Bachelor's project

NTNU
Norwegian University of Science and Technology
Faculty of Economics and Management
Dept. of Industrial Economics and Technology Management

Frida Vestnes

A Quantitative Analysis of the Product Development Process in the Norwegian Automobile Industry and its Comparison to the Toyota Lean Product Development Process

Bachelor's project in Economics, Management and Sustainability
Supervisor: Halvor Holtskog
September 2020

NTNU
Norwegian University of Science and Technology

SAMMENDRAG

Tittel:	Kvantitativ analyse av produktutviklingsprosessen i norsk bilindustri og sammenligning med Toyota sin Lean Produktutviklingsprosess	Dato:	15.09.2020
Deltaker/	Frida Vestnes		
Veileder(e):	Halvor Holtskog		
Stikkord/nøkkelord	Lean, produktutvikling, Toyota, norsk bilindustri		
Antall sider: 55	Antall vedlegg: 2	Publiseringsavtale inngått: ja	

Denne bacheloroppgaven, i Økonomi, ledelse og bærekraft (BØKLED) ved NTNU i Gjøvik, kartlegger den teoretiske bakgrunnen for hvordan Toyota sin Lean-produktutviklingsprosess er implementert og faktorene for at den skal fungere optimalt. Ved en eksplorativ studie ble kvantitativ data om produktutviklingsprosessen i norsk bilindustri benyttet for å danne en modell av denne. Modellen ble brukt for å kunne bedømme hvilke ulikheter og likheter mellom de påvirkende faktorene og de som er avdekket i teorien rundt Toyota sin prosess.

Formål: Finne sammenhenger og påvirkende faktorer i produktutviklingsprosessen hos norsk bilindustri og avdekke ulikheter og likhetstrekk til Toyota sin Lean-produktutviklingsprosess.

Funn: Toyota sin produktutviklingsprosess er forankret i å eliminere ikke-verdi-skapende prosesser. Dette gjøres ved å holde et sterkt fokus på å bla. øke de ansattes kunnskapsnivå, kundens definisjon av verdi, ulike teknologiske løsninger, standardiserte formelle prosesser, kontinuerlig søk etter forbedringsområder. Basert på kvantitativ data brukt i oppgaven, er det mulig å danne en modell for produktutviklingsprosessen til norsk bilindustri.

Begrensninger: Manglende representativt utvalg for alle ulike funksjoner i industrien begrenser modellen for «samtidig» utviklingen i industrien. Da den enkelte bedrifts organisasjonskart ikke er tilgjengelig er muligheten for en sammenligning her begrenset.

Konklusjon: Modellen forklarer de påvirkende faktorene i norsk bilindustri med statistisk signifikans $p<0.05$. Den viser likhetstrekk med Toyota på følgende punkter: kunderelasjon, kontinuerlig læring og søk etter forbedringer, fokus på å høyne kunnskapsnivået hos de ansatte. Ulikheter som ble avdekket er informasjonsflyten som i diskusjonsdelen blir forklart ved større grad av uformell kommunikasjon i norsk bilindustri. Det viser seg at det ikke er en enkeltperson som er innehaver av Toyota sin «Chief Engineer» rolle, men at dette ansvaret er delt mellom alle team-deltakere. Med dette er det mulig å konkludere at det i enda større grad er sentralt i norsk bilindustri å implementere Lean metoden og tankesettet i alle deler av organisasjonen for å kunne få maksimalt utbytte av den.

Type: Bacheloroppgave

ABSTRACT

Title:	A Quantitative Analysis of the Product Development Process in the Norwegian Automobile Industry and its Comparison to the Toyota Lean Product Development Process	Date : 15.09.2020
Participants	Frida Vestnes	
Supervisor	Halvor Holtskog	
Keywords	Lean, product development, Toyota, Norwegian automobile industry	
Number of pages/words: 55	Number of appendix: 2	Availability (open/confidential): open

This bachelor thesis in Economics, management and sustainability at NTNU in Gjøvik investigates the theoretical background of the Toyota Lean Product Development (LDP) process and the important factors for highest degree of efficiency. Through an exploratory study, quantitative data was used to generate a model of the product development process in the Norwegian automobile industry. The model is then used to assess the differences and similarities between the predicting variables in the product development of Norwegian industry versus the important factors in Toyota.

Purpose: To find a model that can describe the product development process in the Norwegian automotive industry and to uncover differences and similarities to Toyota's Lean product development process.

Findings: Toyota's LDP process has its main focus of eliminating non-value-adding processes. Some of the most important factors of LDP in Toyota is knowledge creation, customer's definition of value, exploring various technological solutions, standardized formal processes, continuous learning. From the exploratory research a model for the product development process for the Norwegian automotive industry was generated.

Limitations: The respondents of the survey may not be representative for all the different functions, which limits the findings related to concurrent engineering. As the organization chart of each company is not available, the comparison to Toyotas structure could not be elaborated on in detail.

Conclusion: The model that has been generated predicts the development process in the Norwegian automobile industry with a statistical significance level of $p<0.05$. The industry show similarities with Toyota on the following factors: customer relationship, continuous learning and knowledge creation. One of the differences were found to be the flow of information, whereas the Norwegian industry is assumed to be more reliant on informal communication rather than formal. The model also depicts that the Toyota's "Chief Engineer" role and responsibilities is scattered amongst all product development team members. As a result, it is critical in the Norwegian car industry to adopt every aspect of the methods and philosophies throughout their entire organization, with managerial support, to have a positive impact on product development.

Type: Bachelor thesis

Preface

This thesis marks the end of my bachelor studies within the field of Economics and Management at NTNU Gjøvik. The thesis is written by Frida Vestnes, whereas the aim has been to investigate the similarities and differences between the product development process in the Norwegian automobile industry and the Toyota Lean Product Development process.

I would like to thank my supervisor Halvor Holtskog for his dedication and keen interest in this project, his comments and prompt responses to my questions as well as his kind and understanding support. The completion of this report would not have been possible without his extensive knowledge of the subject, which has been a great resource to understand the theory presented in this report and the elements presented in the discussion section. Furthermore, I would like to thank Anne Grethe Syversen as coordinator for all bachelor assignments at NTNU Gjøvik for her patience and her understanding of the challenge it has been to balance full-time work with my studies. Lastly, I would also like to thank Karolina Paquin for her assistance in proofreading this thesis.

Longyearbyen, 15.09.2020

Frida Vestnes

Contents

List of Figures

List of Tables

Chapter 1

Introduction

Lean thinking is an extensively studied subject, whereas especially lean manufacturing and implementation is well known in the industry today. According to (F. Ballé 2007), production represents only half of the manufacturing problems found in industry. Another important source is found in the product development process. According to a National Center for Manufacturing Science report, the Toyota product development projects uses only half the time of US equivalents, with 4 times their productivity. To understand what this development process entails, this thesis aims to map the Toyota development process though a literature study. The study that is performed is mainly based on scientific papers provided by Halvor Holtskog, which was then used to find additional sources based on the reference literature of these papers. To find the reference papers, the database Oria was utilized. To further support the information found, course literature in the study program of Economics and Management at NTNU was utilized.

With the theoretical background of the Toyota development process in place, the thesis further goes into an exploratory statistical study to investigate if there exists similarities between the Toyota development process and the one found in the Norwegian automobile industry. The qualitative data was based on an extensive survey performed by Geir Ringen (NTNU) and Halvor Holtskog (NTNU) in 2008 on the Norwegian automobile industry based on the theoretical background of the Toyota Lead Development Process (LDP) as presented by Kennedy (2003). The survey covered several different topics within LDP, including:

- Knowledge - utilization and development of an employees knowledge base
- Decision making process within the team
- Planning and control - definition of roles, plans, resources and costs are controlled and managed
- Motivation and leadership - employees sense of project ownership and involvement

- Information flow - internal communication within the group
- Continuous learning - the incremental innovative process in the company based on experiences
- Formal processes - quality management, routines, procedures and information storage
- Set based concurrent engineering
- Customer relation

Resulting from that exploratory analysis, the aim of this thesis is to investigate if there exists a linear relationship between the above mentioned categories and the product development process as defined by the ”set based concurrent engineering” category. Resulting from the model that is found through this exploratory study, the different factors will then be investigated in order to explore if there exists similarities and differences between the Toyota and Norwegian automobile product development process.

Chapter 2

Background of Toyota LDP

2.1 Lean Manufacturing and -Product Development

The "Lean" terminology often refers to an operational approach, that was initially developed by the Toyota Motor Corporation, to eliminate waste in all forms; defects that required rework, unnecessary processing steps, unnecessary movement of materials or people, waiting time, excess inventory and overproduction. The process in itself involves identifying and eliminating non-value-added activities throughout the entire value chain to achieve faster customer response, reduce inventories, higher quality and improve utilisation of human resources. Simply put, the goal and philosophy of lean is "getting more done with less" (Evans 2016).

In a historical perspective, the assembly line production introduced in 1913 by Henry Ford that culminated in the achievement of mass production of his motorized vehicles in 1926 were the building bricks for Lean production. However, the key to mass production wasn't the assembly line in itself. It was the complete and consistent interchangeability of parts and the simplicity of attaching them to each other that made the assembly line possible (Womack et al. 2007).

After World War II, Taiichi Ohno and his technical collaborators, concluded that the real challenge was to create continuous flow in small-lot production. The reasoning behind this was that human need is more well represented through humble streams, rather than a few mighty rivers. At Toyota, they were able to achieved continuous flow in low-volume production, in most cases even without assembly lines, by learning to quickly change over tools from one product to the next and by "right-sizing" machines so that the production could be conducted immediately adjacent to each other (Womack & Jones 2010). The principles of Just-in-time (JIT) and pull production emerged, where customer demand triggered the production instead of the traditional push production. The transformation performed at Toyota culminated in what was defined as the Toyota Production System, or Lean Manufacturing as it is more commonly known today.

One of the most important building blocks of Lean thinking is the termonology "muda" meaning "waste", and is more specifically defined as human activity which absorbs resources but does not create any value, whereas the value can only be defined by the ultimate customer (Womack & Jones 2010). However, the term value is only meaningful when expressed in terms of a specific product, service or both at the same time, which meets the customer's needs at a specific price at a specific time. Through Lean thinking, the goal is to eliminate waste throughout the entire value chain.

The value chain is the complete set of all business activities that increases the perceived value of the product or service of the end-customer (Bø 2015). The value chain terminology was first defined by Porter (Porter 1985) and is limited to the value adding processes taking place within the frame of one specific company. As opposite to the supply chain, which can consist of several different companies and thereby a line of different value chains (Bø 2015). The value chain of a company flows from the end-customer and back through the production and backwards to the raw materials, i.e. part of the supply chain, and also includes activities that you would not typically associate with a sypply chain, such as product development. In the definition by Porter, the activities within the value chain were separated into primary activities and supporting activities as seen in Figure 2.1.

