of plates or other mechanical dimensions. The main rival of the force department is Siemens; however ABB is still in lead globally in the manufacture of Stressometer. Compared to their competitors, ABB has a rather heftier price on their products, but makes up for it by its quality and durability.

3.3.1 Value Analysis – Cost vs. Performance

Price and performance are two factors that often stand in contrast to each other. A high quality product often comes along with a higher price, while an inexpensive product tend to have lower performance; consequently there is always a trade-off between these two factors. ABB focuses on quality products with a more expensive price than their competitors, although alterations can occur depending on the targeted market segment.

ABB’s customers can be divided into several categories but the important ones are the *Original Equipment Manufacturer (OEM)* and *high-end* customers. The OEM customers take care of building and deliver a complete facility, in this case a *rolling mill* to their customers (and not for their own use). These OEM customers will therefore want to purchase building materials and components for as low price as possible. On the other hand, the high-end customers (professional rolling mills) want as high quality products from ABB as possible in order to handle and produce more advanced materials and products. Thus they are willing to invest more money as long as the tools they receive have good performance. There is a third group of customers, who roll in larger volumes with lower quality where accuracy on thickness or other measurements are less significant, hence makes it less important for them to purchase high accuracy products (Norlund, 2012).

ABB’s production is greatly depending on their customers. They will manufacture products with different performances in order to retain the price customers are willing to pay; the functions are basically the same with only the quality being different. Due to this, ABB constantly needs to keep *cost vs. performance* in mind during production. Although they are not using the VA method, the approach is very similar. They are asking themselves the same four questions (see 2.1) as the VA method during the construction phase.

3.3.2 Customer and Quality – Basic functions and unique measurement principles

ABB is neither using the QFD method nor the house of quality. However, their way of dealing with the customer needs is very similar to QFD. Although QFD is not strictly followed, they are touching many elements of it. A high valued customer orientation is ingrained in the backbone of the enterprise. ABB also has good relations with their customers. They make frequent visits concerning how their products are functioning for them or if the customers have any additional demands.

The customer opinions are very important for ABB's product development. They gather information about customer requirements, then adjust and find solutions for their products accordingly to the demand from their customers. ABB stresses on no matter how fancy a product becomes, the basic functions it serves will still be the most important determining factor for it. In other words no matter how good grip a screwdriver has, if it doesn't fulfill its role, it will be useless for the customer.

Fredrik Norlund (2012), Manager for System Development said that there is a difference on where the weight should be put depending on the product. If it is a new product, then the basic functions it serves are the most important factor. However, if the product has already been on the market for a while, it then will need some extra features or traits in order to have competitive strength against similar products from their competitors. Moreover, a product with good support and service is essential when dealing with the export market. Other ways to improve their market share is finding new *fields* within their areas of expertise to expand into. For example, ABB Force Measurement produces industrial measuring systems. If they manage to discover a new field or methods of measurement where it can be proved to help or make the jobs easier for their customers, then the number of customers will ultimately increase.

The difference between ABB and their competitors is the kind of measurement principles used. ABB uses their own unique principle compared to its competitors around the world. It is a completely self-developed physical principle that was introduced more than 50 years ago, and is only used within ABB (Norlund, 2012). The most famous and standard measurement principle that is used worldwide is strain gauges. However, the principle that ABB uses is based on magnetism and electricity which is utilized for force measurements. Even in dimensional measurement, ABB is the sole enterprise to have developed a completely original principle based on pulsed electromagnetic fields.

The market of force measurement uses products with long lifetimes, between 10-20 years, thus there must be tremendous durability and quality requirements on these products. ABB is known for its very robust products with high resilience that at the same time can handle high temperature. Moreover, their measurement products are also very accurate. The rolling mill industry has a harsh environment that makes it difficult for certain products to survive, and this is where ABB is advantageous with its products (Norlund, 2012).

ABB is a company that put emphasis on ethical principles, and therefore refrains from any hidden benchmarking such as buying products from competitors to disassemble them in order to understand their properties and how they function. It is somewhat a controversial act, but isn't a major problem if it is done openly and in the correct way. ABB has in rare cases also done it. An example is when they bought a product from a German competitor with the purpose of discovering how it is possible that they were selling the product to such a low price for the relative good performance.

