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A Survey Tool for Concurrent Engineering in Infrastructure Projects in Norway

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Project Management
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Preface

The topic of this master thesis is to show the importance of Concurrent Engineering (CE) in infrastructure projects, especially in Norway, and try to identify strengths and weaknesses in its implementation. One important activity is to develop a CE tool, which should be used in a digital portal about CE. This tool could be a useful tool, in the hands of engineers and students, and should motivate them to integrate CE processes. The project is in collaboration with ViaNova.

Trondheim, 2019-06-10

(Your signature)

Athanasios Polonyfis & Evangelos Tyflopoulos

Acknowledgment

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A.P. & E.T

Summary

CE has gradually replaced the traditional product development in companies. On the one hand, the traditional product development is based on stage-gate models. These models alone can have limitations, such as low adaptability to possible changes, and lack of communication between the key stakeholders. These, in their turn, can lead to bad quality products and cost overruns. On the other hand, CE with the implementation of simultaneous tasks, mainly in the design and development phases, tries to overcome these limitations.

Nowadays, there is a steady increase in e-learning's use, due to the introduction of internet and modern technology. Web portals and their plugins are useful e-learning tools where employees, customers, suppliers, students etc. can find collected information from different sources. Hence, the creation of a tool about CE which could be able to collect useful data from the projects and support the users with knowledge about the theory and implementation of CE.

This report presents the main benefits and limitations of CE. In addition, a framework of the successful CE implementation in construction was developed based on the literature findings. Furthermore, the literature research together with a conducted survey helped the identification of the CE tool specifications. The findings of this report can be used as a basis for the creation of the CE tool, as well as guidelines for project managers and persons that are interested in CE.

Contents

List of Figures

List of Tables

Acronyms

ANOVA Analysis of variance

BIM Building Information Model

CAD Computer Aided Design

CAE Computer Aided Engineering

CAM Computer Aided Manufacturing

CE Concurrent engineering

CEMET Concurrent Engineering Methodology for Enhancing Teams

ETO Engineering To Order

IPD Integrated Product Development

PCA Principal Component Analysis

QFD Quality Function Deployment

SCM Supply Chain Management

SPP Samtidig Plan og Prosjektering

VDC Virtual Design and Construction

VLSI Very Large Scale Integrated (circuits)

WBS Work-Breakdown Structure

Chapter 1

Introduction

1.1 Insights from Specialization Project

In our specialization project, the focus of our research was the identification of the theoretical background of a digital handbook (web portal) of CE in large infrastructure projects in Norway. Especially, the goal of our report was to identify relevant content for the CE web portal while considering the user needs. For this purpose, a survey about the employees' experience with CE, their preferred tools and methodologies was conducted. Based on the survey results, we attempted to correlate the users' background with their preferences in order to associate them with their needs. In addition to that, a thorough literature research has been carried out with respect to CE in construction projects, its benefits, challenges, main categories of tools as well as web portals and their importance. The produced results of this project, through surveys, literature review and so on, could be utilized in the development of a web portal with effective and useful content for its users.

Our actual results were both theoretical and practical. The theoretical results could be summarized as the categorization of the CE tools that would be relevant with a CE web portal. These results helped us to create a survey to identify the user needs in connection to these categories. The practical results derived from the statistical analysis of the data collected from the survey that we conducted. Based on this analysis the user needs were identified in connection with the aforementioned groups of CE tools. The goal was to prioritize the focus on these categories,in a CE web portal, according to the respondents preferences.

In the master thesis, our new focus is to create a survey plug-in tool, for a CE web portal. This plug-in will gather all the needed information, from previous projects that used CE, in order to create a database about the outcomes of CE. This database could present, the results of CE integration in projects, to new potential users and inform them with actual data. The ultimate purpose is to help them in the decision of adapting CE in their project or not.

1.2 Infrastructure Projects

A big group of projects with ambiguous environment is the infrastructure project group. The term infrastructure was adopted by the U.S National Research Council in 1987 to refer to fundamental public facilities. According to Grimsey and Lewis (2002), as infrastructure project can be described any crucial service that adds economic value either to industry or household. Good examples of this kind of projects are the projects related to transport (rail systems, bridges, etc.), energy (generation and supply), water (treatment and supply), telecommunications and social services (hospitals, schools, etc.) (Grimsey and Lewis, 2002).

According to Brown et al. (2006), infrastructure projects can be categorized into three different types including:

Soft infrastructure: The infrastructure projects in this category are mainly related to health care, law enforcement, education and governmental systems, and financial institutions. The main goal of these projects is to support the economy maintenance and they usually require human capital in order to deliver their services to the population.

Hard Infrastructure: Some examples of hard infrastructure projects include roads, highways, bridges and their operational assets, such as transit buses and vehicles. Generally, this category includes all the physical systems in a modern industrialized nation.

Critical Infrastructure: This category of infrastructure projects is considered as the most essential in society. Here the projects are related to heating, telecommunication, public health, agriculture, etc.

The big size of infrastructure projects makes their management challenging due to misinformation and bad communication between the different departments. These, in their turn, can lead to inefficient allocation of financial resources, and finally to cost overruns (Flyvbjerg et al., 2003). Many studies (Flyvbjerg et al., 2003, 2007), have addressed the reasons of these cost overruns and have tried to highlight the importance of the implementation of simultaneous approaches in this type of projects. Especially in Norway, the infrastructure projects are characterized by long planning and design processes, which in their turn, result to inevitable long lead times. The potential for reducing the lead times in these types of projects, led the Norwegian government to the aforementioned decision of reducing the projects' planning time by 50% (ProsjektNorge, 2018).

1.3 SPP Project Overview: "Samtidig prosjektering i samferdselsprosjekter"

This master thesis as well as our specialization project are part of a bigger project in Norway, called 'Samtidig Plan og Prosjektering' (SPP). The involved companies, in this project, are from the Norwegian infrastructure sector and are the following; ViaNova Plan og Trafikk, Rambøll, Metier, Epsis, ViaNova Systems, Jernbaneverket, Sweco Norge (Hauan, 2018).

The infrastructure sector has been unable to follow the competitive pace of other industries. As a result, there is a high interest to identify new ways to improve the competitiveness in the infrastructure industry. In Norway, there is high interest to reduce the duration of infrastructure projects in transport. At a political level, the goal is to reduce the projects' planning time by 50%, a quite hard goal to be achieved. The success of this goal is of high importance for the major transport infrastructure contractors in Norway. Especially, the SPP-project aims to develop the CE method in order to reduce the duration of transport infrastructure projects (Wolden, 2017). One of the reasons of these delays, in such projects, is that there are not big enough contractors to take over them and thus, there is a need for cooperation among several companies. This fact leads to a high demand for communication and that, in its turn, leads to delays (ProsjektNorge, 2018).

1.4 Project Description

In this report, the focal point is to develop a survey CE tool that aims to be integrated in a CE web portal. Its main purpose is to extract empirical data about the effects of CE implementation in infrastructure projects in Norway. The data could be utilized to perform a quantitative analysis to get results that will provide guidance for new potential users of CE. One of the needs for this tool is that a potential manager, who would like to implement CE, could get a more realistic perception of its benefits from the real data, before deciding to commit to it. In order to develop the aforementioned tool, a survey about CE should be conducted and the data have to be analyzed and interpreted.

1.5 Limitations and Assumptions

The work related to this master thesis has certain limitations. The focus of this research is the theoretical background of CE and the identification of benefits and limitations in its implementation in construction. This will be used as basis in our master thesis where we will develop a tool about CE that could be used in the SPP web portal. The produced results of this project through surveys ought to be general, but statistics will be conducted in order to identify its significance.

1.6 Thesis Structure

This master thesis consists of eight main chapters. In the first chapter, there is an introduction to our previous work on the specialization project, the SPP project, the purpose of our thesis and introduction to CE. The second chapter consists of the CE theory that is part of our thesis. Chapter three, contains theory of web portal and relevant tools. In chapter four, there is a theoretical research about surveys and types of data. In chapter five, there is a thorough description of the methodology and in chapter six there is content relevant to our group management during our work. In chapter seven, there are the results of our thesis as well as a discussion on them. Finally, chapter eight consists of the conclusion and the proposed future work.

Chapter 2

Concurrent Engineering (CE)

In this chapter, a literature research about CE is conducted. The purpose of our thesis requires a deeper understanding of the topic and especially its aspects which are related to the survey tool that has to be designed. The chapter contains sections relevant a historical background of CE and its current state of the art. It addition, there is content about CE versus traditional engineering, a comparison of CE in manufacturing and construction projects, and detailed research about CE benefits and challenges. Finally, a first attempt in creating a framework of CE in construction projects is presented.

2.1 Lean as a Predecessor of CE

New technologies and their challenges have made the reorganization of companies' indispensable. As it is illustrated on Figure 2.1, during the last century many changes have been embraced in the manufacturing industry (Pullan et al., 2010). It is shown that the flexibility and adaptability of the product development methodology seems to be necessary and should be in correlation with a changing environment. For this reason, many new approaches and tools have been introduced during the last decades. Among them, Lean manufacturing and CE are the latest and most known systematic approaches.

It was at late 90's when Taiichi Ohno, a Japanese engineer and businessman at Toyota, introduced the Toyota Production System (TPS) (Ohno, 1988). The reason that Ohno is considered to be the father of Lean manufacturing is that the Lean principles were derived from the Toyota production system. The term was first coined by John Krafcik at his scientific paper 'Triumph of the Lean Production System' where he described the different range of performance levels among Japanese, North American, and European plants (Krafcik, 1988). Krafcik embraced the Toyota's process thinking and demonstrated, with practical examples, that even with a 'lean' production, it is possible to increase company's quality and productivity.Lean manufacturing is defined as a minimization of waste in the production of a product. The term is mostly used

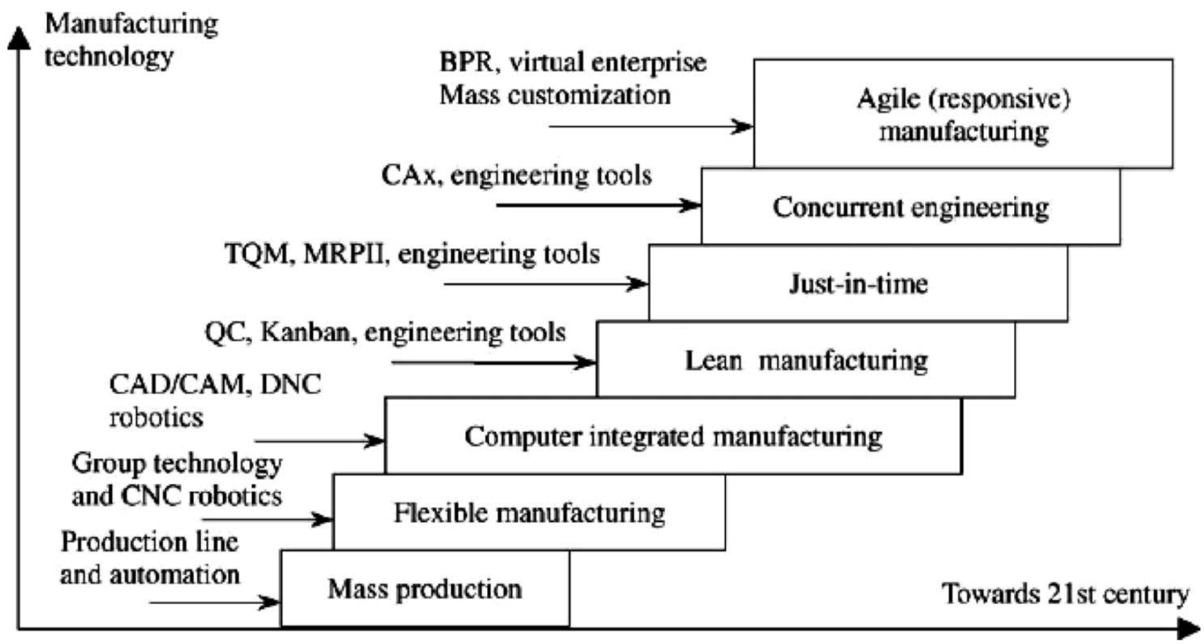

Figure 2.1: Development of manufacturing technology (Pullan et al., 2010).

in manufacturing to describe the goal of instant delivery of a desired product to the customer. The attempt to eliminate waste includes the production line, the defects that lead to rework, the unnecessary inventory etc. In other words, its goal is not only to optimize the production but also the whole procedure of delivering a product to the customer. Thus, wasted resources have to be minimized in every level of the process (Tommelein and Ballard, 1999).

Another definition of Lean manufacturing is that is a managerial practice which has as goal to fulfill the customer needs with the smallest cost for the company (Tommelein and Ballard, 1999). In 1997, The Lean Enterprise Institute (LEI) tried to formulate the Lean practice by defining five key principles (Figure 2.2) that can describe it. These principles are: a) identify value, b) map the value stream, c) create flow, d) establish pull, and e) seek perfection.

Metrics: Identify value: Value has to be specified from the end user point of view. The understanding of the customer requirements is crucial in this identification.

Metrics: Map the value stream: After the determination of the end goal, all the important activities that create value in the value stream have to be mapped. In addition, every step that seems to be wasteful has to be eliminated.

Metrics: Create flow: A tight sequence of the activities provide a smoothly product flow toward the costumer without delays, or bottlenecks.

Metrics: Establish pull: The end customer benefits from the smooth flow with a 'just in time'

Figure 2.2: Five key principles of Lean (Tommelein and Ballard, 1999).

delivery. In other words, customers can 'pull' the product when they exactly need it. A side effect is also that there is an elimination of the bullwhip effect concerning logistics.

Metrics: Seek perfection: This principle is maybe the most important step in Lean. All the aforementioned practices have to be implemented repetitively until a state of perfection is reached and thus, a perfected value is achieved with no waste.

In the case of Lean construction, Ohno's criteria of perfection (Ohno, 1988) are accepted with some small deviations. The main characteristics of Lean construction that make this practice individual are that; the delivery process is clarified by an amount of objectives, the production control is implemented during the whole life cycle of the project, the maximizing of company's performance is customer oriented at project level and finally, product design and processes are concurrent (Tommelein and Ballard, 1999).

On the other hand, CE has been defined by Kusiak (1993, p.1) as 'a design process where all life cycle phases of a product are considered simultaneously from the conceptual stage through the detailed design stage'. The difference with Lean manufacturing is that it is based on new theoretical insights while CE is a more holistic engineering practice (Sobek and Ward, 1996, p.18-22). However, it can be shown that both approaches are based on the same conceptualizations (Koskela, 2006, p.26-43).

2.2 CE vs. Traditional Product Development

The term CE was first used in the US in 1989 and means simultaneous engineering. Other terms, which are used to describe the CE methodology, are simultaneous engineering or integrated product development (IPD). The general idea was to overcome the existing limitations of the "traditional" product development models such as the waterfall model (Figure 2.3) (Royce, 1970, p.328-338).Although that CE is widely used in practice many years, academics have started researching about it recently (Koskela, 2006, p.26-43).

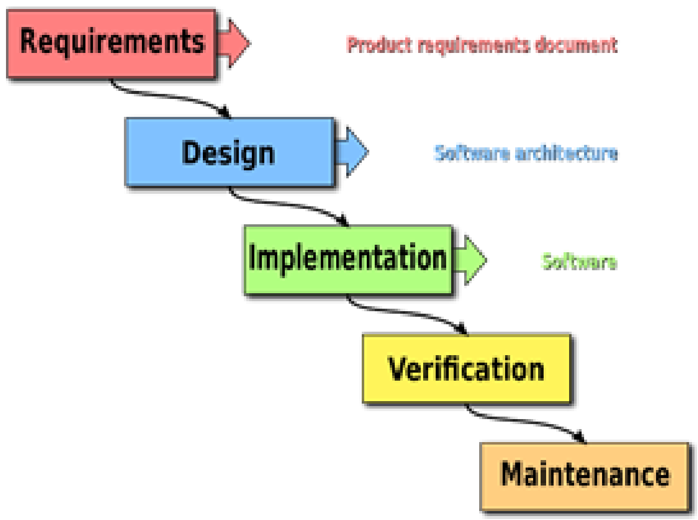

Figure 2.3: Waterfall model as it was illustrated by Royce (1970).

On the one hand, traditional product development is based on stage-gate models, which are a sequential design flow of the different tasks. This type of models has limited flexibility and thus it challenging to confront the possible uncertainty during project life (Figure 2.4).

On the other hand, CE together with Agile software development represent a more iterative development method where it is possible for the designer/project manager to go back and make modifications in the project activities. NASA and IBM firstly used these methods in order to avoid the waterfall life cycle (Larman and Basili, 2003). A good example of a flexible product development model is the so-called “Hunter-Gatherer Model” (Figure 2.5).This model is developed at Stanford University in order to integrate flexibility in fuzzy front-end phase of product development in the presence of many unknown unknowns (Steinert and Leifer, 2012).

2.3 CE in Manufacturing and Construction Projects

The need of cost and time reduction in the construction projects, especially in big infrastructure projects, introduced CE methodology in the construction industry (Sweis et al., 2008).