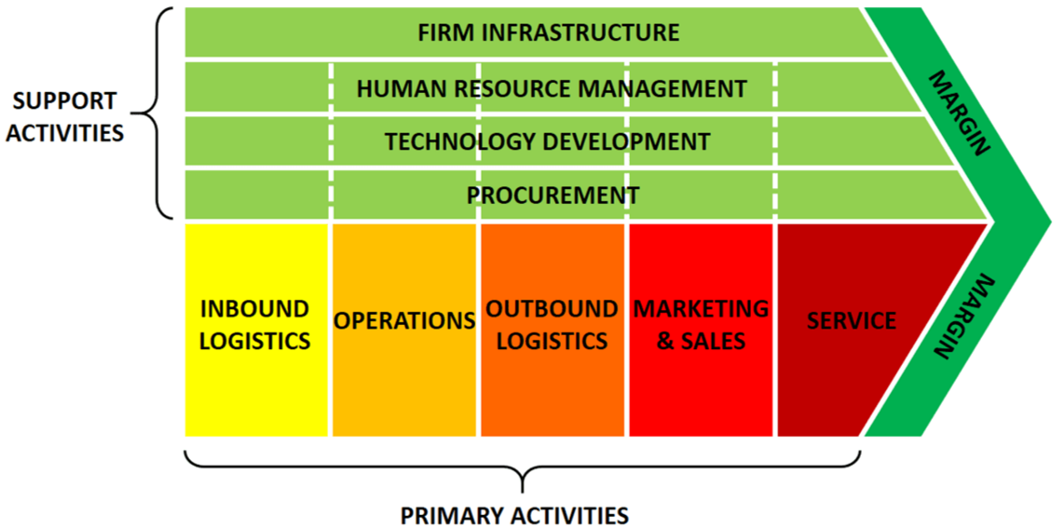

Figure 2.1. The value chain of a company as defined by Porter (Porter 1985)

Whilst ”Lean manufacturing” focuses on the method of planning, controlling and the continuous flow of the day-to-day operations and is closely linked to the supply chain aspects of the value chain (Slack et al. 2013), the Lean Product Development Process (LPD) comprises of the activities beginning with the perception of a market opportunity aligned to the company's competitive strategy and technical capacity, and ending in the production, sale, and delivery of a product, while considering all aspects that will evolve and keep the product competitive in the market until its discontinuity as seen in Figure 2.2. Even though the two terminologies are separated, they are both intertwined by the lean thinking philosophy of being “a system for the absolute elimination of waste” (F. Ballé 2007).

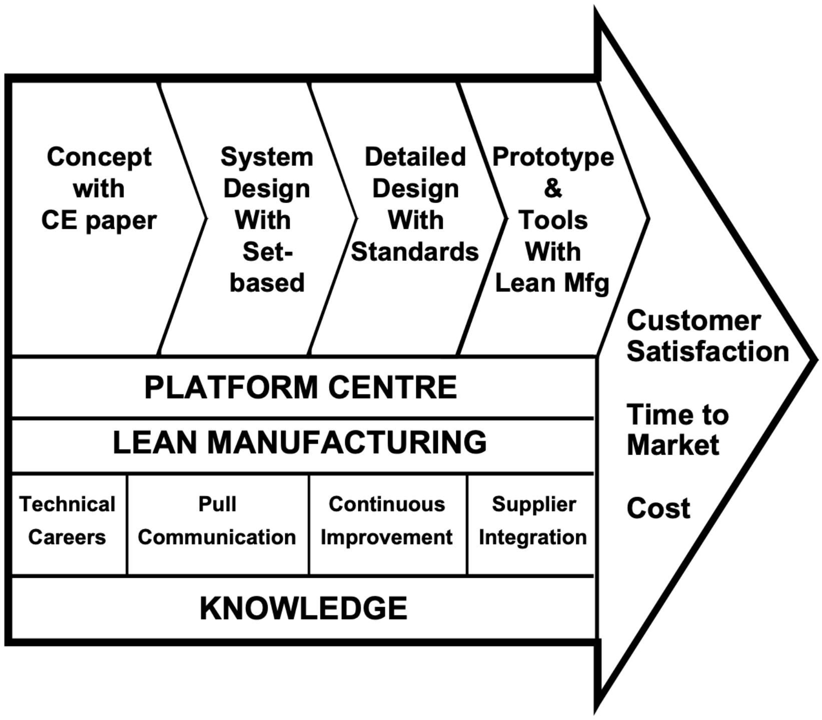

Figure 2.2. Lean Product Development Process (F. Ballé 2007)

The LPD system can be separated into four different layers:

- Process layer: The product development process
- Practice layer: lean manufacturing with the Toyota Product Development Process in production
- Organizational layer: platform centres
- Culture layer: the “knowledge-based” paradigm

The following sections within this chapter will further elaborate on these different layers.

2.2 Toyota's product development process

At Toyota, one important step in the development process, is to make sure that all of the engineers actually care about what customers think of their product. As a consequence, a strong vision for the future product is made and also communicated across all players in the development process (F. Ballé 2007). Secondly, the Toyota development process mitigates the risk of late engineering changes, which plague any industrial development process by creating chaos both in therms of rework and quality assurance. This is done by having a firm line to where the design-loop is being closed by the "perfect drawing" or "Zero EC" point (Kobe 2001). By setting such a firm line, Toyota aims to push the development-mentality of "If you think you will not have a chance to change it later, you do your homework early and you speak up if there is any doubt". The development process is therefore heavily front-loaded, which enables Toyota to focus on a precise, tightly scheduled production within the target cost.

The Lean Product Development process can be separated into four phases:

- A concept phase leading to the Chief Engineer's (CE) concept paper
- A system-designed phase with concurrent engineering
- A detailed design phase with design standards
- A prototype and tooling phase with lean manufacturing

The following sub-chapters will further elaborate on these stages within the LDP process.

2.2.1 Chief Engineer

A practice which has its roots back to the 1950s in Toyota is the notion of a "heavy-weight project manager" (Clark 1991). This person holds the title of Chief Engineer (CE) in Toyota and is responsible for the product all the way from the concept stage to the market. The CE is first and foremost a technical expert. At an organizational level, the CE has little formal authority, but is recognized for the experience, technical and communication skills. The responsibilities of the CE is extensive and entails:

- Coordinating responsibility in wide areas, not just engineering but also production and sales.
- Take responsibility for the concept creation and concept championing.
- Maintain responsibility for specification, cost target, layout and major component choices, making sure that product concept is accurately translated into technical details of the product.
- Build direct and frequent communication with designers and engineers at work level and can effectively communicate with designers, engineers, testers, plant managers, controllers, and so on.
- Establish direct contact with customers
- Walks around and advocates the product concept, rather than doing paperwork and conducting formal meetings.
- Is mostly an engineer by training. Has broad, if not deep, knowledge of total product- and process engineering. (Fujimoto 1999)

The CE has a very small dedicated team of experienced product engineers as well as manufacturing engineers, while all the other resources are in the functional organization. The CE summarizes the vision for the product in a "concept paper" which leads the development process into the system design phase (Morgan 2002).

2.2.2 System Design with set-based concurrent engineering

To further elaborate on the system design phase, it is important to establish the definition of "Concurrent Engineering"; the simultaneous consideration of more than one aspect of a system during its design phase, as seen in Figure 2.3 (Nielsen 2003).

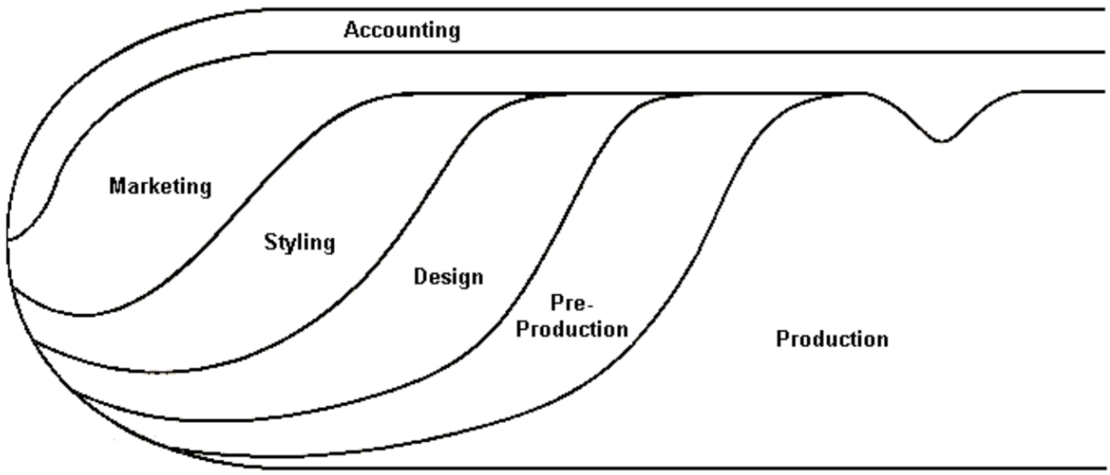

Figure 2.3. Concurrent Engineering at Toyota (Nielsen 2003)

As described in section 2.2, LDP is a front-loaded development process that aims to decrease the innovation lead-time and increase product quality by identifying product-related issues as early as possible. LDP identifies that core issues related to innovation are found in the conflict of interest between the different functions in an organization. Through the LDP process, these conflicts are then resolved through compromises where the customers view of product value and ”customer satisfaction” is of greatest importance (F. Ballé 2007).

At Toyota, concurrent engineering has been further developed into ”set-based” concurrent engineering (Sobek et al. 1999), where the process is described as follows:

1. The team defines a set of system level solutions (instead of one single solution).
2. Various possible solutions are defined for various sub-systems.
3. The different sub-system options are analyzed in parallel.
4. The analysis is used to gradually narrow the set of solutions, converging slowly towards a single solution and determine the appropriate specifications.
5. When the single solution has been established for the design, it is not changed unless absolutely necessary; In particular, the single solution is not changed to gain improvements (i.e. to climb the optimality hill) (Sobek et al. 1999)

As part of the analysis of the different sub-systems, Toyota develops two series of prototypes to check their integration. The first series is very carefully and slowly built to check all interfaces whilst using lean manufacturing techniques and the second series is fast built to identify manufacturing and assembly issues. After these issues have been resolved this stage is finalised by the production of design drawings with the objective to attain "Zero EC" upon its release (Morgan 2002).

In the second part of the development process, the focus lies on reducing variability of the product by relying on standardization of skills, processes and design. This is done to minimize the risk of waste and reworks which in turn opens up for capacity flexibility. In this process, Toyota utilizes standardisation tools such as:

- Checklists (process checklists and product checklists)
  - The engineering checklists contain detailed information concerning any number of areas including: functionality, manufacturability, government regulation, reliability, etc.
- Standardized process sheets
- Common construction sections.

The production of the engineering checklists of what can, or cannot be done as part of the operational production phase, are considered to be a key ingredient to the success of set-based concurrent engineering in Toyota (Sobek et al. 1999).

The LDP method is therefore not only front-loaded but also delaying key decisions by exploring several different design options before reaching the single solutions. This results in faster product development as it minimizes the amount of engineering changes and re-work and emphasizes the philosophy of "doing it right the first time". Furthermore, by segregating the "noisy" development process from the execution phase, the downstream process variation is minimized which is crucial to both speed and quality (F. Ballé 2007).

2.2.3 Continuous improvement

Resulting from the high degree of standardization of the product gained through the set-based concurrent engineering, the grounds for continuous improvement for the development process has been set. Through TPS, Toyota has introduced the concept of "hansei" (F. Ballé 2007) which translates to "self-reflection". As described in section 2.1 LDP and lean manufacturing has certain similarities, as they are both systems to eliminate waste. "hansei" is also applied in Lean manufacturing, through the continuous incremental improvement process known as "kaizen". At a Kaizen event, the engineers take a specific area that is in need of improvement, e.g. a bottle-neck in production, and within a limited time frame of 72-hours perform an analysis by utilizing different lean tools such as value-stream-mapping to identify potential solutions to solve the issues in manufacturing (Slack et al. 2013).

Similarly, through the "hansei" process, the engineers work with the product development team to challenge the activities that have been done, identify production issues and perform an overall review of the emerging product. With this process, the product is "certified" in a meticulous manner in order to minimize the risk of operational issues and changes required after the production has started (F. Ballé 2007). Such "hansei" meetings can be performed at different stages of the development process and from the learning outcomes the different check-lists and other standard documents are improved. Through this procedure, TPS provieds not only an opportunity to learn and improve, but also focus all involved parties on the common outcomes and the shared destiny of the team (Morgan 2002).