There are times when it is hard for ABB to benchmark their products against similar products that exists in the market since the technology they use is unique. However ABB can still improve their product development process by comparing the procedures, sales and other statistics of other enterprises.

3.3.3 Error Analysis – Trial by customers

Systematic error analyses are done in ABB to discover faults on the products, with the purpose of refining and attain as flawless products as possible. There are different methods to execute error analyses depending on the company, and one of the methods that ABB uses is FMEA. FMEA is done during the construction phase because it is always cheaper and require less work to remedy the problems that occur at the beginning. Nonetheless, there are still occasions where errors arise when the products reach the customers. For those situations, the products will either be sent back or ABB will personally go there to fix it. ABB has become better the past five years in locating errors in time, and deliver more error-free products to their customers.

Before a product reaches the market, it always undergoes a testing phase. ABB has good relations to their customers and often cooperates with them to have their prototypes tested. This is advantageous for both parts. For example ABB doesn't have a rolling mill to try and drive out the full potential of their stressometer and can do it with the help of their customers, while the customers are able to use a more modern product and stepping ahead their respective competitors.

3.3.4 Assembly

ABB Force Measurement manufactures a great variety of products for force and dimensional measuring, but the majority of the equipment is produced in small volumes. As a result, manual assembly is more favorable for this department. They make use of some robots to handle certain jobs, but most of their assembly work is done manually due to the low production volume and the distinctiveness required for the assembly which can only be done by man. They have not been stressing on *Design for Assembly* for some of their products, and therefore it takes longer time to manufacture them than needed.

3.3.5 Modular System – Software Modularization

The modularization in ABB Force Measurement doesn't have its focus on the hardware, but instead on the self-developed software. This is necessary for ABB because a large part of their product value today lies in the software. It is therefore imperative to be able to make use of modularization on the software. ABB is investing heavily in this area. The major advantage in modularization of the software is to reduce the number of software and integrate it into different kinds of products. If this is made successful, it will save both time and money (Norlund, 2012). ABB is very strong in MFD, they identify the similarities and commonness of their different products, and standardize it to build an infrastructure. Only designing the new feature remains each time during the development of a new product, which significantly reduces the development time. The end result will result in only a single maintenance on the infrastructure is required for maintenance on every product that is based on the same infrastructure. Modularization is greatly helping the company in many perspectives.

3.3.6 Environment

As like other companies and industries there are environment laws and rules that ABB has to fulfill in order to conduct their production. The laws concern issues such as restricting certain amount of

emissions or forbidding the use of some materials. Fortunately, ABB reaches these regulations with ease and can therefore spend their time to focus on other aspects in their organization.

4. Similarities and Differences between Practice and Theory

In this section, we will describe the similarities and differences of the various methods for product development used in practice compared to the theoretical principles. A comparison between the companies (Atlas Copco, Scania and ABB) and an elaboration for the reasons of their own methods - in the situation when it differs from the theory - will also be presented in the following analysis.

4.1 In Context of Value Analysis (VA)

Value analysis is a principle for finding the manufacturing method with the lowest cost and at the same time retaining the same functionalities of the product. None of the three companies, Atlas Copco, Scania, or ABB are using this exact method. However, Atlas Copco and ABB are using similar methods which yields the same results although they are not called value analysis.

Atlas Copco values the performance of their product more than the cost needed to produce it, which results in a higher price of the product. But due to the high performance, the customers are willing to pay for it, thus this business strategy works for them. Nevertheless, there is a limit on how high the price can become, and for calculating the various factors in order to attain the balance, ABB uses a method called *Profitability Calculations* instead of VA. In this method, they bring forth an ideal solution which compromises the trade-offs between price and functions as they make the product as profitable as possible from the price and function perspective.

ABB is very similar to Atlas Copco in a way that they value performance more than cost. There are yet situations where they manufacture products with different performances (lower performances in this context) in order to retain the price that the customers are willing to pay with the reason of not wanting to lose the market segments of the more *casual* users and customers; Atlas Copco is also doing the same in alike situations. Due to this, ABB constantly needs to have the thought of *cost* vs. *performance* during the production in the back of their head. Although they are not using the VA method, the approach is very similar.

Scania is very different from the two previously mentioned companies. The VA method is not on highest priority of their list and they only use it when they have extra time. They would prefer to put their focus on developing new products instead. Conversely, if they had the time, they would rather try to find a way to implement VA on their *existing products* than on the *new products* for decreasing production cost.