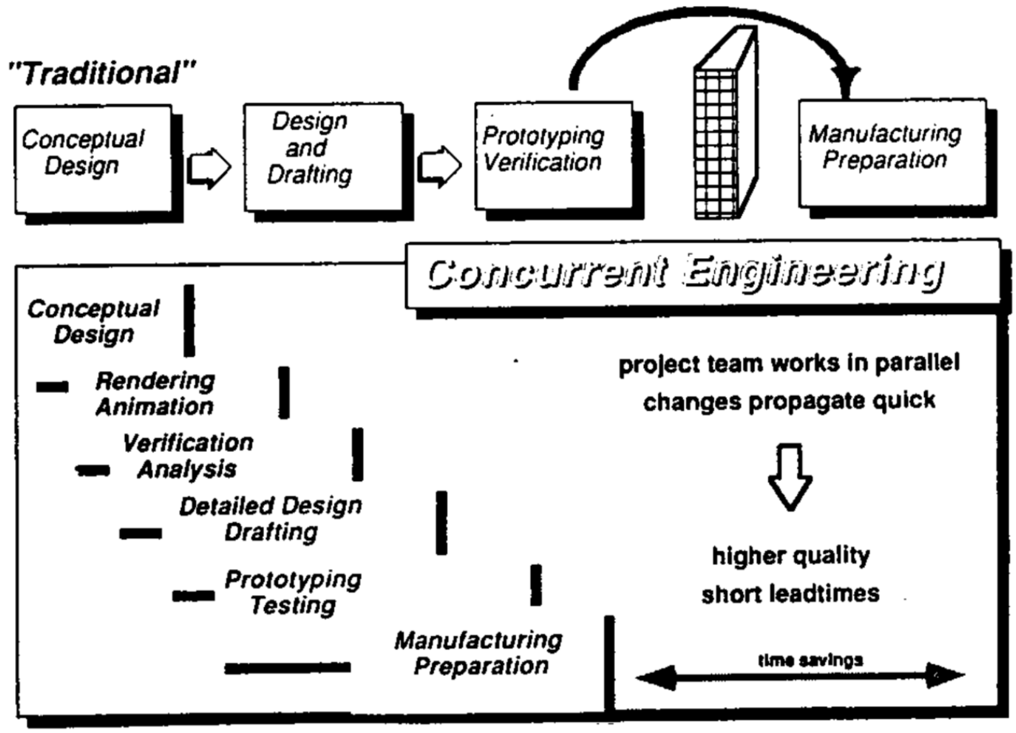

Figure 2.4: Traditional vs CE (Sohlenius, 1992).

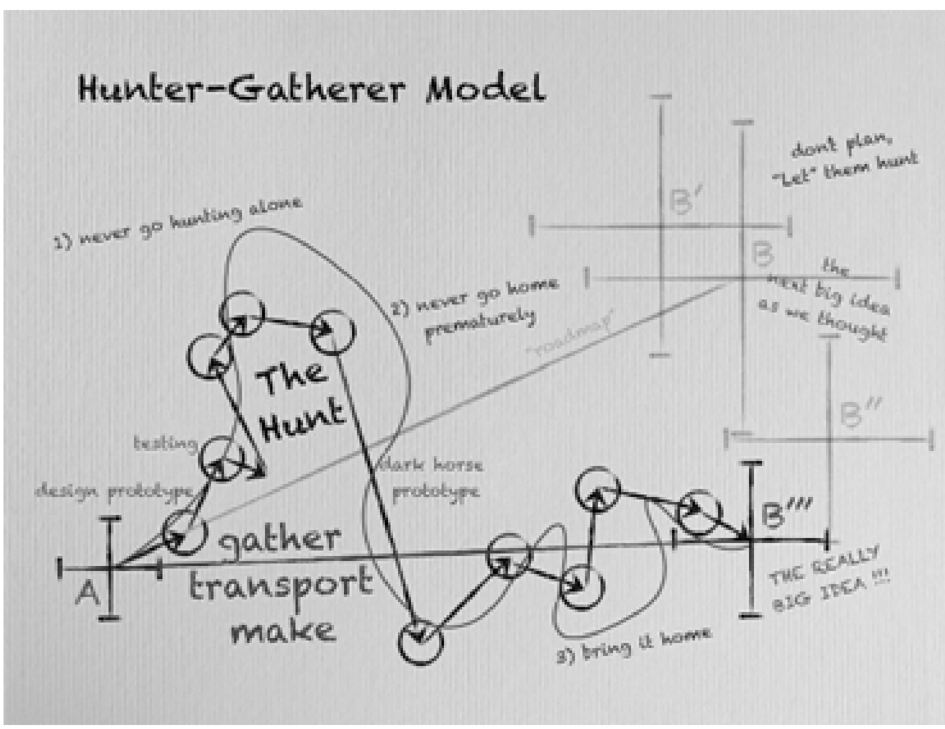

Figure 2.5: Hunter-Gatherer Model as it is described by Steinert and Leifer (2012) at the VIII Harvey Mudd Design Workshop (2012).

One way to reduce the duration of a project is to increase the overlapping activities and thus, introduce concurrent engineering that could be a managerial strategy for procuring construction projects (Love et al., 1998). This is also the way that manufacturing industry has managed to reduce the delivery times and has developed the principles of CE. On the other hand, the infrastructure industry has failed to evolve like the manufacturing industry and thus, there is a need to investigate whether the principles of CE can be applied in infrastructure projects (Zidane et al., 2015).

According to (Kamara et al., 2007, p.5), a point of view that can support the introduction and implementation of CE in construction is that a construction project can be handled as a project in manufacturing. In other words, the lessons that have been learned from the replacement of the traditional product development process by CE in manufacturing industry can be used to benefit the construction industry too. Hence, it is of high importance to identify similarities and differences between manufacturing and construction, both in a managerial and processing level.

On the one hand, both industries produce products that satisfy customer needs. Furthermore, comparing their supply chains, both consist of supply of raw materials, development of components and their assemblies, utilization of repetitive processes and distribution/sale of final products. In addition, they experience similar challenges such as cost decrease, adaptability to design changes, ideal resource utilization and sufficient information management (Kamara et al., 2007, p.5).

On the other hand, the manufacturing and construction industries differs mainly with respect to location of production activities and number of products. The manufacturing industry is characterized from the mass production and the indoor facilities while the construction facilities are primarily outdoors and the number of its products cannot be considered as mass production (Anumba et al., 2006, p.5). Furthermore, the construction industry is different from other industries when it comes to stakeholders. In construction, stakeholders are involved only in some phases of the projects because contractors are the ones responsible for the implementation. Thus, integration of the stakeholders is challenging in infrastructure projects. This is a hinder for CE because integration is an important part of it (Zidane et al., 2015). Furthermore, the absence of the operators/users, in all project phases, is possible to lead to missing knowledge and information about what should be delivered. This, in its turn, can have a negative impact to the project effectiveness and its outcome. Hence, it is crucial to involve these stakeholder categories in the beginning of project planning (Samset, 2003). A summary of the most common similarities and differences between manufacturing and construction are shown on Table 2.1.

Table 2.1: Similarities and differences between Manufacturing and Construction.

Trait	Manufacturing	Construction
	Similarities	
Goal	satisfy customer needs	satisfy customer needs
Supply	raw materials	raw materials
Development	components and assemblies	components and assemblies
Challenges	cost decrease, adaptability to design changes, ideal resource utilization and sufficient information management	cost decrease, adaptability to design changes, ideal resource utilization and sufficient information management
Repeatability	utilization of repetitive process	utilization of repetitive process
	Differences	
Amount of products	products	constructions
Facilities	mass production	not mass production
Stakeholders	can be involved in all phases	usually are involved in some phases
Staff	participation of operators in all phases	absence of the operators in all phases
Communication	usually enough information between phases	often insufficient information between phases

2.4 Benefits and Challenges of CE

The main goal of CE is to integrate the product development and the development of the design- and production processes, so that the different phases of engineering are mostly done in parallel rather than in sequence. This is implemented by reducing the lead-time while improving quality and cost and hence increasing competitiveness. Good cooperation among team members, as well as good knowledge of relevant theories, are crucial for successful CE (Sohlenius, 1992). The integration of CE, in a traditional product development model, can lead to many benefits but can also create challenges.

2.4.1 Benefits of CE

CE, as a simultaneous approach in product and process development, minimizes waste especially in the design and production phases (Sohlenius, 1992). Among others, it allows the early involvement of the key stakeholders from the front-end phase. In addition, CE tries to improve communication, quality of production and production process, cash flows, firm competitiveness, customer satisfaction and the profitability (Figure 2.6) (Pullan et al., 2010). Another research by Wheelwright and Clark (1992, p.181) has shown that integrated CE, due to gained knowledge about downstream activities and ability to point out early warning signs, can minimize the amount of changed orders. In the next sections, the benefits of CE will be presented with respect to flexibility, time, cost, quality, and other aspects such as the multifunctional teams and collaboration.

Benefits and metrics	Results
Decreased lead time	-
Development time	30-70% less
Time to market	20-90% less
Improved quality	-
Engineering changes	65-90% fewer
Scrap and rework	Up to 75% less
Overall quality	200-600% higher
Reduced cost	-
Productivity	20-110% higher
Return on assets	20-120% higher
Manufacturing costs	Up to 40% lower

Figure 2.6: Common benefits from CE (Pullan et al., 2010).

2.4.2 CE and Flexibility

Project flexibility is a controversial term among managers. According to Sager (1994), flexibility is right in the middle of opportunism and rigidity. Although that flexibility can generally be described as something that should be avoided, it is an important part of the project in order to handle uncertainty and changes that occur in business environments (Olsson, 2006). Flexibility in projects can be divided into internal and external based on the scope. Internal project flexibility's scope is related with flexibility on "how" requirements are met, while external flexibility's scope is about flexibility on "what" requirements should be met (Olsson, 2008). According to Olsson (2008) with internal flexibility in the projects, a manager can use the available resources in an optimal way and this leads to increased efficiency. On the other hand, external flexibility leads to increased value for the project owner. This happens because the objectives are possible to change over time and flexibility helps steering the project to a new, more profitable direction (Olsson, 2008).

At the most of traditional product development methods, with the use of stage-gate models, there is little space for flexibility. The designs and costs are mainly stable with small fluctuations due to uncertainty. In addition, the communication between the managers, engineers, designers and the other main actors, related to the project, can be ineffective (Wheelwright and Clark, 1992, p.185). Each of these groups can assume that one phase of the project is completed and thus there is no need for a continuous communication among them. It seems that everything is clear and effective from the front-end until the end-phase for each key stakeholder. Although, the whole project can easily fail due to small inevitable changes in the design or construction, possible cost overruns, market pressure and environmental changes. This problem is thorough described by Evbuomwan and Anumba (1998) under the name "over the wall" syndrome and it is illustrated on Figure 2.7.

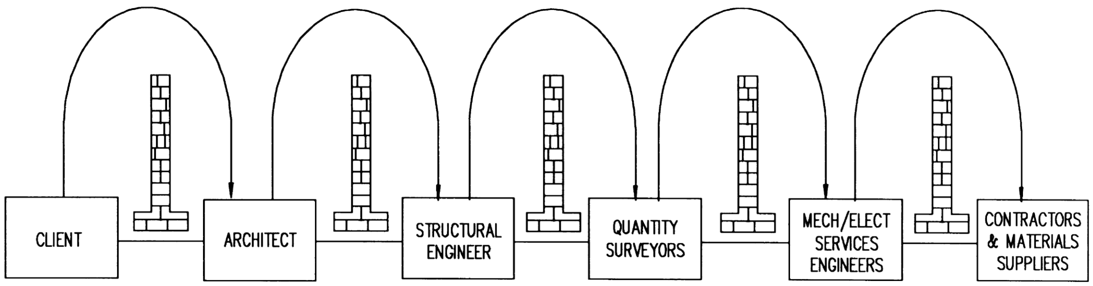

Figure 2.7: The Over The Wall syndrome (Evbuomwan and Anumba, 1998).

For example, a small design change can cause a sequence of problems at the product development model. The designers do not have the opportunity to change the original designs because the design phase is completed. The paradox here is that a prototype has to be built and tested before the identification of possible construction fails. In addition, the prototyping cost includes only the cost of building and testing and not the cost of re-design and that in its turn can lead to a cost overrun (Phillips and Srivastava, 1996). On the other hand, CE holds the design phase open as soon as possible to maximize the flexibility in all related phases. In this case, the cost of prototyping includes the re-design cost and the cost of investigation of manufacturability and decision of the production mode. According to Hicks et al. (2000), CE is crucial especially for the engineering to order companies (ETO) which have a challenging supply chain management (SCM). The SCM tries to monitor and cover the different factors related either to customers (e.g. delivery times, available capacity, new design, product alternatives, and reduced price/cost) or to companies (e.g. alternative plant utilization and internal/external capabilities). It is observed (Hicks et al., 2000) that production flexibility on ETO companies can be increased due to their vertical disintegration which is driven by financial and cost pressures. Although, a not balanced vertical disintegration is possible to reduce the flexibility in design phase.

2.4.3 CE and Time

CE is a management method and it is widely used in different kind of industries such as aerospace and electronics. According to the findings of Pullan et al. (2010), which are based on 25 researches, the development time is reduced by a range of 20-75% with respect to different types of industries, as it is shown in Figure 2.8.

INDUSTRY	Time reduction (%)	
	range	median
Agriculture	54	54
Aerospace	38-43	40
Automotive	25-75	50
Chemical	44	44
Computer	59-71	65
Consumer Goods	20-56	47
Electomechanical	24-79	52
Electronics	40-67	50
Heavy Machinery	60-63	61
Medical Devices	42-50	46
Telecommunications	33-67	50

Figure 2.8: Time reduction by CE (Pullan et al., 2010).

The simultaneous execution of tasks can lead to time reduction in the different product development phases; from the design phase to product lead-time. Time to market can be reduced by 40% or more even if the design time is doubled. In addition, the good communication between the designers and the manufacturers has as a result the decrease of the design and construction cycles, which in its turn can guide to faster production and at the end to better products. Product quality is now matching the customers' needs because customer requirements are considered from the start of the design. This results to a product that goes to market at the right time and right cost (Hartley, 2017, p. xviii). Many notable companies have experienced remarkable time reductions. Rolls-Royce reduced the development lead-time of a new aircraft engine by 30%. The design cycle-time of ITT's (USA) electronic systems was reduced by 33% (Pullan et al., 2010).

2.4.4 CE and Cost

When it comes to cost, CE is more than a trend. In Japanese industrial culture, CE is the key factor for competitive leadership. This can be easily understood by the facts that most Japanese companies do not have a word for CE and are very reluctant to share information about it. To understand this reaction, we can consider some examples of the manufacturing industry in the product design phase. Even if the design cost is doubled e.g. from 7% to 15% of the total production cycle, there is still a reduction in total production cost by 60% from CE (Hartley, 2017, p. xviii). This is because redesign, which constitutes the second biggest expense in the product design phase after materials, can be avoided with CE. For example, McDonnell Douglas reduced production costs by 40% and Ford Motor Company has estimated that 70% of all production savings came from the improvements in the design phase comparing to material, labor and overheads (Pullan et al., 2010). So, if the main goal of a company is to integrate CE in design and product development phases, for flexibility purposes, then the extra revenues from the early market launch of products should offset the expected increases in cost (Phillips and Srivastava, 1996).

2.4.5 CE and Quality

According to Winner et al. (1988), and his research about CE in the weapon manufacturing industry for the US ministry of defence, several companies have reported improved quality when applying CE. The author defines quality of a process or product as the satisfaction of the expectations and needs of its users in operational environments over a period of time. In order to measure quality, which is a broad term, it was attempted to assign a measurable product characteristic to it. In the manufacturing industry a term that is commonly used related to quality is robustness. Furthermore, robustness as it is defined here means that the product has a decreased performance variation of the target value when there is a variation of the external conditions. Additionally, there are companies that often associate quality of design with fewer changes to the designed product after it goes to high volume production. Moreover, the reduction of scrap or rework is often considered as a measure of quality for the process. This method of quality measured by robustness as described here was firstly proposed by Genichi Taguchi.

The following companies have reported quality improvements, as it is measured by Taguchi's robustness evaluation, when they applied CE principles:

Aerojet Ordnance: The company salvaged 400.000 pyrotechnic pellets because they redesigned the loading parameters based on the Taguchi experiments. The consistency of tracer rounds, as measured by mean value divided by standard deviation, by a factor of 5. Additionally, Identifying the correct design parameter settings led to 400% improvement.

AT&T: A fourfold reduction in variability in a polysilicon deposition process for very large scale integrated (VLSI) circuits (1,75 micron design rules) and achieved two orders of magnitude reduction in surface defects. Furthermore, AT&T reduced defects in the 5ESS™ programmed digital switch up to 87% . This happened during a product and process redesign that took place during a quality improvement program.

Boeing: Increased teamwork and computer based support led to decreased number of changes per drawing from 15 to 1. Additionally, the inspection-to-production hour ratio decreased from 1:15 to 1:50 due to teamwork as well as the use of process control methods.

Deere: The number of inspectors were reduced by two thirds by emphasizing process control and by linking the design and manufacturing processes.

ITT: The company performed over 3000 Taguchi experiments during a period of three years. Approximately 90% of them did not require capital investment from the company. The main savings from using robust designs and manufacturing processes are: 28 percent improvement on a power supply product losses,$1,100,000 savings on a solder process, $500,000 by reducing rejects, $125,000 savings on tool costs, and $97,000 annual savings in a traveling-wave tube process.

McDonnell Douglas: They reduced defects per unit in a weld process by 70%. The scrap costs were reduced by 58% and the rework costs by 38%. Moreover, non-conformances were decreased by 38% due to a corporate renewal effort that included improved teamwork, better computer support and better process controls.

Hewlett-Packard: In this company, scrap and rework in some operation have been reduced as much as 95%. Furthermore, its company-wide field failure rate for all products was decreased by 83% during a seven year period. The company performed thousands of experiments over a period of a few years and only 7% of them required any capital investment. The results of these experiments led to million dollar savings such as the following: 88 percent decrease in labor and material cost in another chemical plating operation, 75 percent error reduction in an automatic component insertion process, 35 percent reduction in process development time for a product, $1,000,000 in one year warranty savings for one product, $650,000 savings on a solder machine and $260,000 per year savings in a gold-plating process (Winner et al., 1988).

According to the reported improvements from these companies, there are significant increases to process and product quality as it is defined in this chapter. The CE principles that were used led among others to improved teamwork, increased efficiency with regard to error reduction, process improvements that led to reduced scrap etc.

While there are many quality improvements in the aforementioned examples, the correlations with CE should be further investigated as the number of the companies is not statistically sufficient. In some of the examples the correlations of CE are not completely obvious as other factors come into play and produce these improvements. Although, quality seems to be improving for this sample and further investigation is recommended.

2.4.6 CE and Multifunctional Teams

In order to implement CE, teams of employees are brought together to work concurrently. This introduces the term multifunctional teams, which consist of personnel from different disciplines and even organizations. This fact has major benefits by itself and especially, in the problem resolution the positive effect is vast. These multifunctional teams take responsibility for the decisions that have to be made and as a result the process and product development times are reduced significantly (Winner et al., 1988).