2.3 Toyota Organizational Structure

From the beginning, Toyota was organized in a functional organizational structure (Clark 1991). In a functional structure, each of the major business functions within the company is managed by a functional manager, i.e. a marketing manager leads the marketing function who reports to one person who usually has the title as CEO (Barney 2014). In time, this structure became unsustainable for Toyota due to its growth where one manager had too many projects going in parallel within the functional department and the Chief engineer had to coordinate too many people from different departments. Toyota therefore went through a reorganization and shifted from a function-oriented to a multi-project-oriented structure and introduced platform centers, as seen in Figure 2.4, that focused on developing a specific product family, i.e. rear-wheel-drive platforms and vehicles. Each platform center was managed by the General Manager, who was in charge of the functional managers and chief engineers and the platform also has a separate planning division. In this manner, the structure of the company encourages coordination within the different projects, helps optimize the utilization of human resources and product standardization (Nobeoka & Cusumano 1995).

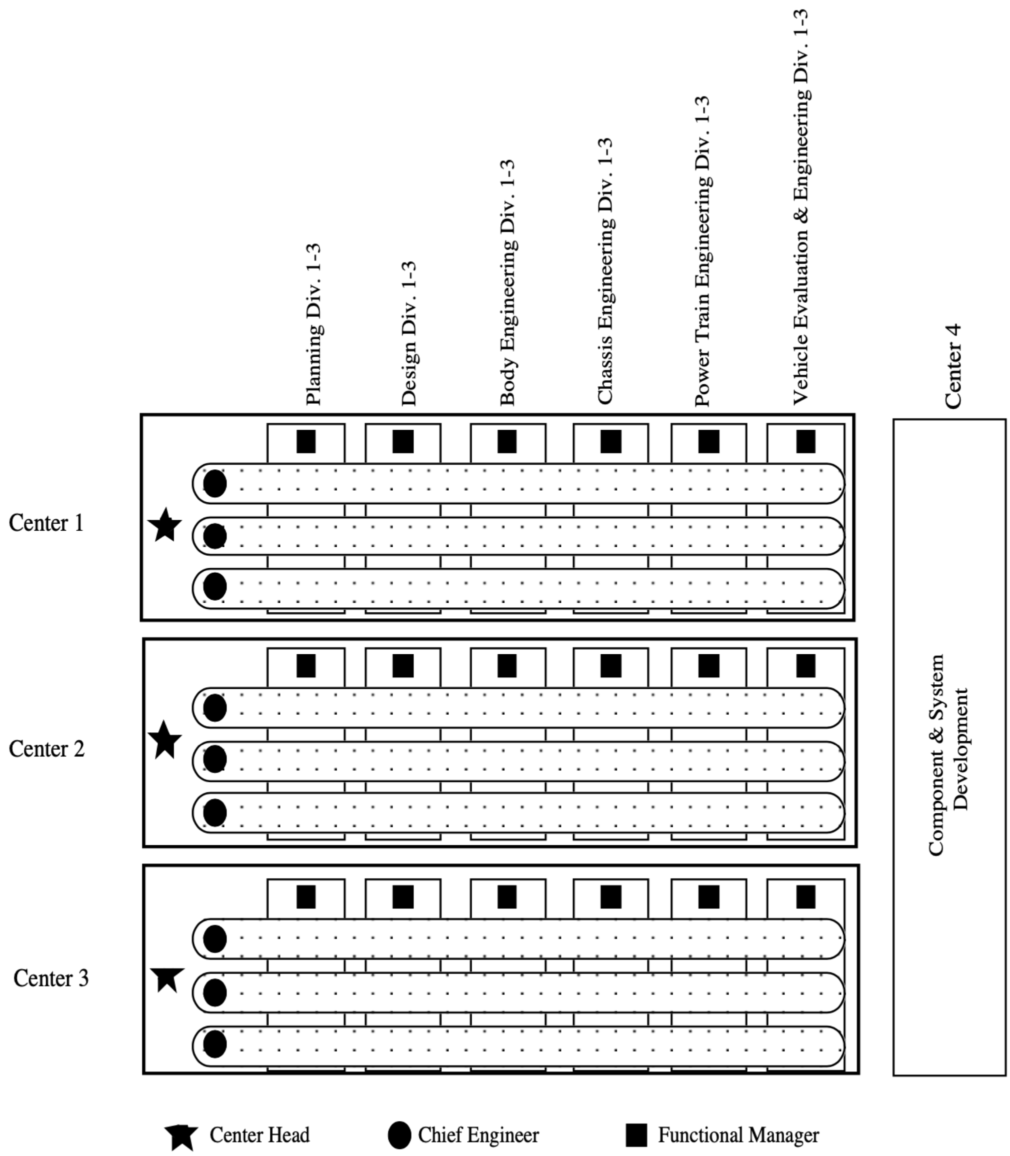

Figure 2.4. Platform centers at Toyota after the re-organization (Nobeoka & Cusumano 1995)

2.3.1 Information flow

In Toyota, the organization of the information flow within the company bears a resemblance to the famous kanban just-in-time system in its factories. The Toyota principle is that the participants in the design team should be able to obtain the information when they need it and in the right amount i.e. a pull system of information flow (F. Ballé 2007). It is therefore up to the downstream processes to retrieve the information from the upstream ones. With this type of information flow it requires that anyone can and is able to talk to anyone else in the company and that the relevant information is available at an identifiable and known place. Furthermore, in case a decision involves a large number of people from different functions in the organization the process follows three stages

1. Initiate one or more rounds of written exchange
2. If the problem persists, hold a face-to-face meeting
3. If there is still a problem, meet with the Chief Engineer

This information flow and established structure of communication aims to aid the decision making processes, so that the decision makers may make a conclusion based on the correct information and involve the correct people.

2.4 The Toyota Culture

Laying underneath the organizational structure is the Toyota culture. According to Jacobsen (2019) a culture is defined as a set of common opinions amongst humans in a community; a system of common values, symbols and opinions in a group and forms the foundation of how individuals should behave in an organization. Culture is based on learning and is maintained only as long as it is perceived as correct. To understand the Toyota culture it is important to understand how deeply entrenched "lean thinking" philosophy is and the fact that it is functioning almost as the "DNA" of Toyota (F. Ballé 2007). The philosophy can according to Morgan (2002) be described as "customer satisfaction with lean manufacturing". The lean approach to manufacturing can be seen in every aspect of its product development process. In Toyota one can therefore see practices that are not seen in an organizational chart, but are important in the LDP process. One example of that is the "genchi genbutsu" which can be translated to "go see for youself", where the engineers in the concept phase go around the production area and dealership to get a hands-on impression of the product they are developing. One can therefore see how much of a vital role the people in the organization themselves play and that the development of their skills is paramount. As described by the researchers Spear and Bowen:

"All the organizations we studied that are managed according to the Toyota production System share an overarching belief that people are the most significant corporate asset and that investment in their knowledge and skills are necessary to build competitiveness. That's why at these organizations all managers are expected to be able to do the jobs of everyone they supervise and also teach their workers how to solved problems according to the scientific method." (Spear & Bowen 1999)

It is therefore not unexpected that Toyota's engineers have a highly technical profile, as a result of the strong focus on specialization within a function and that a career within the company is built on several years of increasing technical and management responsibility.

2.4.1 Knowledge creation

With the strong technical focus both within the culture and the product development process itself, Toyota as a company is more "knowledge-based" rather than structure-based and relies heavily on knowledge creation (F. Ballé 2007). In an organization, knowledge functions as a renewable resource that accumulates and can be re-used (Jacobsen 2019). It can be separated into two categories; tacit knowledge, that cannot be expressed in writing, and explicit knowledge, that can be expressed, communicated and be discussed. After studying the interaction between tacit- and explicit knowledge Nonaka et al. (1995) he found that there exists four different components of knowledge creation in an organization:

1. socializing - knowledge is transferred without consciously being aware of it.
2. externalization - the tacit knowledge is made known (e.g a colleague informs others of the secret behind the work that was done that led to the success)
3. combining - organizing the already known explicit knowledge into a system
4. internalization - the explicit knowledge is used in such a large extent within the company that it is incorporated and adapted into tacit knowledge. (Jacobsen 2019)

Nonaka et al. (1995) argued that innovation is caused by the interaction between the "knowledge spirals" between tacit and explicit knowledge (Nonaka et al. 1995).

As mentioned, in Toyota there exists a strong commitment to knowledge creation. This can be seen through the technical career paths that exists for the engineers, which encourages specialization within their own fields. For the young engineers, Toyota in addition assigns them to improvement projects to utilize their ability to question the established methods and look for improvements Morgan (2002). With the pull-based information flow in the company the exchange of information between different specialists is supported. Coupled with the concept of "Hansei" of continuous improvement, the knowledge creation and human development can be considered as the very core of the Toyota LDP process (F. Ballé 2007). This aspect is often overlooked when other companies try to implement LDP according to TPS, as it is seemingly easier to try to launch the utilisation of other Lean tools like kanban, heijunka and jidoka. According to Convis (2001), "For TPS to work effectively, it needs to be adopted in its entirety, not piecemeal. Each element of TPS will only fully blossom if grown in an environment that contains and nourishes the philosophies and managerial practices needed to support it."

Chapter 3

Methodology

The work performed in this thesis is based on secondary statistical data that has retrieved by Geir Ringen and Halvor Holtskog at the Norwegian University of Science and Technology. The survey utilized LDP to map several different relations within three cornerstones of LDP; product development, organization and the culture within different companies based in the Industrial Park of Raufoss. The survey had in total 122 respondents out of 150 from 18 different companies. The survey was sent to all Norwegian companies that deliver products to the automobile industry, whereas only their employees in the product development departments could become a respondent. In case of a no-return on the survey, Holtskog reported that these were followed up with via phone calls or in person to ensure that a response was provided. The professions of the different respondents were mapped and can be seen in Figure 3.1. The majority of respondents are working within the field of design and engineering, which is expected in project oriented organizations as exemplified in the Toyota organization in Figure 2.4. In terms of evaluating phenomenons within the field concurrent engineering, the different departments are represented in this survey and the respondents are therefore considered as representative to provide statistic validity of the analysis.