4.2 In Context of Quality Function Deployment (QFD)

To manufacture products with the purpose of pleasing and satisfying the customer and market is the philosophy behind QFD. All three companies value this viewpoint very highly. Despite that none of them practices the exact *QFD-method*, all three uses very similar methods of their own that includes most of the aspects contained in the QFD-method.

Atlas Copco for instance gathers information from other companies for the purpose of understanding and obtaining inspiration on how they should produce, develop or improve their products. Approaches are suggested and viabilities are analyzed in order to decide on what will be passed to the next step. Atlas Copco is not using the house of quality, but instead they use an identical method called *product planning*. Scania on the other hand has their own *future groups* which gathers information from customers to satisfy their needs. ABB is again also using a similar approach to QFD

by collecting information and requirements from their customers and adjust their products accordingly. They also emphasize on no matter how much you tweak your own product, it is essential for the basic function to remain.

All three companies do benchmarking to know thy enemy. Atlas Copco's external benchmarking includes disassembling their rival products to understand the engineering behind it and how they were produced. They see it as something usual since they are well aware of their competitors doing the same.

Scania has different styles of benchmarking for their development and production department. They are more secretly with the former one, while being more open with reoccurring visit by other companies for the latter. They deem that visits are good due to the companies can mutually exchange information with each other which contributes to technological advancement in the industry as well as organizational improvement within the company.

ABB thinks differently than Atlas Copco and Scania, external benchmarking along the line with *sneak-peeking* other company's products is more controversial for ABB due to ethical reason. It is also sometimes hard for ABB to do benchmarking with product comparison because they are using other techniques and measurement principles for their products compared to other companies who expertize in the same area.

Market benchmarking is widely used by all three of them with the purpose of obtaining useful information about their customer and market share.

4.3 In Context of Failure Mode and Effects Analysis (FMEA)

FMEA is a type of error analysis done based on the evaluation of imperfections that may appear on products already at an early stage during development. This is done in order to prevent and remedy the fault before it causes greater future problems. The method has very different attachments to all three of the companies.

Atlas Copco is the company that doesn't use FMEA. They have tried to implement it before, but due to they have too many components it was too troublesome and time consuming with the FMEA method. Atlas Copco employs another method called *Risk Analysis*. It checks the risks factors of projects, and validate the type and probability of the risk happening, which is in some way similar to FMEA. However, Atlas Copco can use FMEA on their products if a customer specifically demands it.

Scania has started to make use of FMEA recently on their products. They do not use it on their existing products in the market since it is not worth the trouble and time. Actual statistic of those products can already be obtained if they wanted to see where the errors usually occur. Nonetheless, for each new product that Scania releases from now on, it has to go through the FMEA procedure.

ABB uses FMEA among many of their other error analysis methods in order to find errors as early as possible during the construction phase. ABB let their customers take part in the other error analysis methods that they use. This is because ABB doesn't have the optimal facility to try their products, therefore they let their customers test them instead in a real set of conditions. By doing this, ABB will be able to discover if anything would go wrong in a real situation and environment before the product being released into the market.

4.4 In Context of Design for Assembly (DFA)

As can be heard from the name, design for assembly is used during the development of products so that its components are designed for easy assembly. All three companies are using DFA, but the degree of implementing a successful DFA varies a lot between the companies. Something they all have in common is that they focus a lot on manual assembly.

Atlas Copco has started to use DFA the recent 10 years. Due to the smaller volumes of high quality products they produce, the design is mostly for manual assembly. Their engineers gather to find the optimal solution during the design phase to determine how the assembly should be done. ABB has a similar situation as Atlas Copco, small volumes and high quality, thus design for manual assembly is also used by them. However, they aren't as good in DFA as Atlas Copco, and cases exist where products have taken longer time to manufacture than the actual time needed. To mend these gaps, they have their own ABB consultant who is professional in production systems and methods. These consultants travel around to different ABB factories in order to optimize and improve their production methods such as DFA.

Scania, yet again with same reasons as the above mentioned companies, uses manual assembly. They have tried with automatic stations, but due to the wide variation of products they have, it became hard for the robots and machines to adjust for all of them when frequent changes were implemented. Scania is the company with the most profound and clear method for DFA. They have a long DFA checklist with many requirements before establishing an assembly method appropriate for the products. They also have designers and engineers who gather during the design phase to rule out the best solution and assembly method. It should be noted that there are occasions where semi-automatics are used.