While there are obvious benefits in teams that consist of well trained specialists in various fields, there can also be interpersonal communication problems among their members. This happens because specialists have different viewpoints according to their individual experience and previous training and this makes them see the product development with different perspectives (Fotta and Daley, 1993).

According to Fotta and Daley (1993), in order to handle these interpersonal problems the concurrent engineering methodology for enhancing teams (CEMET) is proposed. This methodology consists of five phases. In phase one, we have the identification and evaluation of the problem. In phase two, there is the discussion of the data collection for the problem at hand. In phase three, it is analytically discussed how CEMET makes employees express their own viewpoints of the issue through personal interviews. In phase four, a classification scheme to compare every viewpoint is used. In phase five, there is a discussion of the aforementioned comparison of the viewpoints, starting from these that are quite similar and ending with those that are conflicting. These phases are explained analytically bellow and in order to be implemented require a person who will play the role of the team performance consultant (TPC).

Phase 1: Problem identification and Evaluation

In this phase, the TPC is responsible to identify opportunities for applying CEMET or handling requests that come from people such as project managers, the organization's upper management etc. After the opportunity is identified and the decision to proceed with CEMET has been taken, the TPC is required to gather information about the product to be developed, the team and the project manager. The next step is to meet with the team and explain the goal of this procedure, get their commitment and verify whether the first problem is appropriate. The TPC has the ability to replace the current problem with a more appropriate one during the meetings.

Phase 2: Develop data collection materials

When it comes to the data collection of the procedure there are two options. One is to collect data by hand and the other is to use a software tool. Both options are giving the same results but a software tool would speed up the process. An important step of this phase is to create a set of entities. These will be drawn from a domain where the whole team is working. Then the entities are presented and explained to the team in order to ensure that they all understand them properly. Some examples of such entities are: team roles, major inputs or outputs, project goals etc. The next step is to create triads of entities (groups of three). The interviewer has to decide how many of these triads should be presented to the interviewee. This process is described bellow in phase three.

Phase 3: Develop team members' viewpoints

In phase three, when the data collection materials are developed, the TPC starts interviewing the team members to elicit constructs and ratings for the entities chosen. Each interviewee has to describe how two of the entities are similar and the other one different. The words used should form opposite ends of a logical scale or dimension to the interviewee. At this point, only entities of each triad are compared and rated. The data sheet should show which are the two similar ones and which is the different one. This is usually done by marking the similar ones with the same number and the different one with another. These numbers form the endpoints of a the scale for the construct elicited by the triad. After that, the interviewee is asked to rate each entity on each construct and this creates an entity attribute grid for him/her. This entity attribute grid acts as a basis for constructing an individual's point of view. In order to avoid redundancy these constructs are further analyzed using various techniques. The most common involve similarity or correlational analysis, which practically compare the similarity of the ratings of the entities along a construct with those of the rest of the constructs. This results to grouping constructs together to functional groups when they have a high degree of similarity. The functional groups show the terminology that a specialist uses in order to compare the entities. After the functional grouping is done, a discussion with the team member follows to verify whether any changes are proposed. In addition, any redundant constructs are merged with their similar ones. These grids are the ones used for the comparisons in phase four.

Phase 4: Compare team members' viewpoints

In this phase, the developed individual viewpoints will be compared. Usually, the CE teams tend to be quite large and the Shaw and Gaines classification scheme has to be modified for multifunctional CE teams. The suggested method by Fotta and Daley (1993), compares the response of all members to the same triad. The analysis of the data for this comparison is similar to the one done for each individual in phase three. The only difference in this one is that the similarity of the constructs among all specialists is considered. The results are classified into four categories based on terminology (same, different) and similarity of ratings (low, high) as it is shown in Figure 2.9.

The discussions which take place is phase five are based on the information gathered so far. When the amount of information is vast the TPC has to pick the content to be presented to the team. The constructs falling into all four categories should be discussed, as well as constructs from every team member. If there are constructs that all the team members agree on, they are presented in the beginning of the discussion to show that the team has a foundation of commonality. Lastly, constructs that a lot of the team members disagree on should be included, as they could be a source of interpersonal communication problems among them.

Phase 5: Discuss comparison of viewpoints

In phase five, the discussions of the data take place. The first meeting should include the

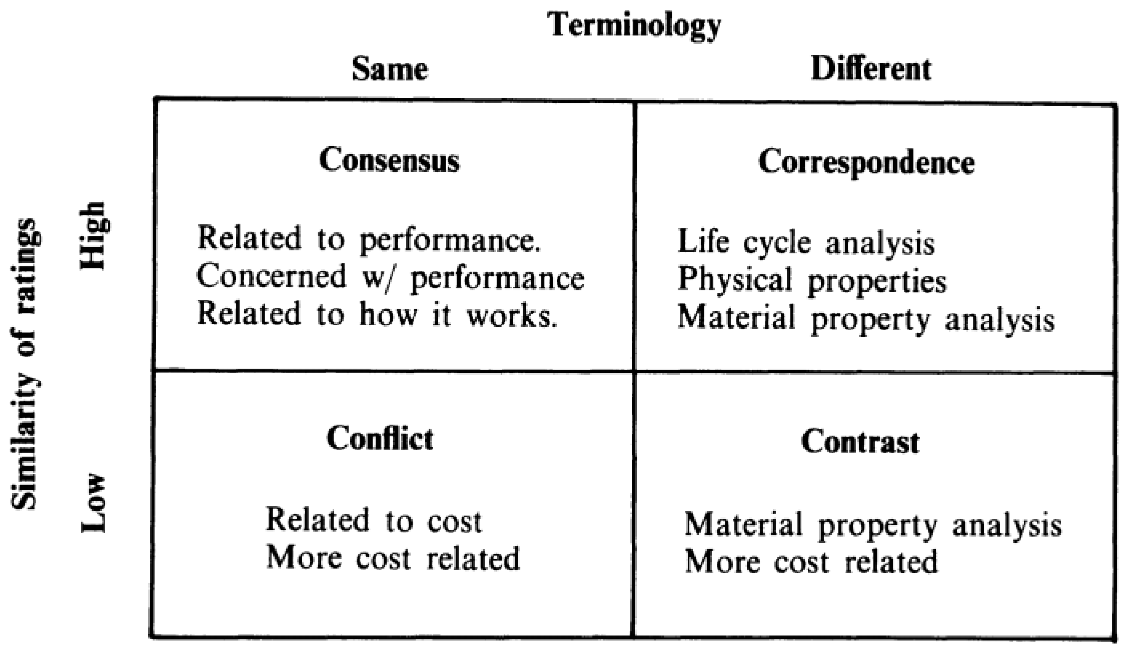

Figure 2.9: Terminology of eight specialists categorized by Shaw and Gaines communication classification scheme (Fotta and Daley, 1993).

whole team. The rest of the meetings could be done individually or in groups. The following steps have to be repeated for as many triads as possible. The TPC has to take into consideration the time constraints and limit the triads between three and five. Phase five is generally speaking, quite subjective and the TPC should have strong interpersonal skills to make it as successful as possible. The discussion should begin with verifying obvious consensus as it is an easy way to start a conversation. Although, the TPC could identify that a few specialists do not completely agree on the terminology and the reason for this should be clarified. The next step is to move the conversation to the least severe communication problem. Then, gradually the conversation moves towards the severe communication problems of the team. A common problem in these communication constructs is that specialists misinterpret terms that they agree on and during this procedure they find out about it. When it comes to the constructs that the specialists completely disagree, it is valuable to explain their perspective to the team and sometimes it is useful even to make presentations in order to teach the specialists that belong to other fields of study. The TPC usually has to do several meetings to cover most of the constructs in order to yield good results.

The CEMET method presented in this chapter could be of help to every specialist in order to understand better the viewpoints of the members of the team. This aids the team to resolve communication issues, that appear in multifunctional teams, leading to better cooperation and results overall (Fotta and Daley, 1993).

2.4.7 CE and Collaboration

It is already said in previous sections, that an important aspect of CE is that brings professionals together to work towards a common goal of a project.This process requires good collaboration in order to be successful and in its turn collaboration improves after applying successful CE. Although the direct benefits of CE when it comes to collaboration are not sufficient and should be further investigated. In this section there is an attempt to give a definition of collaboration and some guidance for successful collaboration, as it is something required for CE . However, the direct benefits of CE and collaboration are of interest for this thesis and will be investigated in following sections with the help of the survey that is conducted.

According to Wood and Gray (1991), when researchers are going to investigate collaboration, they assume that the topic is already defined. Although, Wood and Gray (1991) found that there is not a common definition on collaboration and each of them has a part to offer but its not complete. Taking into consideration these definitions he attempts to make one that is entirely satisfactory. The definition that he gives is the following:

> "Collaboration occurs when a group of autonomous stakeholders of a problem domain engage in an interactive process, using shared rules, norms, and structures, to act or decide on issues related to that domain."
>
> Wood and Gray (1991)

One condition that is useful in order to have the formulation of an alliance is the presence of a convener. The convener uses various forms of authority in order to establish, legitimize and guide the collaborative alliance. The four main types of the convener behaviours appear in Table 2.2.

Table 2.2: Dominant modes and central attributes of conveners (Wood and Gray, 1991).

	Type of Influence by Convener	
Type of Intervention	*Formal*	*Informal*
Requested by stakeholders: Convener is responsive	Legitimation: Convener is perceived as fair	Facilitation: Convener is trusted
Initiated by convener: Convener is proactive	Mandate: Convener is powerful	Persuasion: Convener is credible

A central characteristic is associated with each type of convener. Each of these types play a significant role when it comes to collaboration but researchers need to investigate a larger set o cases in order to assess more systematically the presence and functions of the aforementioned convener types.

According to Prasad (1998), collaboration is one of the seven elements that are needed in an organization philosophy for successful cooperation, known as the "7c": collaboration, commitment, communications, compromise, consensus, continues improvement and coordination. An organization should pay close attention to the aforementioned factors.

2.4.8 Challenges of CE Implementation

As it is mentioned before, CE has many benefits but if its implementation does not go according to plan, it can have the opposite effect. According to Love and Gunasekaran (1997), there are three requirements that have to be satisfied in construction CE in order to be successful. First, the identification of the associated downstream design and construction processes, second the elimination of non-value-adding activities, and third the effectiveness of a multidisciplinary team. The success of this procedure depends on the organization's ability to overcome all kinds of cultural, behavioral or organizational barriers, which might exist among participants. According to researches by Portioli-Staudacher et al. (2003) and Zidane et al. (2015) cultural differences can affect the performance of CE. For example, it seems that Italians and Norwegians are more open to CE than Belgians and can benefit more from its implementation. Moreover, a survey of Swedish manufacturing companies in 90's showed an awareness of the importance of product development in the Swedish industry (Trygg, 1993). In another study, in the British industry by Ainscough and Yazdani (2000), it is noticed that CE is not equally spread among British industry sectors. The smaller companies have the smallest practice of CE compared to large and medium-sized companies. Furthermore, due to behavioral diversity, people tend to resist to changes and feel more comfortable with their traditional roles and procedures. This fact, in combination with lack of CE knowledge and tools, can hinder the replacement of traditional product development methods in a company by more simultaneous methods (Lawson and Karandikar, 1994). When it comes to organizational barriers, it has been observed that CE increases the complexity of tasks and stakeholders integration which in their turn can increase the projects constrains and bring up managerial issues like how and when to meet (Shouke et al., 2010; Sohlenius, 1992). Possible negative rework, in the cross-functional teams, can be another challenge of the CE (Arundachawat et al., 2009). In addition, the project type and size affect the flexibility level, and thus the integration grade of CE. In large projects, such as those in infrastructure and oil and gas sectors, the application of CE is more challenging due to high complexity and uncertainty (Zidane et al., 2015). As Malkin (1994) claims, in some cases of CE, logistics issues can appear in manufacturing. If these issues cannot be addressed, CE benefits could erode. Although that the adaption of CE in companies can result to time and cost savings, as it is mentioned in Section 2.4.1, it is possible to eliminate the benefits of cost commitment, and in some cases, it is time consuming and unrealistic for the industry. According to Wognum and Trienekens (2015), 23% of the companies cannot succeed to reduce the lead-time using CE. There is a need of additional methods, such as Quality Function Deployment (QFD) and Failure Mode and Effect Analysis (FMEA), to support the companies' lead-time reduction strategy. Furthermore, the design, product development and construction costs cannot be recovered in a potential project cancellation. Thus, CE increases the bailout costs (Phillips and Srivastava, 1996). CE can also lead to limitations in the design phase. Especially in the case of CAD/CAE/CAM, in order to make it work hand in hand with CE, some restrictions have to be applied in the design. This results to certain limitations in the designed product, and hence restricts the generality and complexity of the geometry. In addition, to make CE work, some modeling systems require the designer to use primitive designs as inputs. This requirement can be very tedious and prone to errors (Schmitz and Desa, 1993; Wei et al., 1990). Another challenging case can be the integration of CE in reverse engineering. Reverse engineering is an acknowledged step of the product design cycle. It is the process by which a man-made object is deconstructed to reveal its designs, architecture, or to extract knowledge from the object (Varady et al., 1997). In reverse engineering, the product to be designed is known but all the previous steps to design it are missing. With the current reverse engineering technology, there are insufficient surface reconstruction processes, lack of digitizing accuracy in the digitization process, and bottlenecks from the huge amount of digitized surface points in the modeling process. These consist huge limitations for CE because it is difficult to obtain the optimal design of the product (Chen et al., 2000). Generally, most of CE challenges can appear in the product development phase when CE is applied and/or when the design and manufacturing processes are integrated (Schmitz and Desa, 1993). Valle and Vázquez-Bustelo (2009), have found that CE can have positive effects only in incremental innovation and not in projects with radical innovation.

2.5 The need of a CE framework in construction

Each person is individual, behaves differently, or is a part of a group that can both speaks and understands different technical languages. The industry's ability to overcome all these cultural, behavioral, organizational and institutional barriers can implement more effective a CE approach (Love and Gunasekaran, 1997). A conducted survey among 97 architects in Turkey shown that the construction products can be benefited by the implementation of CE in different ways. For example, an increasing of the meeting time between the interdisciplinary teams helped the architects to their projects implementation due to better exchange of information between the involved companies (Erdis et al., 2015). According to Zidane et al. (2015), the size of the project can affect the success of the CE. On the other hand, a case study of lean construction practices at St Olav's Hospital in Norway shown that even to complex and big projects such as a hospital can lead to notable improvements (time, quality, etc.) (Andersen et al., 2012). Different CE tools and models, such as CRPM can also affect the success result of the CE (Khalfan et al., 2000).

All these findings in the theory have shown that each project is different and has to deal with different challenges (e.g. project complexity, behavioral issues and so on) thus a development of a general CE framework that could be applied and be adaptive to each project is important. There are several CE frameworks in literature which are focused on the successful implementation of CE in manufacturing. A good example of a CE framework in manufacturing is developed by Bhuiyan et al. (2004). This model is depicted on Figure 2.10.

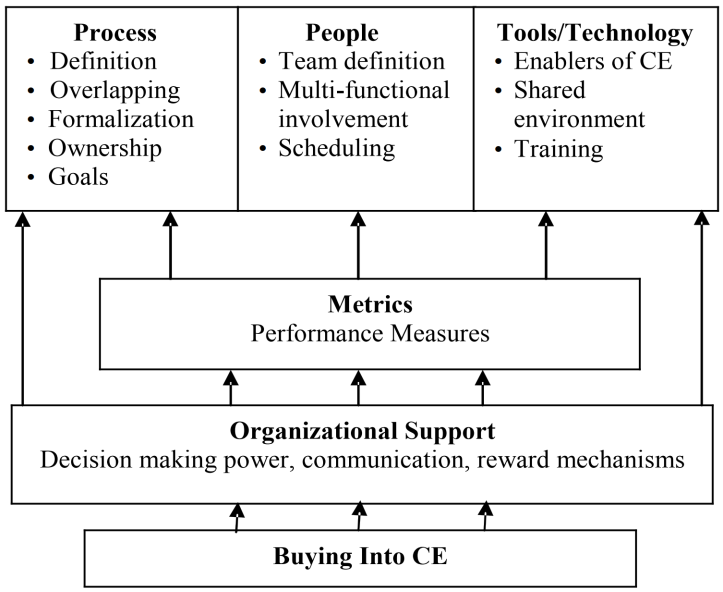

Figure 2.10: Framework of CE in Manufacturing (Bhuiyan et al., 2004).

This framework consists of four sections; Buying into CE, Organizational Support, Metrics, and Process, People and Technology. A brief description of each section is the following:

Process, People and Technology: This section contains all the main activities of CE related to process, people and technology. It is very important to have clear goals, teams, schedules, etc. in the beginning of the CE implementation. That contributes to the success of CE in a project.

Metrics: Concerning this section, It is a collection of all the key performance indicators that can be used from the responsible group in order to conduct a performance measure. In other words, it is a monitoring of the CD implementation.

Organizational Support: This section includes all the activities related to the decision making power, the communication and the reward mechanisms.

Buying into CE: This section represents all parallel activities of CE with an executive support and a continuous training of the employees.

However, there is a lack in the literature of a general framework about CE in construction thus, the authors tried to develop one. Project managers who would like to introduce and implement CE successfully in a construction project could use this framework as a guidance. The used name of this framework will be the 'break the wall model'. An explanation about the structure and the name of this model will be presented later in this section. The presentation and description of the framework is presented at section 5.1.

Chapter 3

The Importance of Web Portals

The main goal of this project is the development of a CE tool for a CE web portal. This tool could be a survey plug-in about CE and become integrated in a CE web portal. The main function of this plug-in should be the collection of project data that have used CE in their implementation. These data, in their turn, could be used from project managers in the involved companies, as well as potential users interested in CE. For this reason, a brief literature research about the new era of internet of things and the new trends of web portals has been conducted in this section.