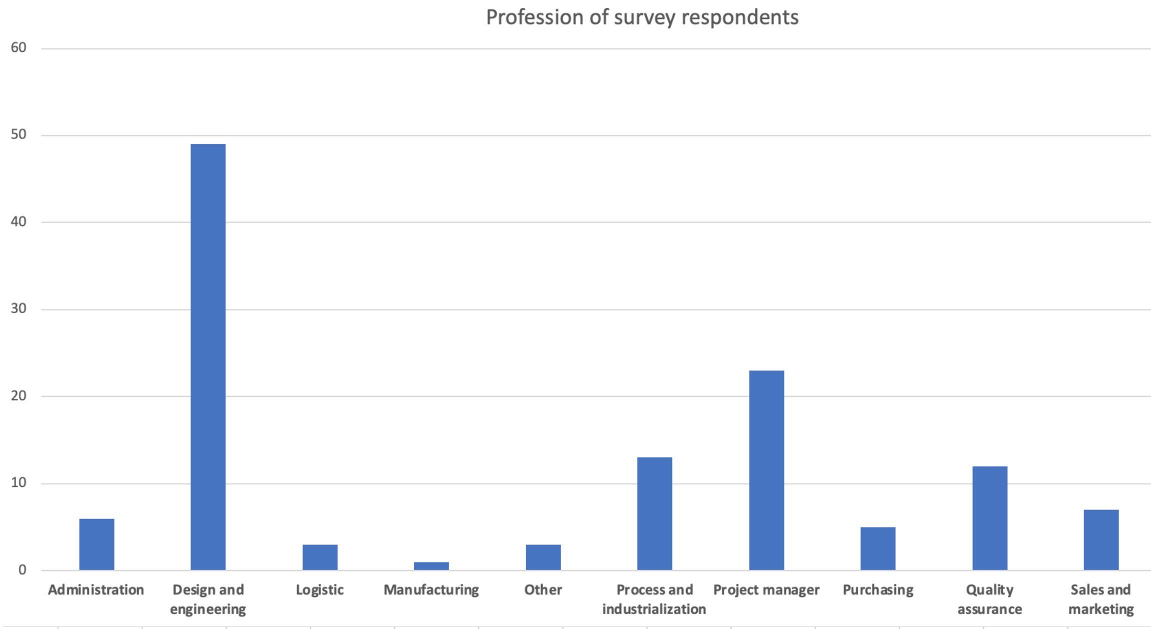

Figure 3.1. Profession of survey respondents

The stochastic variables, which is a function that contains the values of the numerical outcome of the phenomenon (Johannessen 2011), was then grouped into different categories within the different aspects of LDP:

- Knowledge - utilization and development of an employees knowledge base
- Decision making process within the team
- Planning and control - definition of roles, plans, resources and costs are controlled and managed
- Motivation and leadership - employees sense of project ownership and involvement
- Information flow - internal communication within the group
- Continuous learning - the incremental innovative process in the company based on experiences
- Formal processes - quality management, routines, procedures and information storage
- Set based concurrent engineering
- Customer relation

The complete set of variables included into the database that was built in SPSS Statistics version 26.0.0.0 is found in Appendix A. The data mainly consists of 5-point Likert scale items, where 1=small degree and 5=large degree. The variables were therefore coded in the SPSS database accordingly and as ordinal variables. The nominal variables, i.e. profession of the respondents, was only used to evaluate the level of representation of the population. An analysis to find consistency between the variables within the different categories were then performed, with the goal of establishing indicators for each category which could be used to investigate in an exploratory manner if there exists statistically significant correlations between these different categories.

3.1 Cronbach's alpha

Within the field of psychometric statistics, which is concerned with the theory and techniques of psychological measurements, Cronbach introduced in 1952 the coefficient alpha also known as Cronbach's alpha. The coefficient is an estimate of reliability, more specifically an indicator of internal consistency reliability in the data. The coefficient can be used for both dichotomous (can take two values e.g. "yes" and "no") and continuously scored variables. The sample coefficient alpha is defined by (Zhang & Yuan 2016):

$$\hat{\alpha} = \frac{p}{p-1}\left(1 - \frac{\sum_{i=1}^{p} s_{ii}}{\sum_{i=1}^{p}\sum_{j=1}^{p} s_{ij}}\right) \tag{3.1.1}$$

where p is the total number of indicators used in the analysis and s_{ij} is the sample covariance matrix. The value is defined from 0-1, whereas 0.00 indicates no consistency in the measurements, whilst 1.00 indicates perfect consistency in the measurements. In the case where α=0.7 this means that 70% of the variance in the score is reliable variance, whilst 30% is error variance. The coefficient thereby indicates that there exists a certain level of internal consistency in the composite scores, i.e. the sum (or average) of two or more scores, whereas a fully consistent score would entail that if the data was unlimited it would identify the underlying truth. The alpha value was therefore used to investigate if the variables in the different categories of LDP could be summed into one index as long as the alpha value is sufficiently high. The reported cutoff value of alpha that should be used varies in litterature, according to Lance et al. (2006) the most cited reference is Nunnally (1978) who concluded that the acceptable cut-off value of alpha for exploratory research should be 0.7. However, according to Sekaran (Sekaran & Bougie 2016) Cronbach alpha is considered as poor when it is below 0.6. In the analysis performed in this thesis the cut-off level has therefore been set to 0.6.

The most important assumption that the calculation of the alpha constant is unidimensionality in the variables used for the analysis. According to (Sijtsma 2008) the alpha value is persistently and incorrectly taken to be a measure of internal consistency and that the items in the test "measure the same thing", i.e. unidimensional, however this is not correct. Hayes & Coutts (2020) suggests that the McDonald's Omega should be utilized instead, however, this model is not available in SPSS and creating a macro for this was considered as out of scope of this thesis. In order to ensure that the variables used in the Alpha analysis are unidimensional, a factor analysis must be performed. This was done for all categories of variables used in this thesis.

3.2 Multiple regression

In a multiple regression analysis one of the the variables is regarded as a random variable or dependent variable, whilst the other are regarded as ordinary variables that can measure without substantial error and is called independent variables. Through the analysis, one can investigate if there exists a statistically significant dependency of the dependent variable and the independent variables. In an ordinary regression analysis, where there exists one dependent variable Y and one independent variable x, the mean μ of Y can be expressed as a function of x, $\mu = \mu(x)$ (Kreyszig 2006). This resulting curve is called the regression line:

$$\mu(x) = \kappa_0 + \kappa_1 x \tag{3.2.1}$$

whereas κ_0 is a constant, κ_1 is the gradient of the curve. By utilizing the least square principle, where the straight line is fitted through the given point so that the sum of the squares of the distance of thos two points from the straight line is minimum in the y-direction, it is possible to determine the sample regression line:

$$y = k_0 + k_1 x \tag{3.2.2}$$

Whereas the coefficients are defined as

$$k_0 = \bar{y} - \hat{\beta}_1 \bar{x} = \frac{\sum_{i=1}^{n} y_i}{n} - b_1 \frac{\sum_{i=1}^{n} x_i}{n} \tag{3.2.3}$$

$$k_1 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{n}(x_i - \bar{x})^2} = \frac{SS_{xy}}{SS_{xx}} \tag{3.2.4}$$

In a multiple regression, the model is specified as :

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_m x_m + \varepsilon \tag{3.2.5}$$

where y is the dependent variable, x_j represents the 1-m number of different independent variables, β_0 is the intercept and β_j the corresponding m regression coefficient and ε is the random error assumed to be normally distributed with mean zero and variance σ^2. To determine the strength of the linear relationship between the dependent and independent variables the coefficient of multiple correlation, R^2 can be used (Freund 2006):

$$R^2 = \frac{SS_R}{SS_T} \tag{3.2.6}$$

Whereas SS_R is the residual sum of squares and SS_T is the total sum of squared difference between the observation and the mean value of the dependent variable. The coefficient has a value of 0-1, where 1 indicates a "perfect" linear relationship. There is no rule to what value provides a "good" regression, however, within the field of social and behavioral science a determination of 0.3 or higher is considered quite "good" (Freund 2006).

The multiple regression model with the least square principle is based on the assumptions (Takezawa 2014) that:

- Statistically relevant variables have not been omitted
  This is tested for by evaluation through the F-test, whereas the overall significance of the multiple regression model is found. If the F-test proves to be statistically significant it is probable to assume that there actually exists a linear relationship between the variables. Furthermore, the R^2 value that indicates the difference between the observation and mean value of the dependent variable can be used to indicate how well this linear relationship exists in the model. In addition,

the resulting relationship will be discussed based on the theoretical background in chapter 5.

- $N(\varepsilon)$ - Multivariate Normality

  Multiple regression assumes that the residuals are normally distributed. This can be seen in a histogram of the residuals, as well as tested in SPSS via two tests of normality, Kolmogrov-Smirov and Shapiro-Wilk.

- $Var(\varepsilon) = \sigma^2 < \infty$ - Homoscedasticity

  Multiple regression assumes that there exists a constant variance in the residuals. To test for this, a scatter plot of the residuals vs the predicted values was generated to see if there were any clearly identifiable pattern where the residuals increased or decreased with the predicted values. Furthermore, a Breusch Pagan test was performed, where the squared value of the residuals was used as a dependent variable in a linear regression analysis. In this test, the H_0 is that there does not exist a relation between the residuals and the independent variables. A significance level set to $p>0.05$ must be proven in the analysis of variance (ANOVA) to not discard the H_0.

- $Cov(\varepsilon_i, \varepsilon_j) = 0$ - No autocorrelation

  This means that the residuals must no be correlated with eachother in a time-series. In order to test for this, the Durbin Watson value generated for the multiple regression can be used to determine the autocorrelation. Since the data used in this analysis is not a time-series, this is considered not to be relevant for this analysis.

- $Cov(\varepsilon, X) = 0$ - no multicollinearity

  This means that there should not be a correlation between the different independent variables. To detect the precense of multicollinearity, the Variance Inflation Factor (VIF) can be used. The VIF is calculated based on the predictors in the model, i.e. SPSS is used to run a multiple regression where one of the independent variables are used as a dependent variable and the others are left as independent variables. This is then done successively for all the independent variables, and if the VIF value is below 3.0 for the predictors does not bring about multicollinearity.

Chapter 4

Results

4.1 Independent variables

For each category defined based on the LDP process, the coefficient alpha was calculated in SPSS. in order to test for the assumption of unidimensionality, a factor analysis was performed.

4.1.1 Index A: Knowledge Creation

For the first category, knowledge creation, the factor analysis results as seen in Table 4.1 suggests that the items fit onto a single theoretical construct as the other components have an eigenvalue less than 1 and would account for more than 50% of the total variance. All four variables can therefore be considered as unidimensional and Cronbach's alpha can be used.

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.086	52.143	52.143	2.086	52.143	52.143
2	.995	24.866	77.008			
3	.695	17.369	94.378			
4	.225	5.622	100.000			

Extraction Method: Principal Component Analysis.

Table 4.1. Factor analysis of the category A: knowledge

SPSS was then used to perform a reliability analysis of the variables, where α was found to be 0.674. Even though this would satisfy the cut-off level as defined in section 3.1, as seen in Table 4.2 if the first variable, relating to how well the respondent felt that their knowledge was being utilized was removed in order to reach a level of $\alpha = 0.766$. This means that 76.6% of the variance in the composite score of knowledge creation is associated with the three remaining items and is reliable variance. This could be expected as this variable is measuring the current level of knowledge usage whilst the other relate to the continuous learning process and knowledge creation. The first variable was then removed before the index A was calculated by summation of the composite scores and divided by the number of scores i.e. three in order to maximize the index reliability.

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
A_UseOfKnowledge	9.02	6.335	.140	.040	.766
A_UpToDateKnowledge	9.57	5.510	.428	.193	.635
A_FurtherEducation	10.31	3.363	.667	.617	.436
A_AttendCourses	10.27	3.411	.662	.597	.441

Table 4.2. Reliability analysis of the category A: knowledge, with a resulting coefficient $\alpha = 0.674$

4.1.2 Index B: Decision Making

For category B, the decision making process, the factor analysis results as seen in Table 4.3 suggests that the items fit onto a single theoretical construct as only one component had an eigenvalue higher than 1. All five variables can therefore be considered as unidimensional and Cronbach's alpha can be used.

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.533	50.665	50.665	2.533	50.665	50.665
2	.960	19.208	69.873			
3	.549	10.987	80.860			
4	.527	10.547	91.407			
5	.430	8.593	100.000			

Extraction Method: Principal Component Analysis.

Table 4.3. Factor analysis of the category B: decision making process

This resulted in an $\alpha = 0.514$, which does not reach above the cut-off value of 0.6. As seen in Table 4.4 if the last variable, seeking information to how decisions are made, was was removed the alpha constant would reach a level of $\alpha = 0.793$. This result was expected as the last variable was not originally based on the Likert scale, but was attempted to be converted to this scale so that it would be consistent with the other stochastic variables but this seems to be an insufficient method of conversion, which is further supported by the item-total correlation value being negative for this variable.