4.5 In Context of Modular Function Deployment (MFD)

Modular Function Deployment refers to an engineering technique that builds larger systems by combining smaller subsystems. The advantages of this method enable larger variation with less number of articles, moreover it decreases the lead time and risks, which in return grants economic benefits. This method, alike QFD is something that all three of our companies truly believe in.

Atlas Copco really supports the idea of modularization and states that it is important for them. They are not as experienced as the pioneer Scania in this area, but have been implementing more modularized products by each passing year. Atlas Copco states that people will definitely be seeing more modularized products from them in the future. Scania is one of the first industrial companies in Sweden that has started to use MFD. They are well aware of some of its drawback, but the advantages of this method exceed the disadvantages by far, which is the reason why Scania is still using it.

ABB uses MFD, not only on their physical products, but especially for their software development. ABB provides a wide variety of shape and size for their measuring tools due to they are used in many different kinds of industries, thus MFD is not as well applicable for the tangible products. Many of ABB's products require software to control and navigate. It will be more effective for them to use a common foundation for software that regulates the majority of their products. This is when modularization intervenes and makes it easier for development as well as maintenance, and definitely sheds some light in the creativity that can be done with modular systems.

The figure 6 below is a table of the combined result for this chapter. It gives an overview to which theoretical methods the three separate enterprises use.

	VA	QFD	FMEA	DFA	MFD
Atlas Copco	Not exactly, More focus on Performance	Yes, but not aware about it	No, too many components	Yes	Yes
Scania	No, only if they have time	Yes, but not aware about it	Yes	Yes	Yes
ABB	Yes, quality vs. cost	Yes but not aware about it	Yes	Partly, but needs improvements	Yes, especially on software

Figure 7: Table of Theoretical Methods Used

5. Conclusion - How applicable are the theoretical methods in practice?

There is nothing peculiar about different companies using different methods for product development, but how faithful these methods have been to the existing theory is what this thesis has been dwelling deeper into. Throughout the thesis, we have been handling with five theoretical principles for product development. They are the VA, QFD, DFA, FMEA and MFD. According to the companies involved in this paper, some of these methods are better known to them than others. A couple of these are used exactly as portrayed in the theory, while there are others the companies have their own version of. There are also some of the mentioned methods that the companies don't use at all.

Modular function deployment has been a vastly popular method among all three companies in concern. The main purpose of MFD is to simplify the development procedure and the future developments; companies therefore believe that this method would be sustainable for a long time in the coming future. In contrast to MFD, we have the QFD method that isn't as well-known between the companies (or at least so they say). This is the classic occasion when they aren't familiar with the name of a certain method, but once the concept of QFD is explained a bit more to them, they quickly recognize it by saying "oh, we are doing that, but we don't call it QFD". They then start to talk about the method they use to satisfy their customers, how emphasis is put on the customer quality, the market researches they deploy and so on. Ultimately they are unknowingly connecting all the dots QFD brings up. This explains that despite the unawareness about the actual theoretical principles, the philosophy of the companies' own methods is very identical to the theory.

Comparisons have been made between theory and practice and revealed that many basic concepts of the companies' methods have their roots in the theory. Even if some of the companies don't use methods exactly as they are depicted in the theory, the theories are the main base and foundation to the companies' own methods. Certain companies claim that the methods they use have been derived by themselves, but the amount of similarities between the practice and theory is a factor that cannot be overlooked.

Since theories are suited for general situations, it is inevitable for method differences to emerge from situational needs of the companies. Each company has their own criteria and standards they need to meet for product development, therefore methods adjusted to them will also be acquired. FMEA wasn't feasible for Atlas Copco, so they use their own method called *Risk Analysis* instead.

As to why similarities and differences arise, it is because theoretical methods are not always exactly applicable in every company since it depends on their strategy and structure. The companies have to reorganize their methodology - usually based on already existing methods in the theory - in order to combat problems that they may encounter and improve their systems. Again, an example is Atlas Copco who is aware about the FMEA method but cannot apply it in their company. This is due to FMEA is extremely efficient when it is applied to the analysis of elements that cause failure of the entire system, but it can be difficult for the case of complex systems that have multiple components. This is because of the quantity of detailed system information which must be considered; concurring to *Stamatis'* statements. However, this doesn't conclude that the FMEA method is unnecessary by any means but rather hard to apply in certain environments depending on the circumstances.