3.1 E-Learning and Internet of Things

According to Ajaz Moharkan et al. (2017), e-learning is an instruction delivered on any digital device, such as laptop and desktop, in order to support individual learning or the performance goals of organizations. There is an increase of e-learning's use in companies and especially in large corporations, from a 10% in 1980s to 35% nowadays (Weber and Weber, 2010, p.1). This change from the traditional learning to e-learning has been carried out due to the introduction of internet and modern technology. Companies, due to market's competition, have to follow up the rapid technology changes. Thus, a quick access to knowledge and information is inevitable these days (Bayani et al., 2017).

The internet of things, with the extended internet connectivity of any possible device, contributes to the spread use of e-learning and thus, to the exchange of information and knowledge. However, the main challenge of e-learning is the choice of the right knowledge at the right time due to the existence of big data sets (Weber and Weber, 2010, p.2). In other words, there is a shift in the new era of internet of things; from a period where there was not so much knowledge, to a new epoch where there is a large amount of information that have to be evaluated before it could be applied. In this point of view, a web portal can bring useful information and tools from different sources together in a uniform way. That, in its turn, makes the access to the knowledge quicker and more effective for a potential researcher or employee (Rezayat, 2000).

3.2 Web Portals and Internet Tools

A web portal is a website where employees, customers, suppliers, students etc. can find collected information from different sources. The internet of things has, in its turn, made the accessibility on a web portal easy and quick both on a desktop and on a mobile device such as a smart-phone or a tablet.

There are two types of web portals; the vertical and the horizontal portals. On the one hand, the vertical portals can access to a variety of information and services about a particular area of interest (Eboueya and Uden, 2007). An example of this type of portals can be the IMDB, which is a portal about movies. On the other hand, horizontals portals are huge portals such as Yahoo and Google. These portals offer to the user the flexibility to create their personal pages and gain access to various sources and channels (Djordjevic et al.). A web portal can be a starting point for a user who is interested in learning something quick and has little or no experience with it. Furthermore, it can also provide the user with personalized information, such as employee training and safety manuals (Eboueya and Uden, 2007). Moreover, it can be a collaboration tool among the involved partners in a project.

According to van Brakel (2003), a web portal has five alternative uses: a) single access point, b) internet tools, c) collaboration tools, and d) user customization and personalization. The single access point is a single gateway that makes possible for a user to access each of the different systems, which are provided by the portal, without the need to log in to each of them. A good example of this category is Blackboard, which is an e-learning platform that is used by many universities among others NTNU. As internet tools are considered all the search engines and navigation tools (e.g. Google and Yahoo) that provide users easy access to information. Collaboration tools include e-mail, chat platforms and everything that facilitates communication and information sharing. Finally, both user customization and personalization enable the end user to provide information about himself/herself and for example to give him/her the option to (un)subscribe to channels.

3.3 Advantages and Drawbacks of Web Portals and their Tools

According to Eboueya and Uden (2007), web portals are built for corporate employees, customers, suppliers, students etc. The gain benefits by a portal depend on the user's/business' needs and the type of the portal. One user can benefit from a portal in any environment. Some of its provided benefits for the end user are:

- Increased productivity

- Access to customizable features and development tools
- Personalized environments
- Efficiently deliver information
- Increase interaction between customers and employees
- Integration of external applications and services

In some ways, web portals can also offer a technical solution, but not a total answer, to knowledge management (Strauss et al., 2013). However, a web portal can also have some limitations. It is possible for a web portal to have geographical restrictions and thus, only registered members from a particular country can have access on it. Lack of simplified functionalities can be another drawback of a portal. It is possible the interface of a web portal to be very complicated. In this case, it takes time for a user to find the needed information. In addition, the generality of services can decrease the effective information accessibility. The data input overhead, known as the pre-registration of a user before getting access to a web portal, together with possible ethical issues related to personal information, can be other limitations. Nevertheless, if a web portal is developed with a user-friendly interface and with respect to the end user, it can overcome the aforementioned limitations (Zhdanova and Fensel, 2017).

Chapter 4

Methodology

In the previous chapters, there was a literature research about various topics. This research was based on online papers, articles, books etc. The used literature was found in online databases, such as Google scholar and Web of Science.

The first part of the theoretical research consisted of literature about CE and web portals. Especially, the most important of these topics were; CE in infrastructure projects, its benefits and challenges. It was of high importance to investigate how CE is implemented in infrastructure projects, as there could be particularities in this sector. After thorough research in the topic, our findings were used to create a framework for CE in construction. In addition, the benefits and challenges of CE provided us a deeper understanding of the topic and steered our efforts during the implementation of the survey. The second part of the theoretical research consisted of literature relevant with web portals and CE tools.

In this section, a literature research about surveys and data management was conducted. In addition, a survey was created in order to identify the benefits and challenges of CE. It's long term purpose is to have the potential to become integrated on a CE website (plug-in), so the users could get informed based on real project data of whether to use CE or not. The survey was created in Google Forms. The received results were analyzed in MS Excel with the use of statistics. Furthermore, the validity, reliability, and generalizability of the survey results were evaluated. Finally, there is a section concerning the working methodology of our group.

4.1 Literature Research about Surveys and Data

In this section, a literature research is conducted about surveys and types of data. The content of the sections, starts with a brief historical view of surveys, continues with a meticulous theoretical analysis of types of data, survey components and survey design, and ends with survey data analysis.

4.1.1 Web vs. Traditional Surveys

In the twenty-first century, Internet is changing a lot of things and among them are survey methods. The new trend is that online surveys are replacing the traditional survey methods. It is clearly a new era for survey research and while many have their concerns about it, there is a need to take a deeper look in web surveys (Couper, 2000).

Web surveys have many benefits compared to traditional methods. To begin with, they are accessible to a larger amount of people. This is because most people have access to the internet and can easily respond to a survey when they want to. On traditional surveys it is necessary that someone contacts each person one by one, which makes it hard to reach the respondents, as they may not be available at that time. Additionally, this way of conducting surveys is time consuming for the conductor and it consists one of its main limitations. As a result, this approach is much more expensive, especially when there is a need to reach a lot of people. Moreover, the fact that traditional surveys cost a lot were restricting their use mostly to large organizations such as governments and companies. The lower cost of web surveys make them also accessible to individuals and thus democratizes the survey taking process. Furthermore, online surveys offer a vast amount of possibilities by making it feasible to include multimedia. This way, it is easier to convey messages to the participants that otherwise would have been hard or even impossible. Nowadays, web surveys manage to overcome a lot of the problems that the traditional surveys had and as a result their popularity keeps increasing (Couper, 2000).

Although that web surveys have many benefits, their ease of use and accessibility creates an increasing amount of users that conduct surveys. As a result, people become more and more reluctant to respond to surveys. Lastly, the quality of the surveys conducted by non professionals, as it is measured by accepted indicators, may be dropping and makes it harder to find high quality surveys (Couper, 2000).

4.1.2 Qualitative and Quantitative Data

In research, there is a fundamental distinction between two main categories of data; qualitative data, and quantitative data. A description of these two complementary methods, their methods of collecting and analyzing data, as well as their strengths and limitations are described briefly in this section.

Qualitative Data

According to Denzin and Lincoln (2008), qualitative research is an exploratory multidimensional research with a more naturalistic manner to its subject approach. In other words, we can say that researchers using the qualitative research attempt to make sense of or interpret phenomena in terms of the meanings people bring to them. Thus, the goal of a qualitative research is to understand the opinion of the individuals, try to identify trends in them, and dive deeper into the problem or the research topic.

A variety of methods such as diary accounts, questionnaires, documents and participant observations can be used in the collection of qualitative data (Denzin and Lincoln, 2008). A good example of qualitative research method is the unstructured interviews where the qualitative data are generated via open questions to the participants. In addition to questions, photographs, videos and sounds can be consider as qualitative data. These empirical data should be used and interpreted by the researcher in something more tangible and subsequently be categorized in a way that can present a trend or a pattern. A notable method for the interpretation and the analysis of the qualitative data is called thematic analysis and was developed by (Braun and Clarke, 2006). This methodology is divided in six steps; be familiar with the data, generate initial codes, search for themes, review themes, define name themes and produce the report. Each step is shown in detail on Table 4.1.

Table 4.1: Steps on a thematic analysis (Braun and Clarke, 2006).

	PHASES	DESCRIPTION OF ANALYSIS PROCESS
1	Familiarizing myself with data	i) Narrative preparation, i.e. transcribing data ii) (Re-)reading the data and noting down initial ideas
2	Generating initial codes	i) Coding interesting features of the data in a systematic fashion across entire data set ii) Collecting data relevant to each code
3	Searching for themes	i) Collecting codes into potential themes ii) Gathering all data relevant to each potential theme
4	Reviewing themes	i) Checking if themes work in relation to the coded extracts ii) Checking if themes work in relation to the entire data set iii) Reviewing data to search for additional themes iv) Generating a thematic "map" of the analysis
5	Defining and naming themes	i) On-going analysis to refine the specifics of each theme and the overall story the analysis ii) Generating clear definitions and names for each theme
6	Producing the report	i) Selection of vivid, compelling extract examples ii) Final analysis of selected extracts iii) Relating the analysis back to the research question, objectives and previous literature

The strengths of qualitative research are that the researcher gains an insider view of the field due to his/her involvement in the whole process. This, in its turn, helps the researcher to identify shadow issues that are sometimes hidden in the quantitative data. Denscombe (2014) argues that qualitative analysis is open for ambiguities and contradictions, which are a reflection of the social reality. In addition, the participants can benefited by the narrative style of the qualitative research by gaining new insights though its procedure.

Qualitative researches are time and money demanding mainly in collection and analysis of their data and thus, are conducted in a small scale data sets. Hence, the small population and the amount of data can be criticized for their significance. Another problem of the qualitative data is their validity due to their subjective nature that can make challenging their management and interpretation (Denzin and Lincoln, 2008).

Quantitative Data

On the other hand, the quantitative research try to confront the problem using numerical data or data that can be transformed into usable statistics. Researchers using quantitative research collect measurable data to formulate facts and uncover patterns in research. The most of the quantitative researches are experiment based. However, there are many surveys or controlled observations that can produce quantitative information also. A good example is a closed question in a survey that is using a rating scale (Black, 1999).

The most used method in data analysis of the quantitative results is the employment of statistics. Statistics help the researcher to present the data in diagrams and charts and to identify possible correlations between the experimental parameters. Analysis of Variance (ANOVA) and Principal Component Analysis (PCA) are two of the most implemented statistical procedures in research. These methods contributes to the creation of statistical models and to the identification of statistical significant differences between groups of data (Carr, 1994).

According to Carr (1994) and Denscombe (2014) the quantitative data are rational and show scientific objectivity, because they are interpreted using statistics that are based on mathematics. Hence, scientists use them as a support and validation of their experiments. In addition, quantitative data are characterized by their rapid analysis using a plethora of scientific software and by their repeatability (Antonius, 2003).

However, experimental methods together with their quantitative results limit the possible ways in which a research participant can react to and express appropriate social behavior. Thus, the findings from a quantitative research is likely to be context-bound (Carr, 1994). It is also possible for a researcher to be fixated on the data collection and he/she might miss important observing phenomena. In addition, there is a need of statistic expertise by the researcher (Black, 1999). Furthermore, large size samples are needed for a more accurate analysis. A summarized overview of the qualitative and the quantitative research is depicted on Table 4.2.

In this chapter, there was an attempt to investigate several topics about CE. One of the focal points was the benefits and challenges of CE. In addition to that, there was an investigation about web portals and infrastructure projects, in order to gain a deep understanding about these

Table 4.2: Distinction between Qualitative and Quantitative research (Minichiello et al., 1990).

	Qualitative	Quantitative
Conceptual	Concerned with understanding human behavior from the informant's perspective	Concerned with discovering facts about social phenomena
	Assumes a dynamic and negotiated reality	Assumes a fixed and measurable reality
Methodological	Data are collected through participant observation and interviews	Data are collected through measuring things
	Data are analyzed by themes from descriptions by informants	Data are analyzed through numerical comparisons and statistical inferences
	Data are reported in the language of the informant	Data are reported through statistical analysis

topics. Furthermore, there was a literature research about CE tools and an attempt to categorize them. In the following chapter, there will be a thorough description of the methodology that was followed in our research.

4.1.3 Survey Components and Total Survey Design

Surveys, as we know them, exist the last 60-80 years but only the last 20 years there has been a systematic scientific approach on how they are designed, conducted and evaluated. This approach is commonly known as the "total survey error" paradigm. Its focus is on analyzing the various sources of errors in surveys and proposing ways to minimize them with consideration to the available resources (Weisberg, 2009). Moreover, the field that arises from this, is known as "survey methodology" (Groves et al., 2011). Survey methodology aims to minimize the error in the data collected as well as measure the error that is part of any survey (Fowler Jr, 2013). According to Fowler Jr (2013), most of the problems of data collections are due to the faulty execution of details and not due to lack of general understanding. The focus in this chapter is to define the main survey components and discuss the survey methodology in depth. To begin with, the main components of the survey are the following:

- Sampling
- Question Design
- Interviewing

- Mode of Data Collection
- Total Survey Design

In the following paragraphs the survey components are described and discussed analytically based on the book "Survey Research Method" by Fowler Jr (2013).

Sampling: The process of sampling is a very important development in the survey making process. In early surveys the sample of people chosen was based on convenience or on lists that quite often excluded significant portions of the population. In order to have a good sampling methodology probability methods should be used in order to give to every member of the population the same or nearly the same chance to be selected.

The procedures for drawing the comprehensive probability samples were actually developed by the U.S. Department of Agriculture in order to provide statistically reliable results about people living in a specific area. The procedures that evolved to sample land areas for crop yield prediction and sampling housing units and people was an extension of the aforementioned work. During World War II it was in the departure of agriculture where some social scientists were placed to do surveys about the war effort. After that the methods of sampling were broadly established as the way to sample the general population in surveys. The area probability method is still the method that is used for sampling nowadays (Fowler Jr, 2013).

Question Design: An important part of the survey methodology is to use questions as measures. The questions in the initial surveys were merely an extent of the journalism of that time and as a result not carefully designed to measure something. After a while, interviewers were sent out with a set of question objectives and not specific questions, and better results were obtained. Thus, in the beginning of the 20^{th} century there was research about standardized questions in order to measure specific phenomena. At this point we see again the role of the U.S. Department of Agriculture that extended the use of the standardized questions in 1940s when there was a need for more factual information. Payne published a landmark book in 1951 which was providing the guidelines for interviewers for the question making process (Payne, 2014). Likert (1932) is credited for connecting the elaborate scaling techniques of the psychologists with the practical requirements of applied social survey research.

In the last two decades there have been significant improvements in the question design strategies for evaluating questions. The two focal points of the researchers are whether the questions are well understood by the people and whether they are meaningful. Survey pretests are more systematic now and they focus on identifying problem questions. The result is to have questions that the specific wording becomes less a matter of research judgment and more objective (Fowler Jr, 2013).

Interviewing: Interviewing is a method that even though it is not always used, for instance in self evaluating surveys, is quite common and should not be ignored. The main objectives of interviewers are to maximize the accuracy with which the questions are answered by the respondents as well as to avoid influencing them.

The first major step in increasing the interviewers consistency was to give them standardized questions. Another important step was to train interviewers how to avoid introducing biases in the answers they obtained. Studies took place about how interviewers are influencing the answers they get with other ways than wording. These studies led to more training of the interviewers with respect to strategies for probing when the received incomplete answers and for handling the interpersonal aspects of the interview without bias. In addition, there is literature that documents these procedures in order to ensure data quality when training interviewers (Fowler Jr, 2013).

Mode of Data Collection: When it comes to the data collection methods, historically until the 1970s, most surveys were done by in-person household interviewers. Later on, telephone surveys became the main data collection mode and nowadays surveys through internet are replacing them. For some time e-mail surveys were limited because it was hard to sample mail lists. Although, as mail lists of target populations become increasingly available, mail surveys become more popular and the results that they provide are of high quality. More than ever researchers are making choices of the data collection mode that produces the best data quality while at the same time is cost effective (Fowler Jr, 2013).

Total Survey Design: The foundations of the good research practices has been established in the 1950s. However, the procedures have changed due to technology and science advancements. There are specific cases where there is lack of studies on how to optimize data collection. Even when the best methods are used, there is variability in the quality of the procedures followed.

The variability in the quality is due to various reasons. Some of them are, lack of funding, adequate staff as well as lack of methodological knowledge. In addition to these, there are know controversies about the value of strict probability sampling and standardized question wording. Another problem that occurs is the failure of researchers to put together high-quality procedures for the main survey components at the same time. Usually they focus in one of them and neglect the others. The total survey design as it is proposed by Fowler Jr (2013) is an attempt to focus on all the components as a total.

In every survey there are some decisions to be made that affect positively or negatively the precision of survey estimates. In general, in order to have better data more money, time or other resources need to be spent. That means that in order to design a survey efficiently these resources should be optimized through a set of decisions and that should be in connection to all the aforementioned survey components. Especially for sampling Fowler Jr (2013) presents critical issues in the following categories:

- the choice of using or not the probability sample
- the sample frame (those people who have a chance to be sampled)
- the size of the sample
- the sample design (the particular strategy used for sampling people or households)
- the rate of response (the percentage of those sampled for whom data are actually collected)

When it comes to question design the researcher has to choose whether previous literature, expert consultation or the investment made in pretesting and question evaluating will be used or not. With respect to interviewers the research should decide about the training needed as well as the supervision time. About the mode of data collection, a design decision cutting in all the aforementioned topics is the key factor and is irrelevant of the way the survey is conducted (eg.interview,mail,telephone etc.). The decision mode to be used affects directly the cost of the survey as well as the quality of the collected data (Fowler Jr, 2013).

The total survey design is the total of these pieces taken together. These components are connected in two important ways.The first one is that the quality of the data is restricted by the most error-prone part of the survey design. A common mistake in the past was researchers focusing on one or two features of the survey in order to evaluate its quality of data. Secondly, when there are major compromises in a part of the survey, then it makes no sense to use major investments in other parts of it. Concluding we can say that researchers based on the total survey design should aim to ask questions that include all features when then they try to evaluate the quality of the survey as well as the credibility of the data (Fowler Jr, 2013).