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
B_problemSolvingCossFunc	12.74	5.489	.512	.338	.326
B_InvolvedInTeam	12.67	5.208	.488	.435	.319
B_TeamWorkAsUnit	13.07	5.356	.520	.391	.314
B_InvolvedInDecisionMaking	12.57	5.362	.431	.334	.356
B_ReachingDecision	14.49	7.940	-.193	.053	.793

Table 4.4. Reliability analysis of the category B: decision making process, with a resulting coefficient alpha = 0.510

4.1.3 Index C: Planning and Control

For category C, planning and control, the factor analysis results as seen in Table 4.5 suggests that the variables fit into three components and they are therefore multidimensional. The alpha coefficient can therefore not be calculated based on all variables, but only on the different components.

Pattern Matrix[a]

	Component		
	1	2	3
C_MilestoneAndPlanKnown	.839		
C_RolesAndResponsibilityKnown	.793		
C_FollowUpCostTimeScheduleResources	.686		
C_OwnPlanning	.551	.481	
C_PlanChanges		.887	
C_MkProductForCustomer			.807
C_PeopleInProject			.624

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

a. Rotation converged in 7 iterations.

Table 4.5. Pattern matrix result of factor analysis of category C: planning and control, which consists of three different components

For the first component, the factor analysis as seen in Table 4.6 shows that this component accounts for more than 50% of the total variance.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.159	53.971	53.971	2.159	53.971	53.971
2	.831	20.768	74.739			
3	.585	14.617	89.357			
4	.426	10.643	100.000			

Extraction Method: Principal Component Analysis.

Table 4.6. Factor analysis of the first component of category C: planning and control

Cronbach's alpha was used on the first component, and the results can be found in Table 4.7, and the resulting alpha value for this category was found to be α=0.708. As seen in the results, if any of the variables were deleted the alpha value would decrease. The alpha coefficient was also calculated for the two other components of this category, whereas the 2nd component α=0.291 and third component α=0.121, which does not reach the cut-off level and they could not be used as additional indicators in the analysis. The variables in the first component were therefore included into one single Index for category C.

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
C_RolesAndResponsibilityKnown	10.51	4.170	.486	.329	.652
C_MilestoneAndPlanKnown	10.42	4.558	.571	.358	.608
C_FollowUpCostTimeScheduleResources	10.43	4.264	.524	.281	.626
C_OwnPlanning	9.88	4.600	.414	.222	.693

Table 4.7. Reliability analysis of the first component of category C: Planning and control, with a resulting coefficient alpha = 0.708

4.1.4 Index D: Motivation and Leadership

In the analysis of category D, motivation and leadership, the factor analysis results as seen in Table 4.8 suggests that the variables fit into two components and the variables are therefore multidimensional. The alpha coefficient can therefore not be calculated based on all variables, but only on the different components.

Pattern Matrix[a]

	Component 1	Component 2
D_JudingResults	.783	
D_DegOfAffectingGoal	.710	
D_ResponsibleForResults	.707	
D_FeedbackOnWork		.753
D_PerformanceReward		.723
D_MasterDailyChallenges		.571

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

a. Rotation converged in 5 iterations.

Table 4.8. Pattern matrix result of factor analysis of category D: motivation and leadership, which consists of two different components

For the first component, an $\alpha = 0.578$ was reached, and for the second component α=0.42 which does not reach the cut-off level as defined in section 3.1. However, In Table 4.9, one can see that the alpha value would increase to α=0.648 by removing the first variable in the first component, which would be above the cut-off value of 0.6. The remaining two values were then summed into index D.

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
D_DegOfAffectingGoal	8.07	1.783	.294	.089	.648
D_JudingResults	7.54	1.939	.470	.260	.374
D_ResponsibleForResults	7.33	1.847	.425	.243	.420

Table 4.9. Reliability analysis of the first component of category D: motivation and leadership, with a resulting coefficient alpha = 0.578

4.1.5 Index E: Information Flow

For category E, information flow, the factor analysis results as seen in Table 4.10 suggests that the variables fit into two components and the variables are therefore multidimensional. The alpha coefficient can therefore not be calculated based on all variables, but only on the different components.

Pattern Matrix[a]

	Component 1	Component 2
E_FindLastUpdatedInfo	.837	
E_RightInfoRightTime	.804	
E_InfoAvailableInOrg	.650	
E_TeamInternalComm	.537	
E_OtherTeamsComm		-.918
E_UtiliseInfoFromOtherTeams		-.875

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

a. Rotation converged in 4 iterations.

Table 4.10. Pattern matrix result of factor analysis of category E: motivation and leadership, which consists of two different components

The alpha value was computed for the first component and found to be α=0.697, and as seen in Table 4.11 removal of one of the variables would reduce the alpha coefficient. The second component, consisting of two variables, had an α=0.782. As both these components made the cut-off of alpha, the category E was split into two; IndexE1 consisting of component 1 variables and IndexE2 consisting of component 2 variables.

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
E_FindLastUpdatedInfo	9.96	3.023	.579	.382	.569
E_RightInfoRightTime	9.86	3.481	.500	.322	.627
E_InfoAvailableInOrg	9.94	3.202	.412	.177	.681
E_TeamInternalComm	9.50	3.170	.454	.207	.651

Table 4.11. Reliability analysis of the category E: information flow, with a resulting coefficient alpha = 0.697

4.1.6 Index F: Continuous Learning

For category F, continuous learning , the factor analysis results as seen in Table 4.12 suggests that the variables fit into two components and the variables are therefore multidimensional.

The alpha coefficient can therefore not be calculated based on all variables, but only on the different components.

Pattern Matrix[a]

	Component	
	1	2
F_EvaloOfImprovements	.924	
F_DeptContImprovement	.852	
F_ContImpEmphasisAcrossTeams	.806	
F_ImplementationOfAcceptedImprovements	.777	
F_DocumentationOfLessonsLearned	.567	.336
F_SeekInfoFromOthers	-.311	
F_ExperiencesFromPrevProjects		.904
F_LessonsFromManufacturingUsedForNPD		.857

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

a. Rotation converged in 5 iterations.

Table 4.12. Pattern matrix result of factor analysis of category F: continuous learning, which consists of two different components

The alpha value was computed for the first component and found to be α=0.604, and as seen in Table 4.13 removal of the last variable would increase the α=0.873. The second component, consisting of three variables, had an α=0.751 and as seen in Table 4.14 removal of a variable would reduce the alpha coefficient. As both these components made the cut-off of alpha>0.6, the category F was split into two; IndexF1 consisting of component 1 variables except the last one, and IndexF2 consisting of all component 2 variables.

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
F_EvaloOfImprovements	16.03	8.112	.688	.610	.403
F_DeptContImprovement	15.66	8.871	.634	.547	.446
F_ContImpEmphasisAcrossTeams	16.07	8.656	.613	.534	.445
F_ImplementationOfAcceptedImprovements	15.54	9.224	.581	.481	.471
F_DocumentationOfLessonsLearned	16.35	9.117	.528	.444	.483
F_SeekInfoFromOthers	14.49	15.243	-.369	.145	.873

Table 4.13. Reliability analysis of the first component of category F: continous learning, with a resulting coefficient alpha = 0.604

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
F_ExperiencesFromPrevProjects	5.58	2.574	.588	.378	.660
F_LessonsFromManufacturingUsedForNPD	5.47	2.874	.646	.424	.601
F_DocumentationOfLessonsLearned	6.15	2.951	.515	.274	.740

Table 4.14. Reliability analysis of the second component of category F: continous learning, with a resulting coefficient alpha = 0.751

4.1.7 Index G: Formal processes

For category G, formal processes, the factor analysis results as seen in Table 4.15 suggests that the variables fit into two components and the variables are therefore multidimensional. The alpha coefficient can therefore not be calculated based on all variables, but only on the different components.

Pattern Matrix[a]

	Component 1	Component 2
G_FormalRoutineQA	.843	
G_OthersFollowFormalRoutineQA	.839	
G_FindWhatYouSearchFor	.739	
G_InfoIsLatestVersion	.497	
G_MeetingPartShowUpInTime		-.776
G_MeetingPartArePrepared		-.757
G_LatestOInfoLocation		.434

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

a. Rotation converged in 6 iterations.

Table 4.15. Pattern matrix result of factor analysis of category G: formal processes, which consists of two different components

The alpha value was computed for the first component and found to be α=0.726, and as seen in Table 4.16 removal of the last variable would increase the α=0.751. The second component, consisting of three variables, however, in the matrix one can see that in case all were included there would exist a negative correlation between the items. This was expected as that variable was nominal, instead of ordinal as the other variables. The last variable was therefore removed and the issue of negative correlation was no longer present. The two remaining variables reached an α=0.657. As both these components made the cut-off of alpha>0.6, the category G was split into two; IndexG1 consisting of component 1 variables except the last one to maximize the alpha coefficient, and IndexG2 consisting of the first two variables of component 2.

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
G_FormalRoutineQA	10.62	4.009	.494	.392	.678
G_OthersFollowFormalRoutineQA	10.91	3.672	.621	.464	.607
G_FindWhatYouSearchFor	10.82	3.591	.589	.351	.621
G_InfoIsLatestVersion	10.75	3.715	.394	.213	.751

Table 4.16. Reliability analysis of the first component of category G: formal processes, with a resulting coefficient alpha = 0.726

4.1.8 Index I: Customer Relation

For category I, customer relation, the factor analysis results as seen in Table 4.17 suggests that the variables fit into two components and the variables are therefore multidimensional. The alpha coefficient can therefore not be calculated based on all variables, but only on the different components.

Component Matrix[a]

	Component	
	1	2
I_CustomerReqAreUnderstood	.804	.326
I_CustomerChangeOrdersUnderstoodProjMembers	.768	
I_CustomerReqAvailable	.758	
I_DocumentationAndRecalcOfCustomerChangeOrders	.731	
I_TeamCommunicationWithCustomer	.673	
I_FreqOfCommunicationWithCustomer		.911

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

Table 4.17. Pattern matrix result of factor analysis of category I: customer relation, which consists of two different components

For the first component, an α=0.80 was reached and all variables were included into the index as an exclusion would reduce the alpha coefficient as seen in Table 4.18. For the second component, α=0.080, which does not reach the cut-off at 0.6. Therefore, all variables in the first component were added to the index of category I.

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
I_CustomerReqAreUnderstood	14.80	7.191	.663	.532	.740
I_CustomerReqAvailable	15.02	6.958	.586	.473	.760
I_DocumentationAndRecalcOfCustomerChangeOrders	15.05	6.604	.573	.400	.768
I_CustomerChangeOrdersUnderstoodProjMembers	15.23	6.817	.614	.437	.751
I_TeamCommunicationWithCustomer	14.85	7.896	.498	.291	.786

Table 4.18. Reliability analysis of the category I: customer relation, with a resulting coefficient alpha = 0.80

4.2 Dependent Variable

4.2.1 Index H: Set-based Concurrent Engineering

For category H, set-based concurrent engineering, the factor analysis results as seen in Table 4.19 suggests that the variables fit into three components and the variables are therefore multidimensional. The alpha coefficient can therefore not be calculated based on all variables, but only on the different components.

Pattern Matrix[a]

	Component		
	1	2	3
H_HandOverToProduction	.850		
H_RiskAnalysisOfTechSolution	.786		
H_WillingToTryNewTechSolutions	.560		
H_DesignIterationsBeforeFreeze		-.805	
H_SearchForSeveralTechSolutions		-.659	
H_TestBeforeDesignFreeze	.322	-.512	
H_UseOfOffTheShelfSolutions			.802
H_DesigningForCurrentProdMethods			.797

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

a. Rotation converged in 10 iterations.