All theoretical methods are logical and provide useful solutions within many different areas. For instance, VA and MFD are designed to solve the economy problems, and QFD is used for answering and satisfying customer needs. FMEA and DFA are developed to reduce the probability of errors appearing and ease the assembly procedure respectively. Thus the theories are valuable tools that create a foundation for further method refinements which can be used solve profound questions that may arise. The reason for why some enterprises don't make use of the theoretical methods is prominently due to lack of knowledge within the area. Consolidating the link between practice and theory would minimize this gap. *Ledwith et al.* also mentions this from earlier studies in their article which further strengthens our conclusion.

To summarize it, the theoretical methods that exist, have the aim to assist companies to develop their products in the direction to reduce their costs and improve their customer relationship. Despite that the theories aren't applicable in all situations, it is an undeniable fact that they are beneficial to have in every company's toolkit. Even though some companies are not aware of it, fragments of the theory can be seen flowing throughout the industrial world.

6. Discussion

This chapter will discuss about the future questions of product development as well as how it can be improved.

6.1 How to improve the product development

The industrial world is continuously growing toward rationalization and modernization, and the products have to be more user-friendly. To meet the customer needs, products need to be constantly improved and developed, this will in turn be converted into profit. Therefore product development is a process that cannot be stopped or underestimated. There are at the same time a lot of internal and external aspects companies have to consider during product development, such as economy, law and processes.

A problem that may exist for the companies is the time they spend on developing methods for improving *product development* when there already exist tools and principles prepared by scholars and books that explain the same thing. A good relation and collaboration between industrial companies and academic institutes, researchers and universities will greatly contribute to undermine this current problem for some companies. We have been asking the companies if the knowledge and theory we gain from university, although not completely applicable, will eventually become useful. All of them answered that they really recommended that we were learning the background theory due to it will ease the integration with methods used in reality/practice. Therefore maybe the companies should take another look at the theory out there, since many of the answers they seek already exist.

6.2 What will the future look like?

Environment is the current question that needs special attention in today's society. Pollution and emission from the industrial companies are some worrying factors in which laws have been implemented to limit the manufacturers. Achieving these requirements will be more difficult by each year as stricter restrictions will be applied. This is a major obstacle that every company eventually has to face and encounter.

Economy is another aspect that is essential for every company, because almost everything that is done is connected to economy. Companies strive to be as profitable as possible, which is not obtainable without satisfying your customers. Economy will continuously be the core engine for a company even in future. Competitors will not stay still and will continually be seeking new methods to increase their market share. Developing new products and services with the purpose of remaining in the competition will always be an important goal.

A method that has been completely accepted and useful for the companies is MFD; since the method facilitates companies' capability in reducing their cost and improves developing process. This method contains fundamental principles that will be useful independent on how future will look like, as a result companies tend to believe that MFD will be relevant for a long time in the future. Other methods are not going to disappear either because they solve some basic problems that will always exist in any near future. With the evolution of IT and scientific fields, methods for product development also need to be altered and refined. However, the basal principles of the methods will not be replaced, but instead adjusted to fit the future demands.

7. Critical Assessment

Now that the paper is done, there are certain aspects that need to be critically reviewed. First of all we could have used more sources from different literatures to see if all information provided corresponds. Especially the academic papers and articles, the date published is something that we should pay special attention to. If some text was published 20 years ago, then the information and facts delivered may not be accurate for our current date.

When chose to do a qualitative research, it might have been a good idea to interview some more companies as well as in different areas in order to attain a broader insight of what kind of methods the industry is using today for product development.

When holding an interview, we have to understand that the things said by the interviewee might not be fully accurate. Biasness is something that cannot be fully excluded by anyone. The ideal way would be the possibility to interview other mangers or employees from different departments for the purpose of obtaining material from multiple sources and perspectives.

Due to our paper is largely based on the empirical data we have obtained, which in turn is from interviews. It might be a good idea to revise some facts against several other sources.

We have a chosen several theoretical methods to get an overview of the industry world. Further studies can be done on each method by digging deeper and explaining it with more illuminating details. Studies can also be done on a wider array of companies and markets in order to discover if it is still correlating to the theory.

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