4.1.4 Applied Survey Data Analysis

In order to implement applied survey data analysis there is a need for deeper understanding of the sample design, survey data and the interpretation of the results of the statistical methods. According to, Heeringa et al. (2017, p.8-12) there are six steps that are important to be followed in a survey data analysis.

Step 1: Definition of the problem and statement of the objectives

The first step is to define clearly the problem to be addressed and create an objective for the analysis that will follow. Historically, the objectives of surveys were to describe characteristics of a target population, but they can also be used for decision making. The last decades, the objective of many sample data analysis has been to identify the vast amount of correlations among variables in a target population. Although that sometimes these multivariate relationships seem to be barely descriptive tools of a finite population, researchers use them to probe causality in the relationships among these variables.

Step 2: Understanding the sample design

Understanding the sample design is a crucial part of the process. If the research does not have clear understanding, then the analysis could be inefficient, biased or lead to incorrect inference. For example an experienced researcher who designs and conducts a randomized block experimental design should not ignore that in the data analysis procedure.

Step 3: Understanding the Design variables, underlying constructs and missing data

The typical scientific survey contains data sets with hundreds of variables that span many domains of study, such as education, health, family etc. The sheer volume of available data combined with their ease of access tends to make researchers complacent when attempting to understand the properties of data that are important to their choice of statistical methods and the conclusions that they will draw from their analysis. The key features of the sample design will be used to encode the design variables. Before the analysis begins, there are some questions that need to be asked in connection to the data set:

- What are the empirical distributions of these design variables and do they conform to the design characteristics in the technical reports and online study documentation?
- Does the original survey question that generated a variable of interest truly capture the underlying construct of interest?
- Are the response scales and empirical distributions of responses and independent variables suitable for the intended analysis?
- What is the distribution of missing data across the cases and variables, and is there a potential impact on the analysis and the conclusions that will be drawn?

Many researchers tend to skip all the steps until now and rush to step 4. Although all the steps until now help the researcher to do a proper analysis of the data as it is described in the following step.

Step 4: Analyzing the data

Statistical analysis of the data is one of the most anticipated parts of the process. The analytic techniques are important and should be chosen carefully in order to conform to the analysis objectives as well as the properties of the survey data. Moreover, specific methodology and software should be chosen to accommodate the design features which influence estimation and inference.

Step 5: Interpreting and evaluating the results of the analysis

The interpretation of the data is not as simple as a statistical analysis using a software tool. A survey data analysis requires a consideration of the error properties of the data. The variability of the sample estimates will be reflected in the sampling errors (ie. confidence intervals, test statistics) which are estimated during the statistical analysis. The non-sampling errors such as bias to survey non-response and item missing data, cannot be estimated from the survey data (Lesser and Kalsbeek, 1999). Although, it could be possible to use ancillary data to explore the potential direction and magnitude of these errors. The multivariate model of survey data analysis requires care when interpreting the fitted models and the research should ask the following questions (Rothman and Lanes, 1988):

- Is the model reasonably identified and do the data meet the underlying assumptions of the model estimation technique?
- Are there alternative models that explain the observed data equally well?
- Is there scientific support for the relationship implied in the modeling results?
- Are interpretations that imply causality in the modeled relationships supported?

Step 6: Reporting of estimates and inferences from the survey data

The end result of a survey is to present the data in a report, paper, or presentation that aims to communicate the findings. This part should be done according to the standards and proven methods for effectively presenting the results of applied survey data analyses, including table formatting, statistical contents, and the use of statistical graphics. All these six steps are important to begin the process of planning, formulating and conducting analysis of survey data Heeringa et al. (2017, p.8-12).

4.2 Our Survey

The literature findings were used to design the first version of the survey (Appendix A). However, the survey results combined with the literature research could be used to revisit and redesign an improved version of the survey in the future. Furthermore, it was very crucial to take a deeper look in the survey methodology and analyze the relevant theory to avoid mistakes and have the right guidelines.

In order to implement the desired survey it was required to go through a repetitive process where the survey was designed, then sent for feedback to our supervisors and partners and then redesigned based on the suggested improvements. Most of the proposed changes were implemented with the utter goal to improve the survey and make it fit to the purposes of the project.

4.2.1 Survey Tool

More analytically, the process of designing the survey started with picking the right tool to work with. The main two software options were Google Forms and Survey Monkey. After the evaluation of our needs as well as the possibilities that these tools offer, we opted for Google Forms. The main reasons were that Google forms, among others, is a free tool which creates well presented charts of the responses of the survey. Additionally, it could be easily integrated in the WordPress website of the project, which was a requirement.

4.2.2 Survey Content

The most challenging part of the survey was to design the questions. In order to pick the right questions we had to evaluate the information that we needed from the respondents. The main goal was to identify benefits and challenges of CE based on the experience of the respondents as well as correlations between the CE projects and different parameters such efficiency of meetings etc. In the beginning of the survey, there was an introductory paragraph that aimed to inform briefly the participants, about what does the term “CE” mean. This step was important in order to make sure that they understand what CE is, so they could answer the following questions about it. Apart from that, this was necessary because, in many cases, people actually work concurrently but they do not know the terminology to identify it.

In the “Background Information” section, there were questions about the company that they work, their training on CE as well as their participation in CE projects. This section intended to find possible correlations of the answers with the participants’ background. That way we wanted to find whether some backgrounds, based on their training, respond about CE effects differently. Additionally, the question about the respondent participation in CE projects aimed to skip or not a few of the following sections of the survey.

In this survey, it was wanted to get multiple answers per person, so in the section "Number of projects" the respondent is able to choose to reply for as many as three projects. This part was challenging to implement using the specific software but it gave us the opportunity to increase the amount of information we receive from the respondent while it reduced the time needed to reply on the survey, by skipping sections that do not have to be answered twice.

In the next section "Project information" there were questions about the name of the project, the role of the respondent in it, whether he/she was internal or external in the project and whether he/she participated in the meetings and work sessions. Those who did not have meetings and work sessions were skipped to answer only about the impact of CE compared with traditional engineering.

The three following sections, had questions about CE implementation based on meetings and work sessions as well as the challenges of implementing it. The respondents had to answer in a scale of five whether they agree or disagree on several questions. The goal of these sections was to correlate the results that were given about concurrent engineering in later sections with the meetings and work sessions because they consist an important part of successful CE implementation.

The next section is the core of the survey. There the respondents had to answer on a scale of ten (five scale of 100% increase, five scale of 100 % decrease), whether several key aspects of CE improved or deteriorate. These aspects of CE compared to traditional engineering are important for the users of the web portal plug-in because they will consist the basis of them to decide whether CE is beneficial for them or not.

In the last section, called “Open Questions”, there were two open questions for the respondents in connection with CE and the survey. The first one was; "What did you like the most about CE/SPP in your Project?" and aimed to identify aspects of CE that might have not been included in the survey. For this reason there is the second question of the section which is "Are there any questions that you would like to see in this Survey? Please write your suggestion". The answers of this question could be evaluated on whether to be included in the next version of the survey.

4.2.3 Survey Analysis

In this section. the six steps of survey data analysis, proposed by Heeringa et al. (2017, p.8-12) in section 4.1.3, were used in our survey and are as follows:

Step 1: Definition of the problem and statement of the objectives
The problem in our case is to find a way to inform potential users of CE about its benefits, based on actual feedback from CE projects.

Our objectives are:

a) To gather empirical data from infrastructure projects that use CE in Norway

b) Identify correlations among the data

c) Identify benefits and challenges of CE

d) The findings will be used to create a survey tool that extracts relevant data of the key aspects of CE, and presents them graphically to a CE web portal.

Step 2: Understanding the sample design
In our case, the sample design was not our responsibility as the sample was chosen from our external supervisor and our partners in the rest of the companies involved in the project. The procedure was that we send them the survey and they forwarded it to their colleagues. However, sample design is understood and taken into consideration in the analysis of results.

Step 3: Understanding the Design variables, underlying constructs and missing data
In this step, taking into consideration the sample design, we encoded the data variables. The chosen questions, provide qualitative and quantitative data results. Moreover, missing data from the projects, are considered when we attempt to make correlations in the results.

Step 4: Analyzing the data
The analysis of the results could have been done with the analysis of variance method (ANOVA) in order to identify correlations in the survey questions. Although that this method is useful, it is not the one we used due to statistically insufficient number of responses. A statistical analysis with the use of weighted arithmetic mean was the method that was used to analyze our limited survey results. The used formulas for the weighting of the answers are the equations 4.1 and 4.2:

$$SUM = \sum_{i=1}^{n} w_i x_i \tag{4.1}$$

$$Percentage = \frac{SUM_j}{\sum_{j=1}^{k} SUM} * 100 \tag{4.2}$$

where,
i: rating scale (1-n)
j: number of category (1-k)
w_i: weight of rating
x_i: number of answers for each rating

The survey responses were exported to MS Excel for proper grouping of the data, as well as for further visual representation of the findings (e.g. pie charts), which appear in Chapter 5.

Step 5: Interpreting and evaluating the results of the analysis
In this step, we did not just use software to analyze the data, but we did an in depth qualitative analysis of the results. In this procedure we took into account the guidelines of this method. When it comes to the qualitative data we tried to find correlations among the variables. As for the quantitative data the focus was on evaluating, based on the results, whether CE had a positive effect or not. However the sample size was not statistically sufficient identify correlations with certainty.

Step 6: Reporting of estimates and inferences from the survey data
This step was important, especially in our survey, as the graphical representation of the results was one of our objectives. The results were presented with pie charts, tables and bar graphs in order to identify trends as well as to highlight the benefits of CE.

4.3 Group Management and Meetings

In this section, it is described how our group worked during this project; which management methods were implemented and what were our thoughts about the development of the CE tool in our master thesis. In the following paragraphs, there is an analytical description of the processes that helped us cooperate as a group, several tools that supported us to manage our project, and the meetings that took place.

4.3.1 Group Management

It was of high importance for the group to cooperate, according to a commonly agreed schedule, which was defined in the beginning of the semester. For this reason, it was decided to create a project plan, based on stage-gate models, which included all the main phases of the project. In addition, a work-breakdown structure (WBS) was implemented in order to present all the sub tasks of the main project phases. As a work organizer tool we used Trello (Appendix C) to list the project tasks, prioritize and implement them. Finally, a Gantt chart was created with specified deadlines for the group.

4.3.2 Group Work

It was decided, in the beginning of the specialization project that the members of the group would need to work both separately or together. For this reason, Latex was used as a tool for simultaneous writing and information exchange. Latex was opted because it offers writing flexibility, for simultaneous work, as well as an offline version of the file, for single user editing. The group meetings were conducted in a weekly basis and their frequency varied based on our weekly needs. For this reason, the meetings every week were decided on demand. Each meeting began with a scrum where a briefing and debriefing of the project were implemented. Its main focus was to prioritize the most important tasks of the project. The scrum methodology assisted our communication as a group and reduced the amount of time in various tasks. On Figure 4.1, the scrum process is presented.

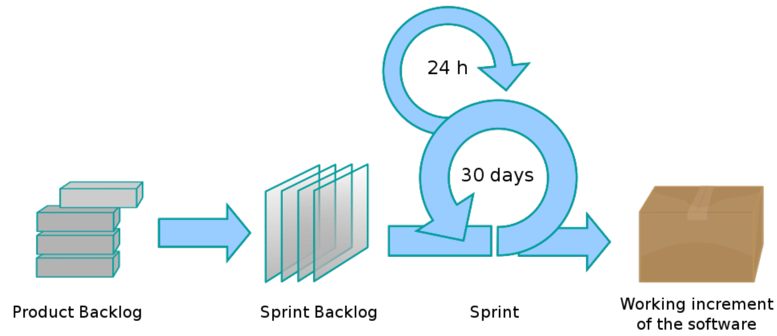

Figure 4.1: The scrum process (Baljé et al., 2012).

4.3.3 Project Plan (Stage-Gate Model)

In the beginning of the project, a stage-gate model was established, based on the Ulrich Eppinger product development model (Eppinger and Ulrich, 1995). The presented model on Figure 4.2 concerns both the specialization project and the master thesis. The model consists of five main phases: a) Vision, b) Identification of customer needs, c) Concept development, d) Development of CE tool e) Tool Prototyping. A short description of these phases is following:

Vision: This is the front-end phase of the project where the group decided the topic of the project, which was the development of a tool about CE.

Identification of customer needs: At this phase, the group decided to conduct a literature research together with an online survey in order to involve the main key stakeholders in the project and identify the customer needs.

Concept development: This is a phase where the "solution room" is open and different concept solutions have to be suggested and compared with respect to user needs and company/group strategies and criteria.

Development of CE tool: At this step, the chosen concept of the CE tool has to be clarified and described in detail. A decision about all the sub tasks has to be committed.

Tool Prototyping: Finally, this phase concerns the development and testing of the CE tool, with multiple design iterations, in order to deliver the final product.

As it is shown on Figure 4.2, the design and creation phases of the CE tool are open in order to have a continuous communication between these two crucial phases and integrate the CE in the stage-gate model. The first two phases, with the vision and the identification of the customer needs, are the main part of our specialization project. On the other hand, the remaining phases

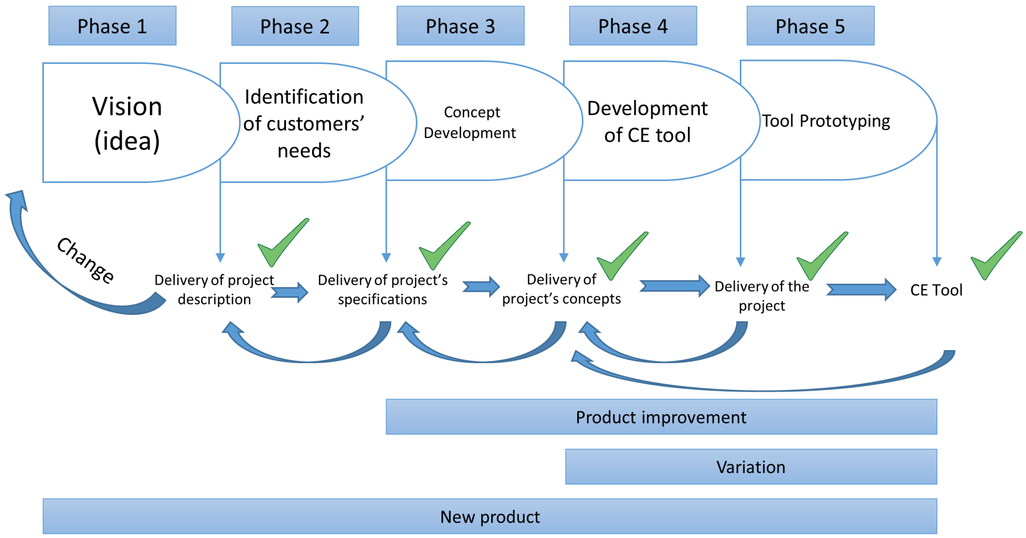

Figure 4.2: Stage-gate model of the project.

with the concept development, the decision of the CE tool content, and its implementation are the focal tasks of our master thesis.

4.3.4 WBS

As it is illustrated on Figure 4.3, the used WBS structure. In this flowchart, all the main phases of the master thesis, with their main tasks and sub tasks, are presented. The same tasks were used in a Gantt chart in order to add specific deadlines.

4.3.5 Gantt Chart

An important step, in the beginning of our work, was to find the key tasks that had to be done, during the semester, in order to complete our project. The Gantt chart Figure 4.4 helped us to visualize our goals and the time-frame to achieve them. However, there was a need to revisit the Gantt chart regularly, as sub tasks were occurring and more than a few tasks had to be replaced with others. Nevertheless, the Gantt chart was of high value for our progress, as we had to set our own deadlines in our schedule.

4.3.6 Meetings

During the project, several meetings took place with our supervisors for discussion and feedback about the project work. Meetings with Bjørn Andersen and Erling Graarud, who were our internal (NTNU) and external (ViaNova) supervisors respectively, were conducted on demand.

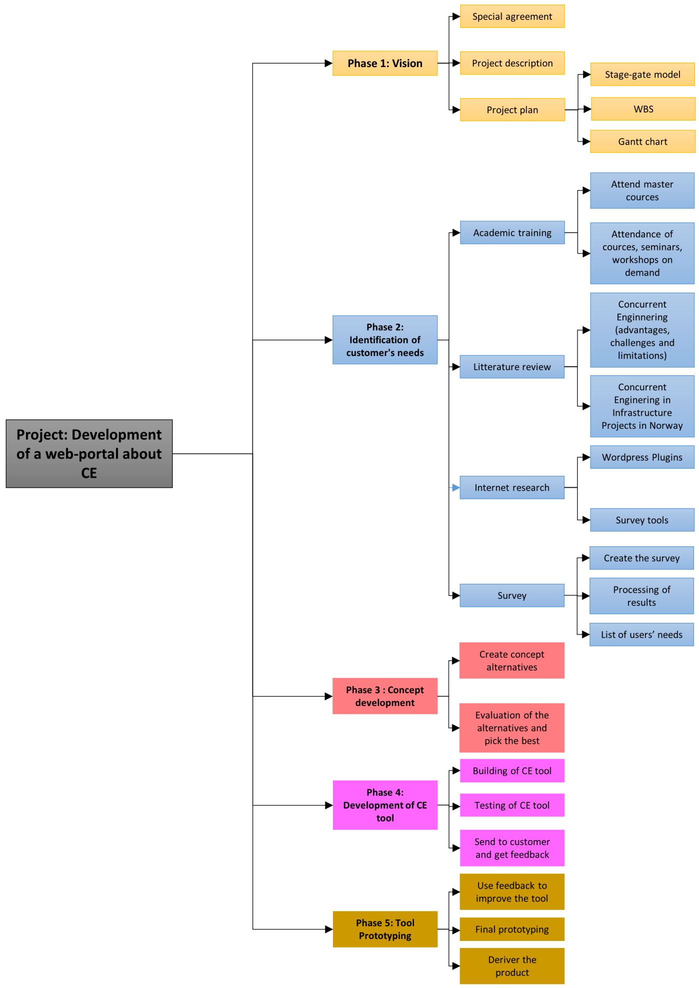

Figure 4.3: The work-breakdown structure of the project.