Table 4.19. Pattern matrix result of factor analysis of category H: set-based concurrent engineering, which consists of three different components

For the first component, an α=0.611 was reached, which is above the cut-off value, and an exclusion would reduce the alpha coefficient as seen in Table 4.20. For the second component, α=0.516, which does not reach the cut-off at 0.6 and removing variables would only reduce the alpha coefficient as seen in Table 4.21. For the third component, α=0.099, which does not reach the cut-off at 0.6 Therefore, all variables in the first component were added to the index of category H.

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
H_HandOverToProduction	10.56	4.011	.448	.257	.496
H_RiskAnalysisOfTechSolution	10.43	3.400	.543	.312	.407
H_WillingToTryNewTechSolutions	9.97	4.838	.305	.120	.598
H_TestBeforeDesignFreeze	10.23	4.499	.283	.130	.619

Table 4.20. Reliability analysis of the first component of category H: set-based concurrent engineering, with a resulting coefficient alpha = 0.611

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
H_DesignIterationsBeforeFreeze	7.18	2.378	.237	.070	.556
H_SearchForSeveralTechSolutions	7.15	1.929	.434	.194	.243
H_TestBeforeDesignFreeze	7.33	1.929	.333	.151	.414

Table 4.21. Reliability analysis of the second component of category H: set-based concurrent engineering, with a resulting coefficient alpha = 0.516

4.3 Multiple Regression Analysis

To find the most optimal solution, the multiple regression analysis was first performed with a step-wise method with all independent variables included. With this method, the independent variables are added to a regression model in a step-wise manner based on the probability of F with entry at 0.05 and removal at 0.10. The analysis found seven different models, the result can be found in Appendix B, and the seventh model was added into a new regression analysis as it includes the most variables with the lowest .sig value, $p < 0.05$ and has the highest R^2 value. This time the analysis was performed with the entry method, where all independent variables are added simultaneously and the coefficient matrix can be found in Table 4.22.

Coefficients[a]

	Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Correlations		
	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part
(Constant)	.402	.322		1.247	.215	-.237	1.041			
INDEX_F1_ContinuousLearning	.199	.072	.242	2.766	.007	.056	.342	.593	.257	.181
INDEX_G2_FormalProcess	.159	.062	.201	2.567	.012	.036	.281	.520	.240	.168
INDEX_A_Knowledge	.183	.062	.239	2.971	.004	.061	.305	.525	.275	.194
INDEX_I_CustomerRelation	.203	.076	.205	2.661	.009	.052	.354	.491	.248	.174
INDEX_D_MotivationAndLeadership	.164	.066	.171	2.474	.015	.033	.296	.375	.232	.162

a. Dependent Variable: INDEX_H_SetBasedConcurrentEng

Table 4.22. Coefficient matrix of the multiple regression analysis with the index of Set-based concurrent engineering set as the dependent variable

As seen in Table 4.22, the independent with the highest p-value is Index D, Sig.=0.015, which means that there is a 1.5% chance that there does not exist a linear relation with this particular independent variable and the dependent variable, i.e. the probability of type I error which would be to discard the H_0 null hypothesis.

4.3.1 Linear Relationship

From the results shown in Table 4.23, the R^2 of this model is 0.734, which is above the desired level of 0.3 as defined in section 3.2. The model is thereby able to explain 73.4% of the variance by the independent, or predictor, variables. Since the variables do not include a time-series, the Durbin Watson result in Table 4.23 will not be further discussed.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.734[a]	.538	.517	.44591	1.997

a. Predictors: (Constant), INDEX_D_MotivationAndLeadership, INDEX_G2_FormalProcess, INDEX_A_Knowledge, INDEX_I_CustomerRelation, INDEX_F1_ContinuousLearning

b. Dependent Variable: INDEX_H_SetBasedConcurrentEng

Table 4.23. R^2 and the Durbin Watson results of the multiple regression analysis with the index of Set-based concurrent engineering set as the dependent variable

From the results in Table 4.24, with the F-test values F(5,108)=25.202, p=0.000, the model can be considered as a significant predictor of the Index H, as the significance level is less than p=0.05.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	25.055	5	5.011	25.202	.000[b]
	Residual	21.474	108	.199		
	Total	46.528	113			

a. Dependent Variable: INDEX_H_SetBasedConcurrentEng

b. Predictors: (Constant), INDEX_D_MotivationAndLeadership, INDEX_G2_FormalProcess, INDEX_A_Knowledge, INDEX_I_CustomerRelation, INDEX_F1_ContinuousLearning

Table 4.24. ANOVA, analysis of variances, in the multiple regression analysis with the index of Set-based concurrent engineering set as the dependent variable

4.3.2 Multivariate Normality

A histogram of the residual was generated in SPSS, and can be found in Figure 4.1. From this figure it is possible to see somewhat of a similarity to a normal distribution in the residuals. For further verification, a test for normality was run in SPSS. This tests utilises a H_0 that the data is normally distributed. If the significance level is higher than $p = 0.05$ the null-hypothesis is accepted and the distribution can be assumed to be normally distributed.

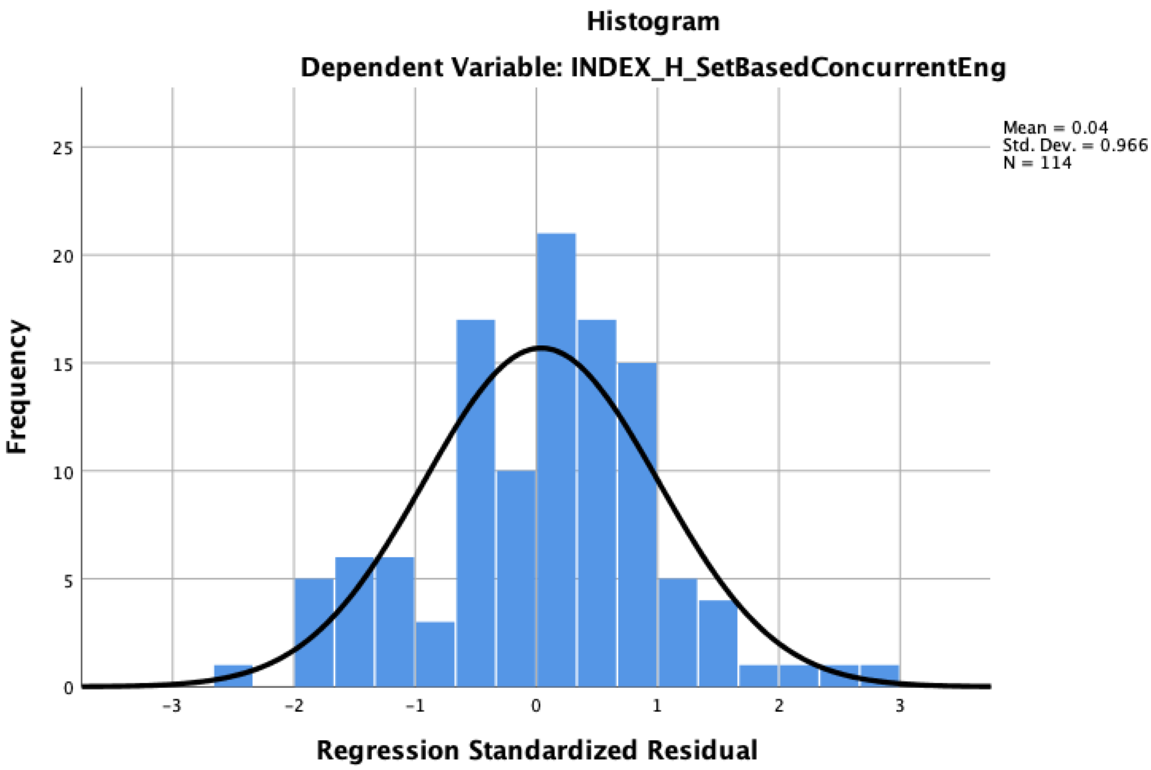

Figure 4.1. Histogram of the residuals in the multiple regression analysis with the index of Set-based concurrent engineering set as the dependent variable

Resulting from the tests of normality, as seen in Table 4.25, the significance level of both the Kolmogorov-Smirnov, $p = 0.200$, and the Shapiro-Wilk, $p = 0.446$, is higher than $p = 0.05$. The residuals of the multiple regression with Index H as the dependent variable are then normally distributed.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Unstandardized Residual	.070	114	.200*	.988	114	.446

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Table 4.25. Normality tets, Kolmogorov-Smirnov and Shapiro-Wilk, of the residuals

4.3.3 Homoscedasticity

To investigate the existence of homoscedasticity or heteroscedasticity, a scatter plot was generated for the residulas vs the predicted values and can be found in Figure 4.2. From this graph, a linear line was inserted to the data points in SPSS and as seen the linear line has a small slope. The R^2 value of this linear relationship is however stated to be $R^2 = 7.119 \cdot 10^{-4}$ and it is therefore unlikely that this relationship exists. However, to further evaluate this, a Breusch-Pagant test was performed.

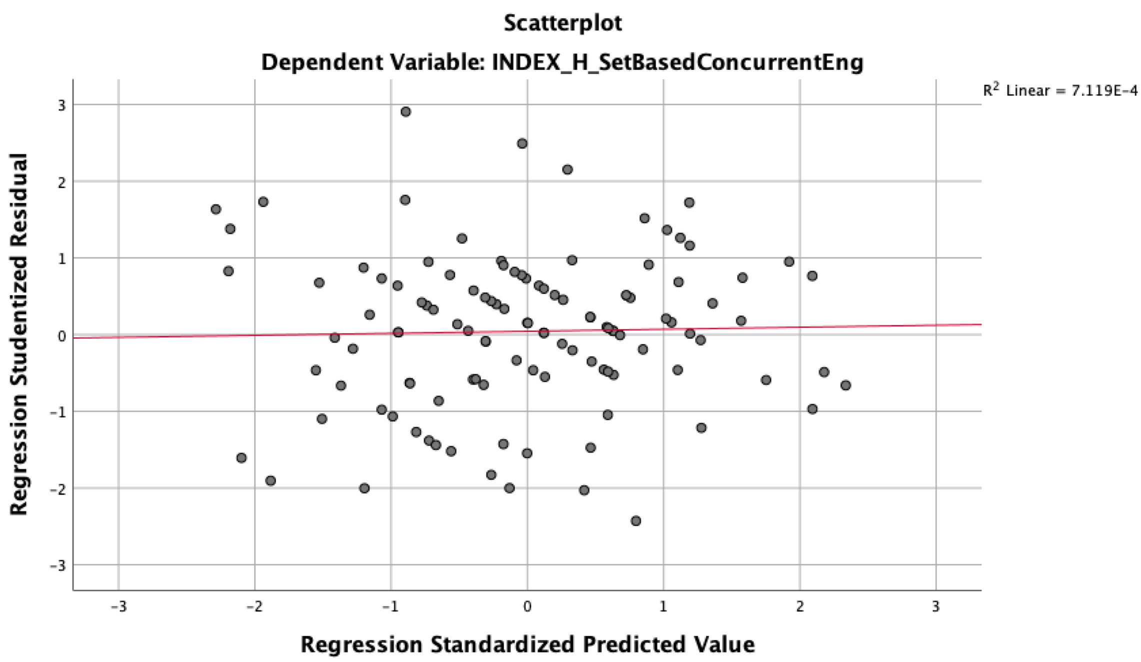

Figure 4.2. Scatter plot of the residuals vs predicted value in the multiple regression analysis with the index of Set-based concurrent engineering set as the dependent variable

In the Breusch-Pagant test, the squared value of the residual was defined as a dependent variable and the predicting values in the regression model was added as independent variables. As seen in Table 4.26, the F-test shows a $p = 0.224$ which is above the

$p = 0.05$ level and the H_0 hypothesis that there does not exist a linear relationship, i.e. correlation, between the residual and the predicting values is accepted. In this manner, the independent/predicting variables can therefore be considered as homoscedastic.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.505	5	.101	1.416	.224[b]
	Residual	7.703	108	.071		
	Total	8.208	113			

a. Dependent Variable: RES_SQUARED

b. Predictors: (Constant), INDEX_D_MotivationAndLeadership, INDEX_G2_FormalProcess, INDEX_A_Knowledge, INDEX_I_CustomerRelation, INDEX_F1_ContinuousLearning

Table 4.26. Breusch-Pagan test of the squared value of residuals as the dependent variable in multiple regression analysis with all independent variables included

4.3.4 Multicollinearity

To investigate for multicollinearity among the predicting/independent variables, the variables were included in different multiple regression analysis whereas one of the independent variables was set as the dependent variable. The resulting variance inflation factor, VIF, for each of these analyses can be found in Table 4.27. As seen in this table, all values of $VIF < 3$, which according to Takezawa (2014) states that it is probable to assume that there does not exist multicollinearity between these predicting variables.