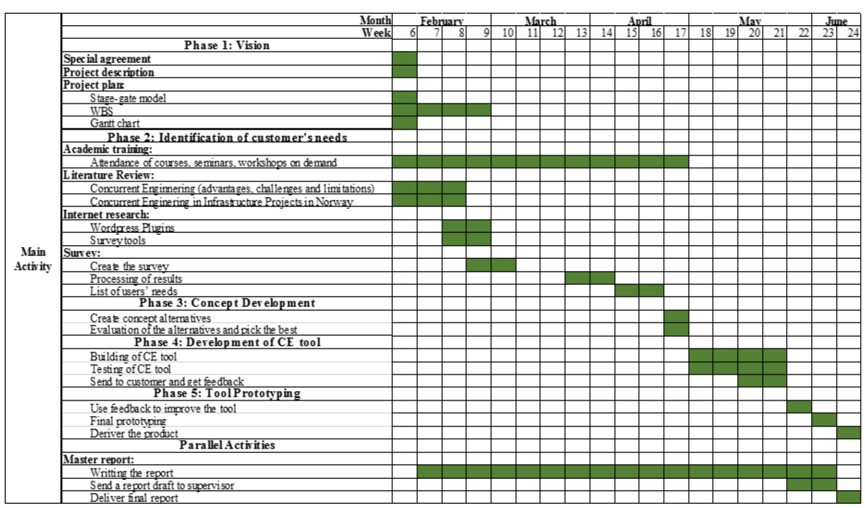

Figure 4.4: Gantt Chart.

It was crucial for the group to have a continuous contact with them, during the semester, in order to include them in the development of the project and to follow their advice and needs. An important meeting was take place in the beginning of the semester where we decided to change the topic of our master thesis from the development of a CE web portal to the development of a CE tool. Additionally, we signed the relevant agreements for the cooperation with them which can be found in Appendix D.

4.4 Validity, Reliability and Generalizability

4.4.1 Validity

According to Litwin (1995), validity is a measure of the survey accuracy. It measures whether the questions of the survey are the correct ones in order to get the desired information. For example, the statement: "My organization inspires me to do my best work" is valid, while the statement: "I'm inspired to do my best work here at my organization" is not. This is because the first statement has been tested a lot of times, to clarify what the respondents understand with it; that the organization is the source of inspiration. On the contrary, the second statement was not valid either because it was perceived that the source of inspiration were the employees themselves or it had not been tested at all.

The validity of our survey is not the desired one as we did not have tested our questions to a statistically large group of people. Nevertheless, there was a focus to avoid possible misunderstandings in the language that we used. We tried to express our questions or statements in multiple ways and picked the ones that fitted the most to our purposes. In addition to that, the questions were tested with our partners and supervisors, in the designing rounds, and were corrected according to their feedback.

4.4.2 Reliability

According to Litwin (1995), reliability of a survey can be summarized as the consistency of the questions to provide the same kind of information each time they are asked. The reliability of the survey is important when comparing results of past surveys where slight changes to wording or structure can lead in different responses.

This survey is not widely tested to measure the repeatability of the answers and there was not a similar past survey that we use to compare results. However, most of the questions were tested a few times. This happened during the procedure of adding questions or changing the structure of the survey, where our partners had to register their answers again and again in the new versions of the survey. That worked as a limited reliability test for many important questions. With that said the reliability of the survey is far from the desired one but still not very low.

4.4.3 Generalizability

According to Mullinix et al. (2015), generalizability is the ability to generalize the survey results to the general population. Generalizability depends on the sample that was chosen and the amount of responses. If the sample was not representative of the general population or there were answers that were neglected then the results cannot be generalized. Moreover, a need for statistically large amount of responses is a necessity.

In this survey, the amount of responses is not enough to have generalizability of results. In addition to that, the sample of the survey was chosen from our partners as they were forwarding the survey to their contact lists. As a result, we do not know how this sample was created. Both of these facts conclude that generalizability does not apply to the specific survey results.

Chapter 5

Results and Discussion

In this section, the results from both the implemented literature research and survey are presented and discussed. In addition, we elaborate on these and try to present our first thoughts about a framework of CE in infrastructure projects. The results from this report could be the basis for further development of this framework and the integration of this survey, as a CE tool, in a CE web portal.

5.1 Literature Results

The findings from literature research have shown that the introduction of CE in a project could improve it, with respect to several parameters such as time, cost, quality, teams collaboration and so on. However, CE has also some limitations which are mainly correlated to its implementation. There is not a secret formula for an ideal CE introduction and implementation in a project, but a collection of methods and guidelines that could be adopted in the project. Concerning construction, there is a need for a CE framework that could embrace all the CE implemented methods and empirical data from manufacturing.

Thus, a CE framework for construction was developed here which could be used as a general guideline for project managers and persons who would like to introduce and apply CE in their projects. This framework model is based on the research findings of this report, and on several models such as the CE model by Bhuiyan et al. (2004) and the stage-gate model by Eppinger and Ulrich (1995). The "break the wall" model consists of two sections; the environment and the project. As environment is considering everything outside the boundaries of the project that can affect its implementation and its results. As it was mentioned at sections 2.5 and 2.4.8, one of the most common drawbacks in the construction is the missing information during the implementation of the projects and the insufficient communication among the project phases and especially between the design and construction phases. This problem was presented under the name "over the wall syndrome" (Evbuomwan and Anumba, 1998). Hence, a construction project should be in a continuous contact with the environment, via exchanging valuable information, that could benefit its implementation. That increases its flexibility and makes it more adaptable to any potential change.

Concerning the construction project, this consists of the following phases; planning, conceptual design, detail design, construction preparation and construction. In addition, there are several parallel activities such as; the organizational support by the project manager and the performance measures. The introduction of CE in this model takes place in the beginning of the second phase (conceptual design). The CE methodology with its theory, multi-functional groups, meetings, and CE environments, technology and tools follows and supports the whole implementation of the project. The successful introduction and implementation of CE it is project manager's responsibility. As it is shown at the "over the wall syndrome" model, the communication among the phases in a construction project is insufficient due to the limited flow of information between the phases. We argue that the "over the wall" approach is not a permanent solution of the problem. The communication could be improved definitely only by breaking these walls. It is project manager's responsibility to break the walls among the detail design, the construction preparation and the construction, as well as to consider a possible merging of these phases.

Finally, according to the Table 2.1, the stakeholders of a construction project are usually involved only in some project phases. As it is shown on Figure 5.1, this model tries to change that by an early involvement of the key stakeholders and employees in the project. This involvement is keeping on during the whole project. The main idea is that the most important stakeholders should participate in the project meetings where they could share their opinions and requirements.

5.2 Survey Results

In this chapter, the most important results from our survey are presented. All the survey results are presented in Appendix B. The presentation of the results is divided to seven different sections based on the survey's structure; background information, project information, CE meetings, CE work sessions, challenges of CE implementation, differences between CE and traditional projects, and feedback from the participants. The number of participants make it statistically unreliable to generalize with certainty in all the questions, although in several of them some trends could be identified and give guidance in the implementation of CE and in the development of a CE tool. However, the survey results were exported at MS Excel where a basic statistical analysis was implemented.

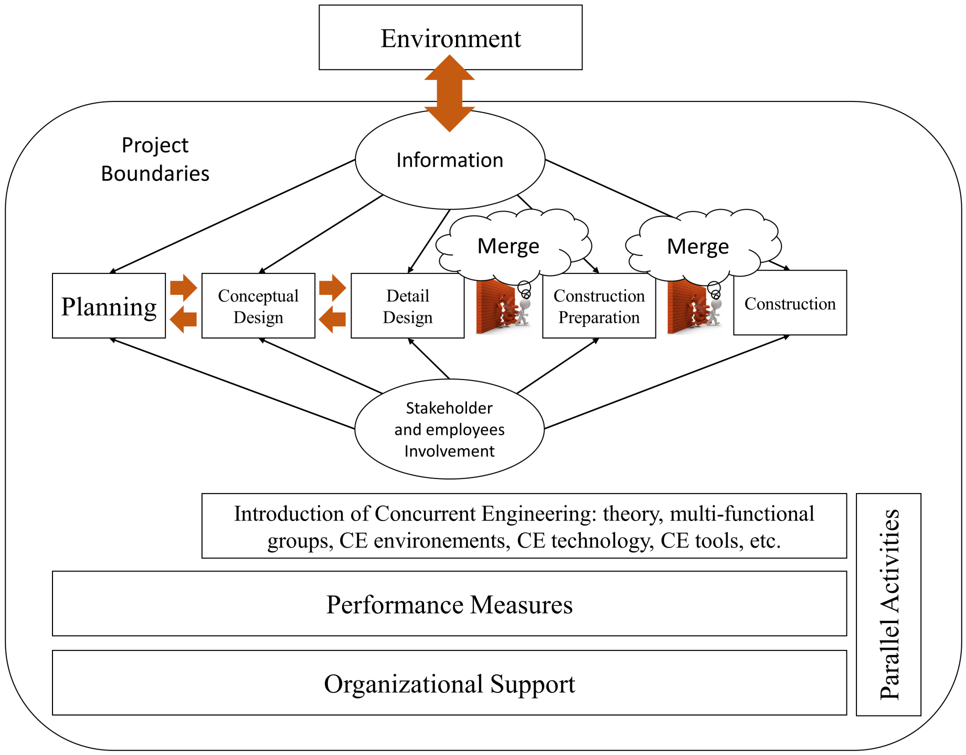

Figure 5.1: The Break-The-Wall Model.

5.2.1 Background Information

In this survey section, we tried to find out in which company the participants are working for and what is the previous experience of the them in cE. As it was mentioned in methodology, the participants who neither used CE nor had so much experience in CE were led directly to the section about the comparison between CE and the traditional product development methods. There, they could submit their general opinions about CE and not their empirical experiences.

Firstly, Figure 5.3 shows that 52% of the participants are working for Sweco and ViaNova and this means that the presented results are highly related to these two companies.

Furthermore, as it is depicted on Figures 5.3 and 5.4 the main part of the participants 74% and 78% had training and experience in CE respectively. That means that the collected data in the next sections of the survey came mainly by experienced participants in CE, which increase their validity.

5.2.2 Project information

The participants in this section of the survey could choose the projects, for which they would like to answer in the survey. The collected projects' names were grouped and are presented on Figure 5.5. There, we can see that the most popular projects were the "Fellerprosjektet Ringer-

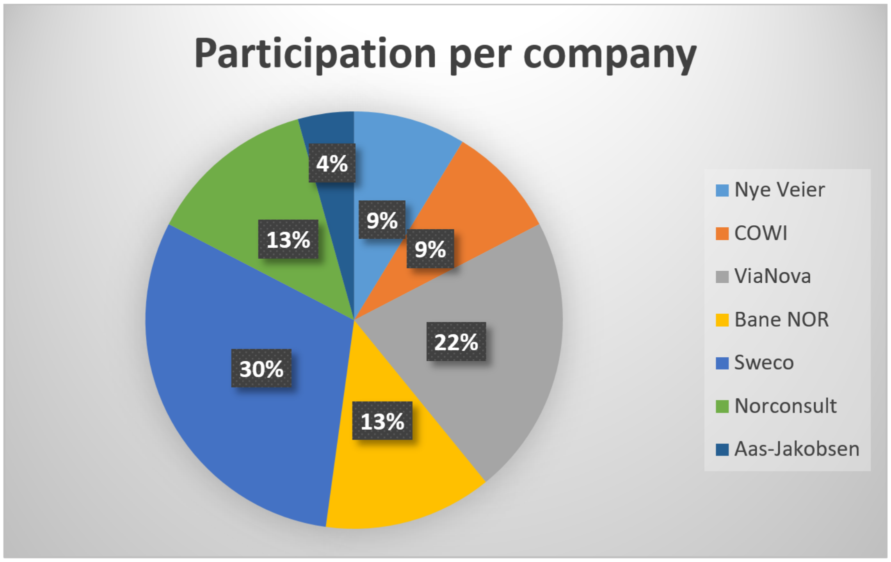

Figure 5.2: The companies that the participants are working for.

Figure 5.3: Training in CE.

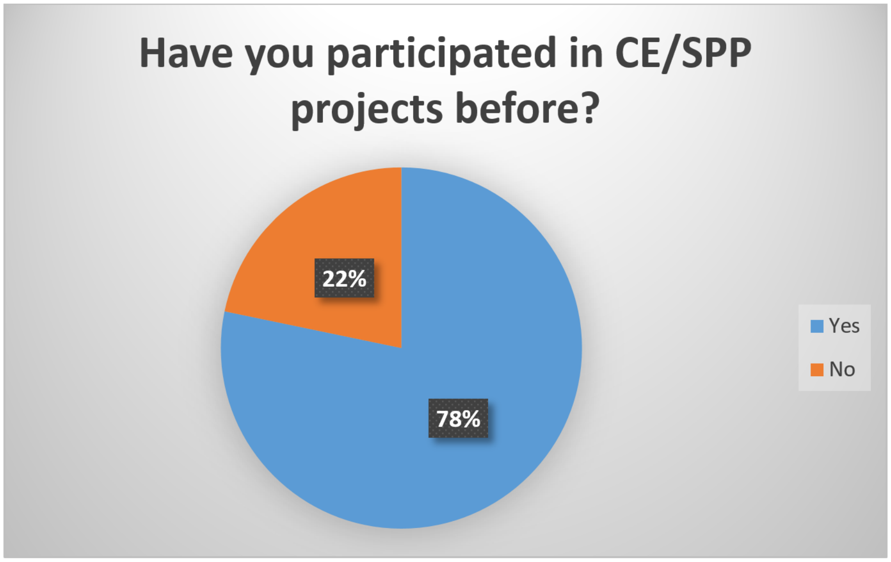

Figure 5.4: Previous participation in CE projects.

ingsbanen og E16" with four participants and the "InterCity Dovrebanen, Venjar-Langset" and "E6 Storhove-Øyer" with two participants in each of them. Thus, possible correlations between the chosen projects, and the benefits and challenges of CE implementation could be identified. However, the limited participation in the survey, did not give us the chance to identify these kind of correlations using statistical analysis.

In addition, the participants had to mention their role in the projects and the results are shown on Figure 5.6. The three main parts of the participants were Project Leaders, BIM Coordinators and VDC Facilitators with 33%, 29% and 14% respectively. It is very important to point out, that a third of the participants were Project Leaders to their projects, and thus they had a more holistic point of view about the projects. The high percentage of BIM Coordinators and VDC Facilitators (43% together), explains the reason that the main part of the participants responded that they had experience with CE.

Finally, a last question about the degree of participation in the implemented meetings and work sessions, helped us to categorize the participants to active and inactive. The active participants could continue to the following sections of the survey, which are about the evaluation of CE meetings and work sessions. On the other hand, the respondents who did not participate in both of them (inactive participants), were led directly to the section about the comparison between CE and traditional product development methods.

As it is depicted on Figure 5.7, there was high participation in both meetings and work sessions, equal to 90%. Thus, there is also high participation at the next survey sections, about CE meetings and CE work sessions.

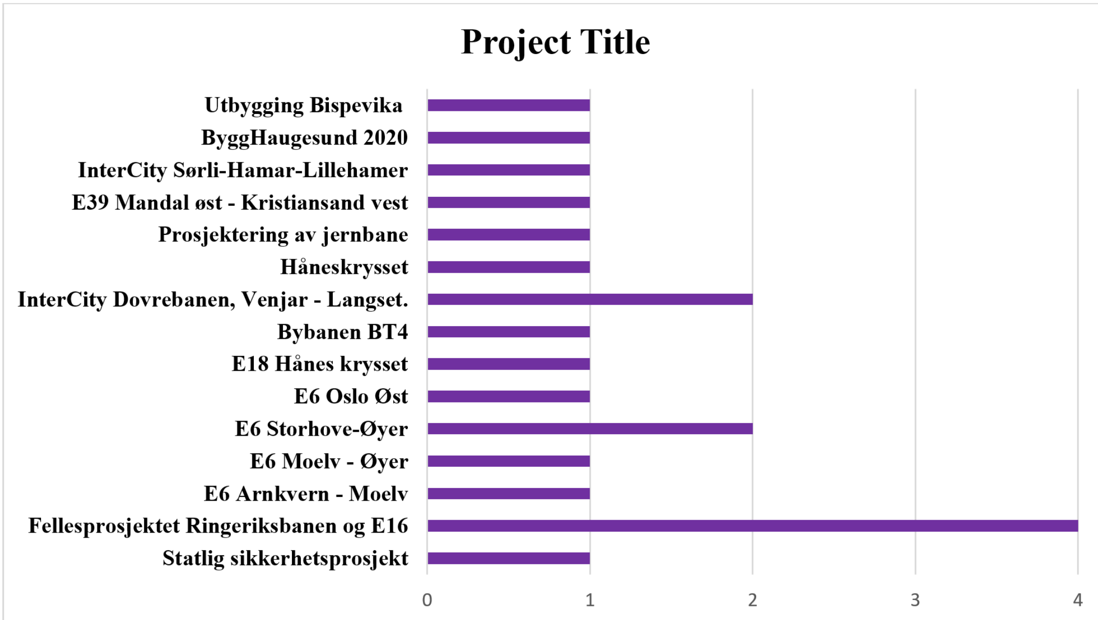

Figure 5.5: Mentioned projects in the survey.