Dependent variable	INDEX_F1	INDEX_G1	INDEX_A	INDEX_I	INDEX_D
Independent Variable	VIF	VIF	VIF	VIF	VIF
INDEX_F1_ContinousLearning	-	1.696	1.375	1.684	1.796
INDEX_G2_FormalProcess	1.357	-	1.422	1.297	1.433
INDEX_A_Knowledge	1.16	1.499	-	1.504	1.487
INDEX_I_CustomerRelation	1.304	1.256	1.381	-	1.352
INDEX_D_MotivationAndLeadership	1.115	1.112	1.095	1.084	-

Table 4.27. Analysing the data for multi-collinearity by the VIF value when one of the independent variables are defined as the dependent variable in a multiple regression model

Chapter 5

Analysis and Discussion

To further analyze the results found in chapter 4, it is important to look at the essence of the different indexes and what they entail. While looking at the variables that were included into the Index H, subsection 4.2.1, they describe the willingness to try out new technological solutions and if testing is performed prior to the design freeze, which can be seen as an indication of how well the industry is able to define and try out different solutions rather than just jumping on the first solution that pops up. It also describes if risk analysis is utilized in the development process, which can be compared to the degree of detailed investigation into the product being developed, and how well the hand-over from the development process to manufacturing goes. As described in subsection 2.2.2 these are all elements of the LDP "set-based" engineering process. The index is therefore able to depict to what degree the Norwegian automobile has a front loaded the product development process.

Since the group of respondents consisted of employees with different professions, this could indicate that the index H would also include the aspect of concurrent engineering and the involvement of all functions. However, since the majority of respondents were from engineering and project management, it is reasonable to question whether the group size of the other professions, such as sales and purchasing, were not high enough to be representative for the whole population. In addition, there were no specific questions related to the concurrent aspect of LDP in the survey. If this phenomenon had been included in the survey, it could have been expected that information flow within the department would have a significant impact on the model. Although, looking into the Index of information flow, it focuses to a larger extent on the information between different project, index E1, and the overall internal team communication, index E2. In this manner, the questions themselves do not specifically relate to the flow of information between different functions, which is the basis for concurrent engineering. In terms of the overall LDP process, a weakness in this model would be that the concurrent aspect of the process may not be very well accounted for.

Although the index for information flow did not provide a statistically significant impact in the model, certain aspects of the elements described in subsection 2.3.1 were still found in the model through the index G2, formal processes. This index provides information to how well meetings are performed, through meeting preparation and attendance. In the LDP process meetings should be focused on solving current issues efficiently and avoid halting further development process. It is reasonable to claim that this would require that the participants come prepared and do not waste the time allocated for the meeting. In addition, the LDP process focuses on pull-communication, which is to a large extent covered through the variables in index G1 in the formal process category. However, this index did not have a significant impact on the development process. This could be explained by the fact that the complexity of the information flow is not covered through a formal process, and the information could still be exchanged in a pull-process, but via more informal ways of communication such as an internal meeting. So instead of searching through formal procedures and documents, people are called in for a meeting to gather the relevant information within the department and at the same time provide information flow between all meeting participants. In this case, although being the lowest contributing factor to the overall model as seen in the coefficient matrix Table 4.22, this would support the rather large impact and significance of index G2 and explain why there is a difference between the Toyota LDP process and the process in Norwegian automobile industry.

Taking a further look into the index F1, continuous learning, the variables here contribute to explaining the different aspects of how well the department work with, emphasize, implement and formally document and evaluate the improvement potentials of the company on a continuous basis. Although it is not clear if the Norwegian automobile industry practices "hansei", as described in subsection 2.2.3, this method is merely a tool to push the mentality of continuous improvement. It is therefore considered not to be necessary to utilize this tool in exactly the same manner as Toyota to preserve the concept of "self-reflection". As seen in the coefficient matrix of the overall model, Table 4.22, continous learning is the next to highest contributing factor in the model. In the LDP process, continuous learning is considered to be a key factor of incremental improvement that contributes to product development. The significant impact of this correlation to "set-based" engineering can therefore be expected to be part of the development process.

With the presence of continuous improvement, Morgan (2002) argued that this would contribute by focusing all involved parties on the common outcome and the shared destiny of the team. This aspect can also be found through the contribution of index D, motivation and leadership, to the overall model. The model does, on the other hand, show that there is no inter-correlation between the two elements, index F1 and D, so in the Norwegian automobile industry the ability to make the employee feel ownership, pride and responsibility in the development is a separate factor and close to equally important as following the concept of continuous learning.

In the LDP process, as described in subsection 2.2.2, it has also been emphasized that the customers view of product value and "customer satisfaction" is of highest importance in case of conflicts in the development process, as it is only the ultimate customer that actually defines value and consequently what can then be considered as wasteful, as mentioned in section 2.1. It is therefore not unexpected that the customer relation, which ultimately describes the customers ability to have an impact on the development process, is the largest contributing predictor in the multiple regression found in section 4.3. Within the index I, customer relations, the aspects which are covered concerns both the communication and the actual understanding of the requirements that the customer has and how well it is understood by all members of the team. So by focusing strongly on understanding what the customer is expecting, this will have a positive impact on the development process, which is highly in-line with the Toyota lean-thinking philosophy.

In addition to having the strong customer focus in the Toyota LDP process, at the very core of the lean-philosophy is knowledge creation and human development, as described in subsection 2.4.1. In the model for the Norwegian automobile industry, this has already been manifested through the impact of index F1, continuous learning, which indicates that there exists a positively correlated attitude towards learning in this industry. Furthermore, the model also depicts the phenomenon of knowledge creation by the index A, knowledge. This index describes the employees perception of how well his or her company focuses on knowledge creation through further education and course attendance as well as the feeling of being up-to-date in their field of work. It is clear that the focus on developing peoples' skills across all functions and providing proper challenges to the employees have a significant impact on the development process. Furthermore, since culture is based on learning, as mentioned in section 2.4, these factors also contribute to describing the culture in the Norwegian automobile industry. With the combined contribution from both continuous learning and knowledge creation, the culture in this industry bares a close resemblance to that of Toyota where people are considered as the most significant corporate asset and that the investment in their knowledge and skills is paramount for the product development process.

In Toyota, one of the responsibilities of the Chief Engineer, as described in subsection 2.2.1, is to establish direct contact with the customer. As shown in Figure 3.1, the respondents in the survey that the model is based on is representing all the different functions in a product development team. By closer inspection of the customer relation index, one of the variables within the index specifically points to the teams communication with the customer. Although the specific organization structure of the different companies in the Norwegian automobile industry is unknown in this survey, the contribution of this predicting variable indicates that the role of the CE, is maintained by the whole team instead of one specific person. The concept presented by Convis (2001) as mentioned in subsection 2.4.1, that LDP has to be adopted in its entirety to work effectively, seems to be an even stronger requirement in the Norwegian automobile industry as the model of cooperation and team organizing has an even stronger position in the organization compared to the Toyota organization as described in section 2.3.

Chapter 6

Conclusion

According to the findings in this thesis it is possible to find a model that is able to describe the linear relationship between the different topics of Lean Product development in the Norwegian automobile industry with statistical significance $p < 0.05$. Through further investigation of the predicting values, it has been concluded that the model may not completely cover the concurrent aspect of the Toyota lean product development process. Conclusions on the similarities were not made on this specific topic and it is therefore suggested as a field of further work in discovering differences between the two industries.

Based on this model it has been made clear that there exists several similarities between this industry and the Toyota Lean product development. The largest contributing factor found in this model was customer relations, which strongly relates to the important area of focus in the Toyota lean thinking philosophy.

A factor which was surprisingly not as well covered in this model was information flow, as compared to that of Toyota. Based on the results it is therefore concluded that the complexity of the information flow in this industry may not have been fully depicted through this survey, as there could exist a difference in degree of formal communication based in the culture of these two separate industries.

According to the theoretical background in this thesis, it has been uncovered that at the core of lean thinking and Toyota LDP, people and the companies ability to perform human development and knowledge creation is paramount for the product development process. Resulting from the model found in this thesis, it is clear that this philosophy has a strong position in the Norwegian automobile industry as well as two of the contributing factors, continuous learning and knowledge creation, which were significant as a predicting value for product development.

Finally, compared to the organizational theory found in Toyota, the thesis model shows that the role and responsibilities of the Chief Engineer are actually scattered throughout the product development team within the Norwegian automobile industry. Due to this significant discrepancy, it is clear that in order to exploit the full effectiveness and efficiency of the LDP process as done at Toyota, it is critical for companies to adopt every aspect of the methods and philosophy throughout their entire organization. This requires managerial support in order to have a positive impact on product development in this industry.

Bibliography

Barney, J. B. (2014), 'Gaining and sustaining competitive advantage'.

Bø, E. (2015), 'Ledelse av forsyningskjeder : et logistikk- og markedsføringsperspektiv'.

Clark, K. B. (1991), 'Product development performance : strategy, organization, and management in the world auto industry'.

Convis, G. (2001), 'Role of management in a lean manufacturing environment', *Automotive manufacturing and production* **113**(7), 64.

Evans, J. R. (2016), 'Quality and performance excellence : management, organization, and strategy'.

F. Ballé, M. B. (2007), 'Lean development: A knowledge system', *Lean Enterprise Institute* .

Freund, R. J. R. J. (2006), 'Regression analysis : statistical modeling of a response variable.'.

Fujimoto, T. (1999), 'The evolution of a manufacturing system at toyota'.

Hayes, A. F. & Coutts, J. J. (2020), 'Use omega rather than cronbach's alpha for estimating reliability. but…', *Communication Methods and Measures* **14**(1), 1–24.

Jacobsen, D. I. (2019), 'Hvordan organisasjoner fungerer'.

Johannessen, A. (2011), 'Forskningsmetode for økonomisk-administrative fag'.

Kennedy, M. N. (2003), 'Product development for the lean enterprise : why toyota's system is four times more productive and how you can implement it'.

Kobe, G. (2001), 'Process of elimination: analysis of toyota camry manufacturing, product development', *Automtoive Industries* .

Kreyszig, E. (2006), *Advanced Engineering Mathematics*, John Wiley.

Lance, C. E., Butts, M. M. & Michels, L. C. (2006), 'The sources of four commonly reported cutoff criteria: What did they really say?', *Organizational Research Methods* **9**(2), 202–220.

Morgan, J. (2002), *High Performance Product Development: A Systems Approach to a Lean Product Development Process*, University of Michigan.

Nielsen, J. (2003), Information Modeling of Manufacturing Processes: Information Requirements for Process Planning in a Concurrent Engineering Environment, PhD thesis, KTH Royal Institute of Technology.