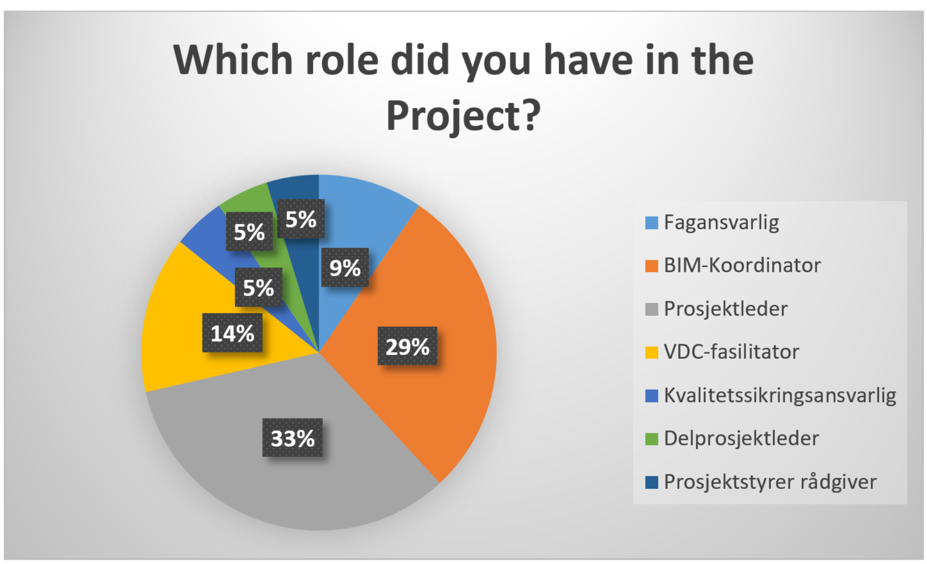

Figure 5.6: The role of the participants in the projects.

Figure 5.7: The participation in CE meetings and work sessions

5.2.3 CE Meetings

In this section we tried to find out the frequency of the CE meetings, the percentage of the participation and the quality of them. For the latter, four questions were used with a grading scale 1-5. As it is shown on Figure 5.8, the meetings were mostly conducted a few times per month and the participation in them was high.

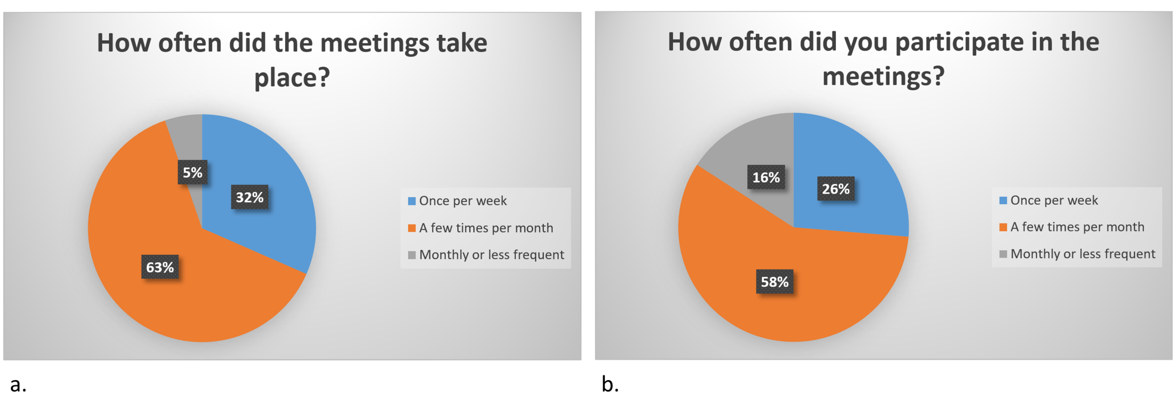

Figure 5.8: a) The frequency of the meetings and b) The percentage of participation in the meetings.

Concerning the four evaluation questions about the quality of the meetings, as it has already been mentioned, a scale of 5 was used. The qualitative meaning of this scale is; 1:strongly disagree, 2: disagree, 3:neutral, 4:agree and 5:strongly agree. The results of the questions are presented on Table 5.9 and are the following:

Contribution to project progress/decisions: In this question the result was 3.7/5. It seems that the participants agree that the CE meetings contributed to the project progress and decisions.

Focus on project challenges: According to the result in this question (4.2/5), there is a high agreement that the CE meetings were implemented with focus on project challenges and solutions.

Same agenda in every meeting: The participants also agree (3.5/5) that the CE meetings had the same agenda each time.

Avoid project failures: Finally, they agree (3.8/5) that the CE meetings helped the involved companies to avoid potential project failures.

Hence, the participants argue that the CE meetings were very beneficial for the projects because they supported their implementation by helping with project decisions, and by identifying and mitigating potential project failures. In addition, the meetings were not boring awitha flexible genda.

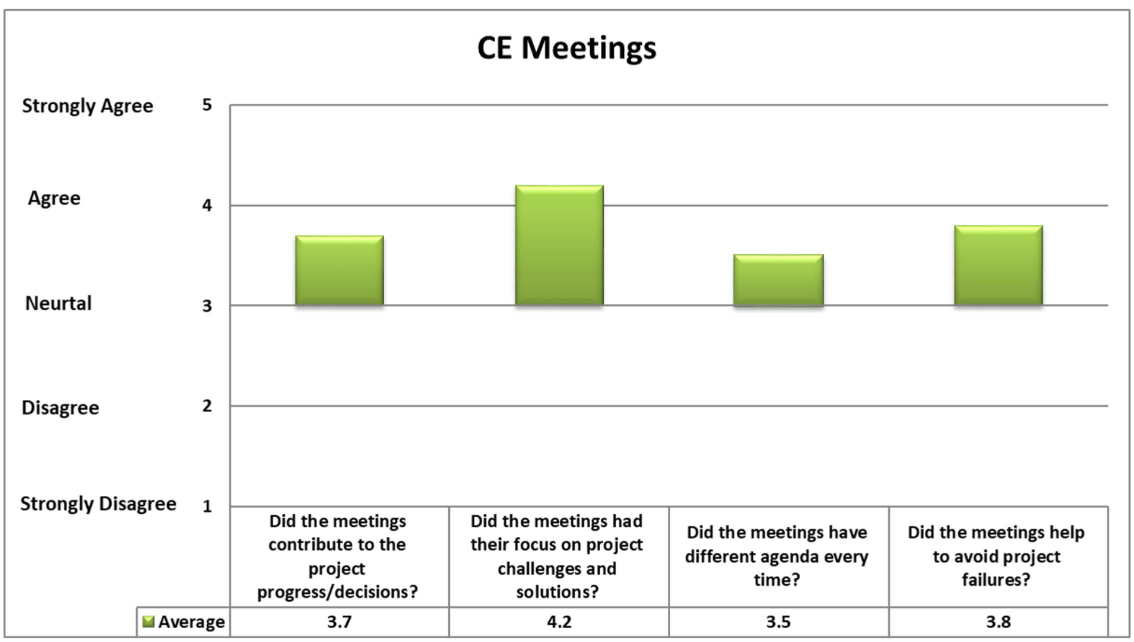

Figure 5.9: The quality of the CE meetings.

5.2.4 CE Work Sessions

In this section we tried to evaluate the quality of the work sessions in the projects based on the participants' answers. For this reason, four evaluation questions used in this survey section.

The used scale here was again a qualitative scale; strongly agree-strongly disagree, with a range of 5 for a quantitative interpretation of the results. This method makes the results more tangible and helps the representation and evaluation of them. The results are presented on Table 5.10 and are the following:

The session goal was described and explained clearly: In this question the participants agree that the work sessions were explained clearly (3.8/5). Hence,the work session participants could understand the goal and the topics of these sessions, which in its turn could increase their participation.

The work session stick to the goal: The participants believe with 3.6/5 that the work sessions had a good flow with a focus on their goal, as it was presented in the beginning of the sessions.

Focus in resolving interdisciplinary issues: In this question we got the highest result 4.1/5. This show that the participants are satisfied with the focus in resolving issues related to their interdisciplinary background. The most important thing in the work sessions between the different involved companies is the common language among their employees. If a CE work session can overcome the difficulties that are appeared due to the different working environments, policies and methodologies that each company has, it can be successful in its implementation with high efficiency and no conflicts.

The preparation grade of the participants: Also in this question the participants have a neutral opinion (3.4/5) that the other groups of the companies came prepared in the work sessions. This could increase the collaboration and communication between them and contribute to the successful implementation of the CE session.

A summary of the results in this survey section could be that the work sessions were implemented in a successful way with clear topics, they stuck to their goals and overcame any potential interdisciplinary issues. Finally, the participants could be better prepared for the CE work sessions.

5.2.5 Challenges of CE Implementation

In this section the challenges in implementation of CE meetings and work sessions were identified. Four questions were used as evaluation criteria with a scale of 5. Moreover, different qualitative meanings were applied on each question's scale. The results are summarized on Table 5.11 and are the following:

Collaboration (very hard-very easy): The participants here are neutral (3.2/5) about the degree of difficulty of collaboration among the involved companies. Hence, it is a little bit unclear if the way of CE facilitation helped or not the collaboration of the teams in the projects.

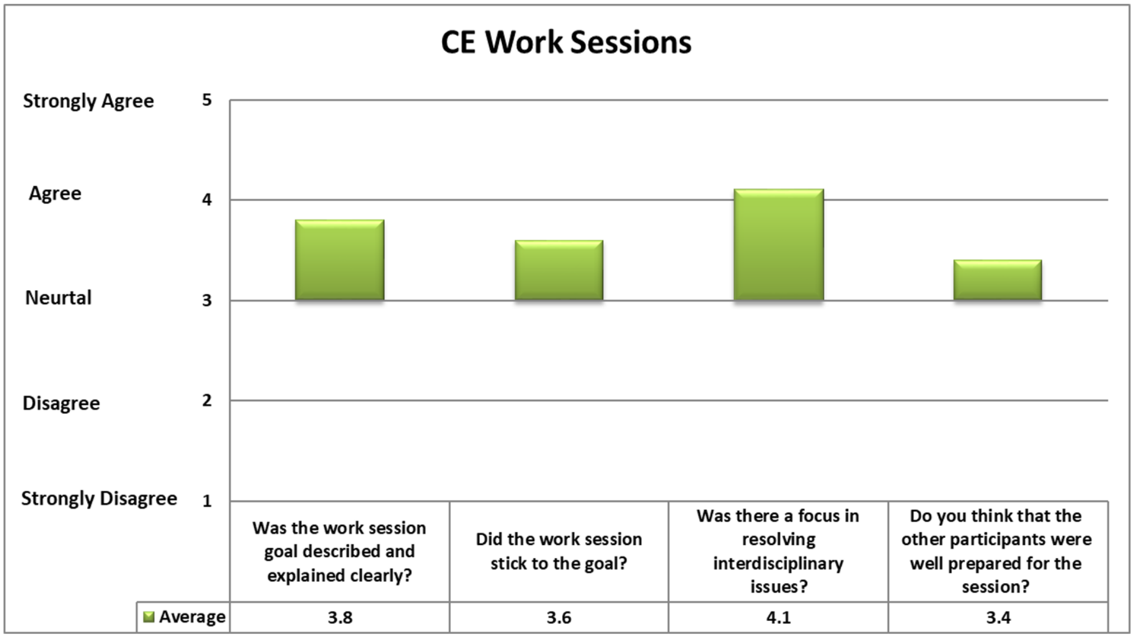

Figure 5.10: The quality of the CE work sessions.

Communication (very hard-very easy): The participants believe (3.5/5) that it was easy to communicate with the employees of the other involved companies. This can be interpreted in two ways. First, it seems that the participants were well prepared and motivated to participate in the CE meetings and work sessions and second that the implementation of CE was successful.

Motivation (very demotivated-very motivated): It is clear from this and the other questions that the participants were motivated and excited for the CE meetings and work sessions. The result in this question was 3.9/5 and was the highest in this survey section.

Meetings and work sessions facilitation (very insufficient-very sufficient): Concerning the facilitation of the CE meetings and work sessions they agree (3.5/5) that it was sufficient. The CE tools, CE equipment, CE methods and facilitation of CE meetings and work sessions are of high importance and can affect the degree of success of CE.

Hence, the implementation of CE can confront some challenges in its implementation and especially in the collaboration, communication and employees motivation. Both an experienced project manager and a CE facilitator are needed for a successful CE. The results show that the CE implemented in a sufficient way in these projects but maybe suffered from facilitation difficulties.

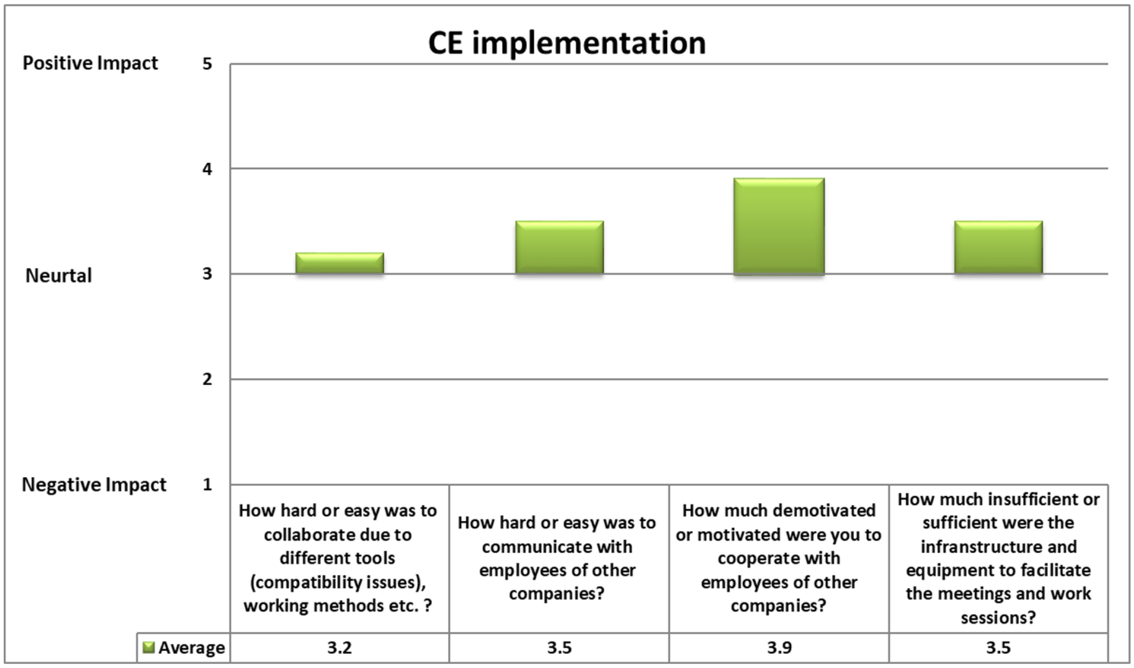

Figure 5.11: Challenges in the implementation of CE.

5.2.6 CE vs Traditional

The comparison of CE vs traditional engineering consists the core of the Survey. It is the focal point of the end product (survey plug-in tool), which aims to provide guidelines about the advantages and disadvantages of CE to the web portal users. Thus, the results in this section are of high importance in order to be able to provide this kind of information.

The results of the 13 questions, in the relevant section of the survey, are presented here. Each of them is analyzed based on the fact that these questions were answered on a scale of 10 ranging from -100% to +100%, and the total responses were 26. It is important to note here that the users reply on the question of whether CE had a positive impact in the following key aspects:

Communication time: In the first question, about communication time, the average value of the user responses is 6, which represents an increase in percentage by 21,4. This means that people think that CE has a positive impact, and thus decreases communication time by 21,4%.

Overtime: In the second question, the average value of the user responses is 5,5 representing an increase of 11,1%. The respondents note that CE decreases overtime by 11,1%.

Total Project Time: In this question, the average value of the user responses is 5,4 which represents an increase in percentage by 9,4. This means that CE leads to an average of 9,4% decreased project duration.

Total Project Cost: In this question, the average value of the user responses is 5,9 which represents an increase in percentage by 19,7. According to that, CE leads to an average of 19,7% decreased project cost.

Operational Cost: In this question, regarding operational costs, the average value of the user responses is 5,7 which represents an increase in percentage by 14,5. Based on that, CE decreases operational costs by 14,5%.

Job Satisfaction: In the question, about job satisfaction, the average value of the user responses is 6,5 which represents an increase in percentage by 32,5. This means that people think that CE has increased their job satisfaction by 32,5%.

Personal Motivation: In the question about the personal motivation of the employees, they replied an average of 7,1 or an equivalent of 47%. The employees perceive their personal motivation to have increased by 47%.

Conflicts: In the next question, asking to evaluate the impact of CE regarding the conflicts among the employees, they replied with an average of 5,3 or 7,7%. Thus, CE slightly decreases the conflicts by 7,7%.

Collaboration: In the question regarding collaboration of the employees, they replied an average of 7 representing an increase of 43,6%. In other words, CE increases the collaboration during the projects by 43,6%.

Common Solutions: In the question regarding commonly accepted solutions by the employees, they replied an average of 6,6 representing an increase of 35%. In other words, CE increases the solutions that are accepted by all involving parties by 35%.

Project Quality: In the question, regarding the quality of the project, the participants of the survey replied an average of 6,5 which represents an increase in percentage by 32,5. Based on that, people think that with CE the overall quality of the deliverable of the project increases by 32,5%.

Project Flexibility: In the next question of this section, about project flexibility, the average rating of the user is 6,2 or 26,5%. This means that the project flexibility (adaptability to unexpected events) increases with CE by 26,5%.

Flexibility in the Workplace: In the last question of this section, about flexibility in the workplace, the average rating of the user is 4,7 or -7,7%. This means that the employees report decreased flexibility (flexible working hours, working from home etc.) by 7,7%.

In order to have a better overview of these results, there was a grouping of the aspects that are positive when increased such as job satisfaction (Figure 5.12) and those that are positive when decreased such as communication time (Figure 5.13). With this representation it is easier to see that the respondents reported on average that almost all of these aspects are benefited from the use of CE. The absolute value of these changes has a lowest of 7,7%, for the decrease of flexibility in the workplace and a highest of 47% for the personal motivation of employees.