Nobeoka, K. & Cusumano, E. (1995), 'Reorganizing for multi-project management: Toyota's new structure of product development centers'.

Nonaka, I., Nonaka, I., Ikujiro, N., Hirotaka, T., Takeuchi, H., Nonaka, P. & Takeuchi, B. (1995), *The Knowledge-creating Company: How Japanese Companies Create the Dynamics of Innovation*, Everyman's library, Oxford University Press.

Nunnally, J. C. (1978), 'Psychometric theory'.

Porter, M. E. (1985), 'Competitive advantage : creating and sustaining superior performance'.

Sekaran, U. & Bougie, R. (2016), *Research Methods For Business: A Skill Building Approach*, Wiley.

Sijtsma, K. (2008), 'On the use, the misuse, and the very limited usefulness of cronbach's alpha', *Psychometrika* **74**(1), 107–120.

Slack, N., Brandon-Jones, A. & Johnston, R. (2013), *Operations Management*, Pearson Education Limited.

Sobek, D., Ward, A. & Liker, J. (1999), 'Toyota's principles of set-based concurrent engineering', *Sloan Management Review* **40**.

Spear, S. & Bowen, H. (1999), 'Decoding the dna of the toyota production system', *Harvard Business Review* **77**.

Takezawa, K. (2014), 'Learning regression analysis by simulation'.

Womack, J. & Jones, D. (2010), *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*, Free Press.

Womack, J., Jones, D. & Roos, D. (2007), *The Machine That Changed the World: The Story of Lean Production– Toyota's Secret Weapon in the Global Car Wars That Is Now Revolutionizing World Industry*, Free Press.

Zhang, Z. & Yuan, K.-H. (2016), 'Robust coefficients alpha and omega and confidence intervals with outlying observations and missing data: Methods and software', **76**(3), 387–411.

Appendices

Appendix A

Survey and Categorization of Questions

#	Question	Category	Index
40	To what degree do you make use of your competence?	A Knowledge	
41	To what degree do you feel up to date in your profession?	A Knowledge	A INDEX
42	To what degree do you think the company focuses on further education?	A Knowledge	A INDEX
43	To what degree does the company arrange so you can attend courses?	A Knowledge	A INDEX
44	To what degree do you experience that problem solving is a cross functional concern?	B Decision making	B INDEX
45	To what degree do you feel involved in teamwork?	B Decision making	B INDEX
46	How well do you feel that the team work together as a unit?	B Decision making	B INDEX
47	To what degree do you feel involved in decision making?	B Decision making	B INDEX
49	To what degree do you feel that functions and responsibilities are sufficient defined in projects?	C Planning and control	C INDEX
50	To what degree do you feel that project plans and milestones are well-known?	C Planning and control	C INDEX
51	To what degree is it focus on follow-up costs, time schedules and resources in projects?	C Planning and control	C INDEX
52	To what degree are you involved in planning your own project activities?	C Planning and control	C INDEX
53	To what degree do project plans and milestones change during a project?	C Planning and control	

#	Question	Category	Index
56	To what degree do you master the daily challenges in your work?	D Motivation and Leadership	
57	How often do you get feedback regarding your work?	D Motivation and Leadership	
58	To what degree does good performance result in rewards like bonuses, office parties, flowers, cakes etc?	D Motivation and Leadership	
59	To what degree can you affect the project goals?	D Motivation and Leadership	
60	To what degree do you feel responsible for the results from your work?	D Motivation and Leadership	D INDEX
61	To what degree can you decide if the results from your work are good or bad?	D Motivation and Leadership	D INDEX
62	To what degree do you experience that other teams communicate with your team in the daily work?	E Information flow	E2 INDEX
63	To what degree are information/results received from other teams utilized by your team?	E Information flow	E2 INDEX
64	To what degree do you manage to get the right information at the right time?	E Information flow	E1 INDEX
65	To what degree are you sure that you find the last updated information?	E Information flow	E1 INDEX
66	To what degree do you experience that your team communicates internally in the daily work?	E Information flow	E1 INDEX
67	To what degree are achieved results/information available for the organization?	E Information flow	E1 INDEX

#	Question	Category	Index
68	To what degree do you feel that the team/department work with continuous improvements?	F Continous learning	F1 INDEX
69	To what degree do you feel that systematic continuous improvement is emphasized across teams/departments?	F Continous learning	F1 INDEX
70	To what degree do you feel that improvement suggestions are systematic evaluated?	F Continous learning	F1 INDEX
71	To what degree becomes accepted improvement suggestions implemented and followed up?	F Continous learning	F1 INDEX
72	To what degree is lessons learned formally documented in the team?	F Continous learning	F1/F2 INDEX
73	To what degree are numbers and facts returned from manufacturing as input to new product development projects?	F Continous learning	F2 INDEX
74	How accessible is documented experiences from earlier projects?	F Continous learning	F2 INDEX
75	How often does the company seek knowledge from others?	F Continous learning	

#	Question	Category	Index
76	To what degree do you follow routines in the formal quality management system?	G Formal processes	G1 INDEX
77	To what degree do you experience that other in the organization follow routines in the formal quality management system?	G Formal processes	G1 INDEX
78	To what degree do you find the information you are searching?	G Formal processes	G1 INDEX
79	To what degree are you confident in finding the last updated version of a document or drawing?	G Formal processes	G1 INDEX
81	To what degree do you experience that meeting participants show up in time?	G Formal processes	G2 INDEX
82	To what degree do you experience that meeting participants are prepared for meetings?	G Formal processes	G2 INDEX
83	Where do you find the last updated document/information?		
84	To what degree are technical concepts tested before design freeze?	H Set based concurrent engineering	H INDEX
85	To what degree does the team search for several technical concepts before design freeze?	H Set based concurrent engineering	
86	To what degree becomes a product or component designed for existing manufacturing processes?	H Set based concurrent engineering	

#	Question	Category	Index
87	To what degree is it necessary with many design iterations before design freeze?	H Set based concurrent engineering	
88	To what degree are ”on-the-shelf solutions” used when designing new products?	H Set based concurrent engineering	
89	How well do you experience that hand-over from product development to production is working in your company?	H Set based concurrent engineering	H INDEX
90	To what degree are risk analysis performed with regard to technical solutions?	H Set based concurrent engineering	H INDEX
91	To what degree is the team willingly to try new technical solutions?	H Set based concurrent engineering	H INDEX
92	To what degree do you experience that customer requirements are understood in projects you take part in?	I Customer Relation	I INDEX
93	To what degree are customer requirements available?	I Customer Relation	I INDEX
94	To what degree become customer change orders systematic documented and recalculated?	I Customer Relation	I INDEX
95	To what degree are customer change orders made known and understood by all project members?	I Customer Relation	I INDEX
96	How well do you experience that the team communicates with the customer?	I Customer Relation	I INDEX

Appendix B

Step-wise Multiple Regression Results

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	95.0% Confidence Interval for B Lower Bound	95.0% Confidence Interval for B Upper Bound	Correlations Zero-order	Correlations Partial	Correlations Part	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	2.021	.196		10.328	.000	1.633	2.409					
	INDEX_F1_ContinuousLearning	.487	.065	.593	7.468	.000	.358	.616	.593	.593	.593	1.000	1.000
2	(Constant)	1.614	.215		7.517	.000	1.188	2.040					
	INDEX_F1_ContinuousLearning	.369	.069	.449	5.319	.000	.231	.506	.593	.466	.398	.788	1.269
	INDEX_G2_FormalProcess	.247	.066	.313	3.713	.000	.115	.379	.520	.345	.278	.788	1.269
3	(Constant)	1.098	.260		4.229	.000	.583	1.613					
	INDEX_F1_ContinuousLearning	.259	.074	.315	3.476	.001	.111	.406	.593	.327	.249	.625	1.601
	INDEX_G2_FormalProcess	.219	.064	.277	3.405	.001	.091	.346	.520	.321	.244	.773	1.293
	INDEX_C_PlanningControl	.268	.083	.278	3.245	.002	.104	.431	.545	.307	.232	.696	1.437
4	(Constant)	.652	.321		2.035	.045	.016	1.288					
	INDEX_F1_ContinuousLearning	.258	.073	.314	3.534	.001	.113	.402	.593	.333	.248	.625	1.601
	INDEX_G2_FormalProcess	.206	.063	.261	3.257	.002	.080	.331	.520	.310	.228	.767	1.304
	INDEX_C_PlanningControl	.216	.084	.224	2.568	.012	.049	.382	.545	.249	.180	.645	1.551
	INDEX_D_MotivationAndLeadership	.165	.072	.172	2.286	.024	.022	.309	.375	.223	.160	.868	1.152
5	(Constant)	.605	.316		1.913	.059	-.023	1.232					
	INDEX_F1_ContinuousLearning	.197	.077	.240	2.545	.012	.043	.351	.593	.248	.176	.536	1.864
	INDEX_G2_FormalProcess	.198	.062	.251	3.186	.002	.075	.322	.520	.305	.220	.765	1.308
	INDEX_C_PlanningControl	.177	.085	.184	2.084	.040	.008	.345	.545	.205	.144	.613	1.631
	INDEX_D_MotivationAndLeadership	.157	.071	.163	2.195	.031	.015	.298	.375	.215	.151	.865	1.157
	INDEX_A_Knowledge	.138	.066	.181	2.086	.040	.007	.270	.525	.205	.144	.632	1.581
6	(Constant)	.323	.338		.954	.343	-.349	.994					
	INDEX_F1_ContinuousLearning	.169	.077	.205	2.185	.031	.015	.322	.593	.216	.148	.520	1.922
	INDEX_G2_FormalProcess	.158	.064	.200	2.459	.016	.030	.285	.520	.241	.167	.696	1.437
	INDEX_C_PlanningControl	.132	.086	.138	1.543	.126	-.038	.303	.545	.154	.105	.577	1.734
	INDEX_D_MotivationAndLeadership	.141	.070	.146	1.995	.049	.001	.281	.375	.198	.135	.855	1.170
	INDEX_A_Knowledge	.158	.066	.206	2.396	.018	.027	.288	.525	.235	.162	.620	1.613
	INDEX_I_CustomerRelation	.172	.081	.174	2.113	.037	.010	.334	.491	.209	.143	.676	1.478
7	(Constant)	.402	.337		1.194	.235	-.266	1.070					
	INDEX_F1_ContinuousLearning	.199	.075	.242	2.649	.009	.050	.348	.593	.257	.181	.557	1.796
	INDEX_G2_FormalProcess	.159	.065	.201	2.458	.016	.031	.287	.520	.240	.168	.696	1.437
	INDEX_D_MotivationAndLeadership	.164	.069	.171	2.368	.020	.027	.302	.375	.232	.162	.897	1.115
	INDEX_A_Knowledge	.183	.064	.239	2.845	.005	.055	.310	.525	.275	.194	.660	1.515
	INDEX_I_CustomerRelation	.203	.080	.205	2.548	.012	.045	.360	.491	.248	.174	.719	1.391

a. Dependent Variable: INDEX_H_SetBasedConcurrentEng

Table B.1. Coefficient matrix from the step-wise multiple regression analysis with the index of Set-based concurrent engineering set as the dependent variable

Model Summary[h]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.593[a]	.351	.345	.51933	
2	.655[b]	.429	.417	.48982	
3	.695[c]	.482	.467	.46843	
4	.713[d]	.508	.489	.45892	
5	.727[e]	.529	.505	.45142	
6	.741[f]	.549	.522	.44372	
7	.734[g]	.538	.515	.44680	1.997

Table B.2. R^2 values from the step-wise multiple regression analysis with the index of Set-based concurrent engineering set as the dependent variable

NTNU

Norwegian University of
Science and Technology