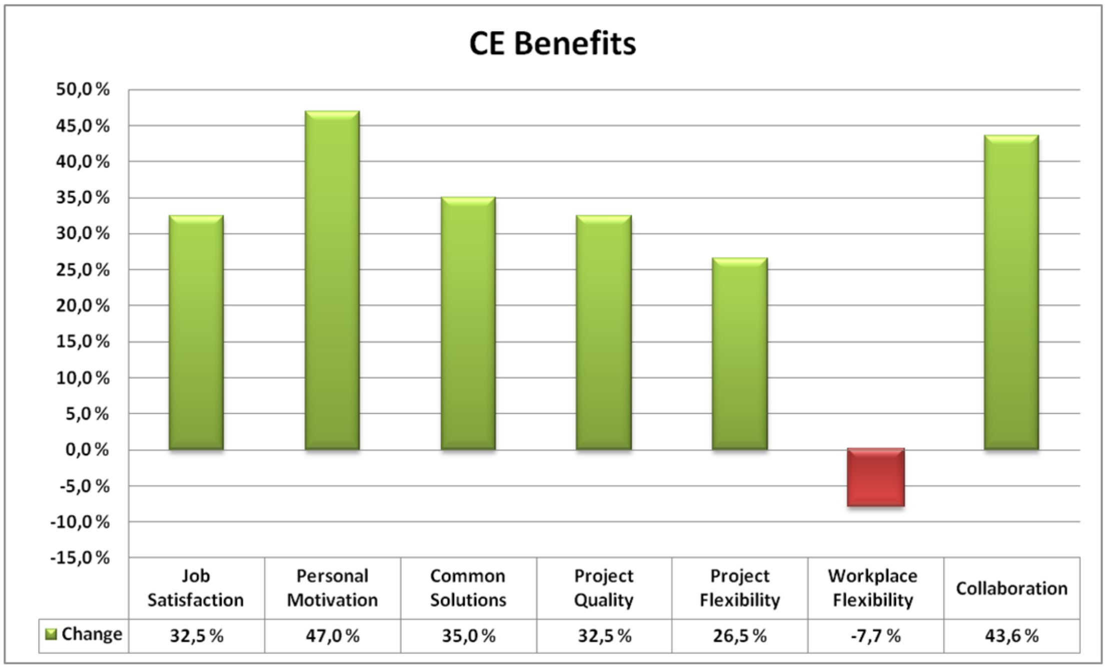

Figure 5.12: Summary of CE benefits 1.

5.2.7 Feedback from Participants on Q1

The survey that was conducted contains two open questions. The first one was "What did you like the most about CE/SPP in your Project?". The feedback that we got in this question had various content. After a qualitative analysis, the results were categorized in four main categories as shown on Figure 5.14:

The feedback included in the first category (Solutions and Decisions) was relevant to better solutions that CE provided in their projects. This was mainly due to better understanding of the problem as a whole, commonly agreed and well grounded decisions taken by interdisciplinary employees, as well as goals that were clearly set.

On the second category (Meetings) there is content relevant to CE meetings. The respondents think that there was a higher focus on the planning of the meetings compared to meetings of traditional engineering. In addition to that, the employees came more prepared for these

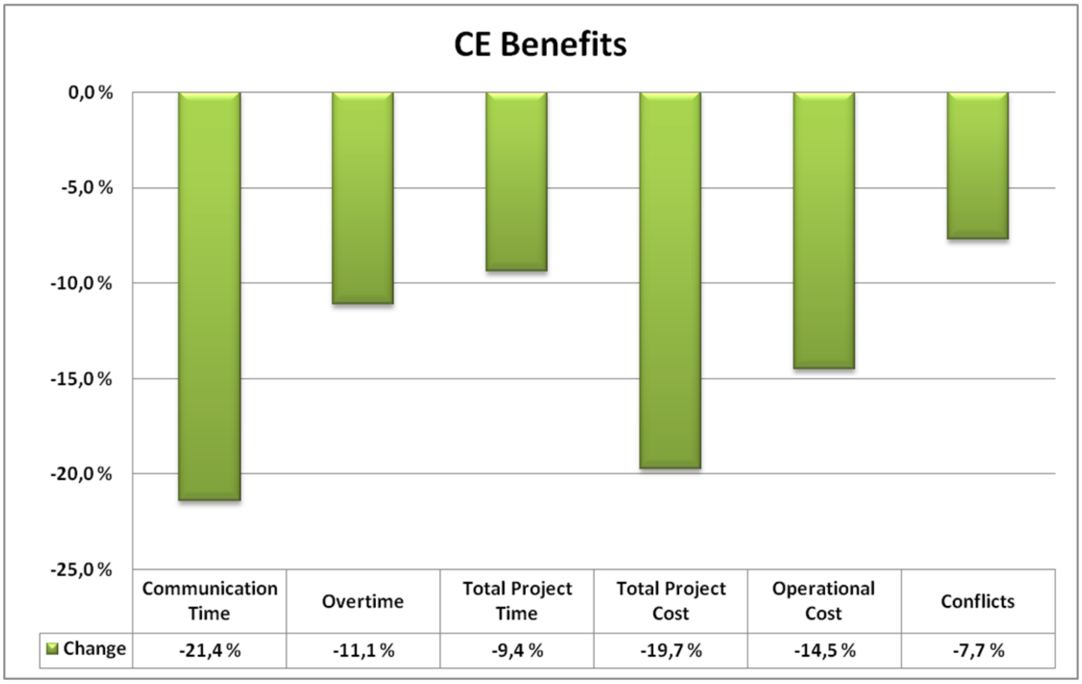

Figure 5.13: Summary of CE benefits 2.

Solutions and Decisions		Meetings	Projects	Working Environment
• More focus on the solutions	• Concrete problem statements	• Better prepared participants in the meetings	• Clarifies the central challenges of the project in the agenda	• The pressure and the dynamics of interdisciplinary working environment
• Clearer interdisciplinary solutions	• The client was involved in all meetings, which led to well accepted and well grounded solutions.	• No planning in the meetings, just decisions on the terms and deadlines	• Knowledge acquired about the big changes of the project in the planning and building phases	• The knowledge sharing and the knowledge acquired for other subjects and their prerequisites.
• Common understanding for solutions	• Clearly defined what should be done	• Higher focus on the planning of the meetings	• The methodology was tested in the planning phase	• Early interdisciplinary work
• Mutually agreed solutions	• Better focus on a good interdisciplinary solution		• Overview planning	• Interdisciplinary work
• Effective method to understand quickly the	• Better understanding of the challenges		• As a Manager, had the chance to plan, facilitate and	• That all the managers meet in person
•Decision oriented method	• Consensus with regard to quick decisions			• Better awareness, among the subjects, for their influence in the project and their impact on each other
• Work with specified goals				

Figure 5.14: First open Question results.

meetings. Lastly, the content of these meetings was to take decisions about the deadlines and not just about planning.

The third category (Projects) contains the feedback that is relevant to projects. Part of the feedback is about how CE helps people realize the bigger changes, that are happening in the planning and building phases, as well as clarify the greatest challenges of the project. Additionally, the employees report that they are positive about the fact that the methodology is tested early in the planning phase.

The fourth category (Working Environment) was created due to the responses about the working environment that CE creates. Most of the users put value in the interdisciplinary work that takes place, especially on early phases of the project. Moreover, they gain increased awareness about their impact in the project. Lastly, they appreciate the knowledge sharing about subjects, other than their disciplines, and their prerequisites.

5.2.8 Feedback from Participants on Q2

The second open question was "Are there any questions that you would like to see in this Survey?". In this question there are unexpectedly two types of answers which are grouped in two categories. Several participants accurately wrote the questions that they think should be included in the survey while others gave generic feedback about CE, the survey or their experiences in the projects.

Direct Questions:

- Which are the success factors and the pitfalls of CE?
- How the decision taking stakeholders, who are outside of the organization, will be better involved?
- Have there been trained meeting facilitators and which influence did they have?
- What is the facilitators experience with CE?
- What is the participants of the meetings experience with CE?

Generic feedback:

To begin with, a participant recommended a distinction on the questions about the project meetings depending on the project phases. This is because he/she experiences different efficiency of the meetings about decision making and the work sessions.

Another answer is about the need to clarify the level of decision making in the meetings. On the one hand, if the goals of the decision making are too open then there is no conclusive goal in the meetings. On the other hand, if the goal of the decision making process is too detailed then the interdisciplinarity is lost. Moreover, it is difficult to anticipate which decisions will be taken and how the group will prepare itself to take these decisions.

Another comment is that when there are not trained meeting facilitators, then the CE meetings tend to become the same with traditional ones. Finally, a participant gave negative feedback about his project, saying that it was an example of bad CE implementation, as it was focusing mainly in the CE facilitation and not to the final results of the project. This led to increased costs while the quality remained low.

5.3 Discussion of the Results and CE Tool

In this section there is a thorough discussion of the survey results as well as an attempt to suggest possible correlations. The focus is to acquire knowledge from the analysis of the results and recommend some guidelines for a future version of the survey tool.

5.3.1 Discussion of the Results

The conducted survey had a some limitations. To begin with, the amount of participants was statistically insufficient, with only 26 responses. In addition, another limitation during the analysis of the results was that half of the responses came only from two out of seven companies (Vianova and Sweco). Nevertheless, it was positive that three quarters of the participants were trained or had experience with CE. Additionally, the answers derived from a plethora of projects (16) which were used increases the reliability of results, concerning CE implementation, from a statistical perspective. Lastly it is worth mentioning that more than three quarters of the responses were from people responsible for the CE implementation (managers, VDC facilitators and BIM coordinators), which had double meaning. On the one hand these roles, do not represent a reliable sample of all personnel, but on the other hand we can assume that have better overview of the projects. All these particularities, were taken into consideration during the analysis of the results and the identification of possible correlations.

Concerning the CE meetings and the work sessions, they were taking place frequently and there was high participation of the employees. Despite that the main part of the participants were not well prepared for the meetings, they argued that they were benefited by them. They articulated that the meetings contributed to the project decisions and solutions, and to the avoidance of possible project failures. Furthermore, there was an agenda variation in the meetings. In addition, they claimed that the facilitation of the CE work sessions was successful because they were explained clearly, they stuck to their goals, and resolved interdisciplinary issues. Furthermore, according to the responses, the implementation of CE in this project was successful because there was sufficient communication and collaboration among the companies as well as infrastructure and equipment.

When it comes to the thirteen key aspects of CE that were investigated, there were some trends that were observed. To begin with, twelve out of thirteen of these aspects were improved from CE and only one declined.

The highest positive impact was in personal motivation and collaboration. In addition factors such as common solutions, job satisfaction and communication time were also significantly improved. In addition to these factors, there is also a possible correlation with the reduced conflicts and overtime that were reported. All these factors indicate that the employees are enjoying the working environment that CE creates. The only negative feedback was a minor decrease in workplace flexibility, which is reasonable due to concurrency of the work (meetings and work sessions).

It is also worth mentioning that, the aspects relevant with the project itself, have improvements related to quality, cost, time and flexibility. The highest improvements in these aspects were identified in the project quality and flexibility. Secondarily, the total and the operational cost of the projects were reduced significantly. Finally, there was a slight reduction in the total project time. While we see a medium or high improvement in almost all of these factors, the project time remains relatively low compared to the rest. Thus, we can attempt to correlate the increased amount of meetings with the lowest improvement in the project time. It is possible that the ratio of work to meeting sessions needs to be further improved.

The open questions helped us to receive a more general feedback about CE and not only based on the given survey questions. The respondents pointed out that the interdisciplinary involvement in the decision making process led to commonly accepted and improved solutions. Furthermore, they believe that the participants in the meetings were better prepared and the planing of the meetings was thorough and effective. In addition, the early introduction of CE contributes in the identification of possible challenges and failures in the project, and supports their mitigation. Finally, they highly appreciate the interdisciplinary work and the exchange of knowledge that come with it. Moreover, it is essential for them to know how their work impacts the others and the project.

5.3.2 Comparison of Survey and Theoretical Results

In this section, a summary of the most important survey findings is presented on Table 5.1. Furthermore, it is attempted to compare the literature results with the survey results. To begin with, it is difficult to compare directly these results but a brief comparison based on the context in attempted here.

According to the theory and survey results the most important aspects of CE were classified in two categories. The first category contains all the benefits related to the project while the second category concerns the employees and thus, is focused on their satisfaction. In addition,

Table 5.1: Summary of Results

	Positive impact of CE			Comments
	Low	Medium	High	
Meetings	-Meeting Agenda	- Project progress and decisions - Focus on project challenges and solutions - Avoid project failures		-Good frequency -Benefits the participants -Prepared participants -Focus on planning
Work Sessions	-Stick to the goal -Preparation of the participants	-Description of the goal -Resolve Interdisciplinary issues		-commonly accepted and improved solutions -interdisciplinary work -exchange of knowledge
Implementation	-Collaboration -Communication -Sufficient/Insufficient infrastructure	-Motivation/Demotivation		
CE benefits*	-Overtime -Total Project time -Operational Cost -Conflicts	-Job Satisfaction -Quality -Flexibility -Communication Time -Total Cost	-Personal Motivation -Common Solutions -Collaboration	-Concrete problem statement -Early involvement of the clients -Early Interdisciplinary work -Focus on specified goals and quick solutions -Better understanding of the challenges

*The only negative impact of CE was found in Working Flexibility.

there were tangible findings in most of them. However, in some cases there were not quantitative results rather than qualitative. The two categories of the CE aspects are the following:

Project (flexibility, time, cost, quality, collaboration, communication time):

Flexibility: Both literature findings and survey results say that there is an increase of flexibility in the CE projects. In the literature, it is found that CE helps with respect to flexibility because it keeps project phases open and thus, increases adaptability to changes. This agrees with the survey results that show an increase of flexibility by 26,5%.

Cost: With respect to cost, the literature shows that significant cost reductions are expected mostly due to decreased redesign time. The findings of the survey those cost reductions with a decrease of total project cost by 19,7% and of operational cost by 14,5%.

Time: As for the total time of the project the literature suggests time reductions due to concurrency of work. The survey results show a total project time reduction of 9,4% which is lower than what is expected from the literature but still significant.

Quality: With respect to quality, the literature shows a positive correlation with CE. Quality is an aspect hard to measure, but the literature recommends worth mentioning increases. That is reinforced by the survey results which show an increase of 32,5% in quality.

Collaboration: Collaboration in the working place, is another important aspect of CE. However the literature does not cover the direct impact of CE to collaboration but correlates it with the successful implementation of it. The survey results show a vast increase in collaboration (43,6 %) as well as a significant decrease in the communication time (21,4%) which supplements it.

Employee Satisfaction (job satisfaction, overtime, conflicts, personal motivation, workplace flexibility, common solutions):

In these aspects there were not relevant literature findings to compare with the survey results. This is the main reason that these were included in the survey at the first place. It was wanted to investigate how these important aspects of employee satisfaction are benefited from CE as well as how they are correlated with its successful implementation. Most of the findings recommend that CE has positive impact on them. Job satisfaction, personal motivation and common solutions have increased by 32,5%, 47% and 35% respectively. Additionally, overtime and conflicts among employees have decreased by 11,1% and 7,7% respectively. However, the workplace flexibility is slightly reduced (7,7%), a fact that is expected from literature as CE requires concurrency of work (meetings, work sessions).

5.3.3 Recommended Improvements in CE implementation

As it discussed in the previous chapters, CE has a positive impact on almost all the investigated parameters of the survey. However, this impact is not as high as it was expected due to various reasons.

To begin with, the feedback from the participants for the CE meetings could be improved. The meetings should be improved with regard to project progress, decision making, avoidance of project failures and their agenda. The employees would appreciate meetings that do not have the same content every time. On the contrary the meetings should adapt their frequency and content based on the project needs. The participants based on the feedback are well prepared for the meetings so, it seems that the facilitator of the meetings should focus on improving their content. He/she should pay close attention to the planning of the meetings in order to make them more effective when it comes to the aforementioned problems.

Concerning the work sessions, there is also space for improvement. The feedback shows that the work session goal could be described more clearly. Moreover, the work sessions did not stick to the goal to the degree that it was expected and the participants were not well prepared for the sessions. One reason for that could be that it is common to misinterpret the work sessions as meetings that do not require actual work. It is the facilitators responsibility to make sure everybody is understanding the purpose of the work sessions and to implement it correctly. One suggestion to improve this, is the employees to have training in the beginning of the project.

The implementation of CE, based on the responses, was quite challenging also. The collaboration due to different tools and working methods was not significantly better, as well as the communication with employees of other companies. Also the infrastructure and the equipment of the meetings should be better. The companies should pay attention in the improvement of equipment and CE tools, as well as in the elimination of compatibility issues due to different software. One idea is to invest in similar tools or train the employees to solve these issues. Additionally, it is expected that the CE web portal that is under construction from the companies will improve several of these issues.

As for the key aspects of CE that were investigated, their improvement is weak compared to what it was expected. These aspects are the overtime of the employees, the total project time, the operational cost and the conflicts. The conflicts could be improved further if the collaboration issues are resolved with the methods that we suggested above. As for the overtime and the total project time, they are depending on the efficiency of the communication and the amount of rework. Their improvement is related with the effectiveness of the meetings and the work sessions. If the meetings and the work sessions implement some of the aforementioned suggestions, they will impact significantly these key aspects. Lastly, the operational cost is expected to be affected as CE demands special infrastructure and equipment. Although, if the initial investments are made these costs will not be as high.

5.3.4 The CE Tool

The analysis of the aforementioned results can lead to an updated version of the survey tool. Especially the two open questions give important feedback of what should be included in the next version of the survey tool. The feedback analysis of these questions was quite time demanding as it concerns qualitative data and not quantitative. Thus, if they remain in the survey tool, they require a person to be responsible for the analysis and the continuous improvement of the tool.

Regarding the rest of the survey results, they are part of the tool, and would be presented to the web portal visitors to gain information about CE. This content consists of quantitative data and could be automatically presented in charts with the use of the right software.

The free version of Google forms worked well for the purpose of this thesis, and especially with the limited number of responses that the survey received. However, as the responses will be increased and the need of automatic presentation of the results will become necessary, it is recommended to try other software such as Survey Monkey. Another possible recommendation is to create software that analyses and presents the data of this specific survey.

The final product of this thesis is the survey tool that is embed in the CE web portal and can be found in the link:`http://www.samtidigprosjektering.no/survey/`(5.15). The portal is currently under construction, but the survey tool is already functional (Figure 5.16).

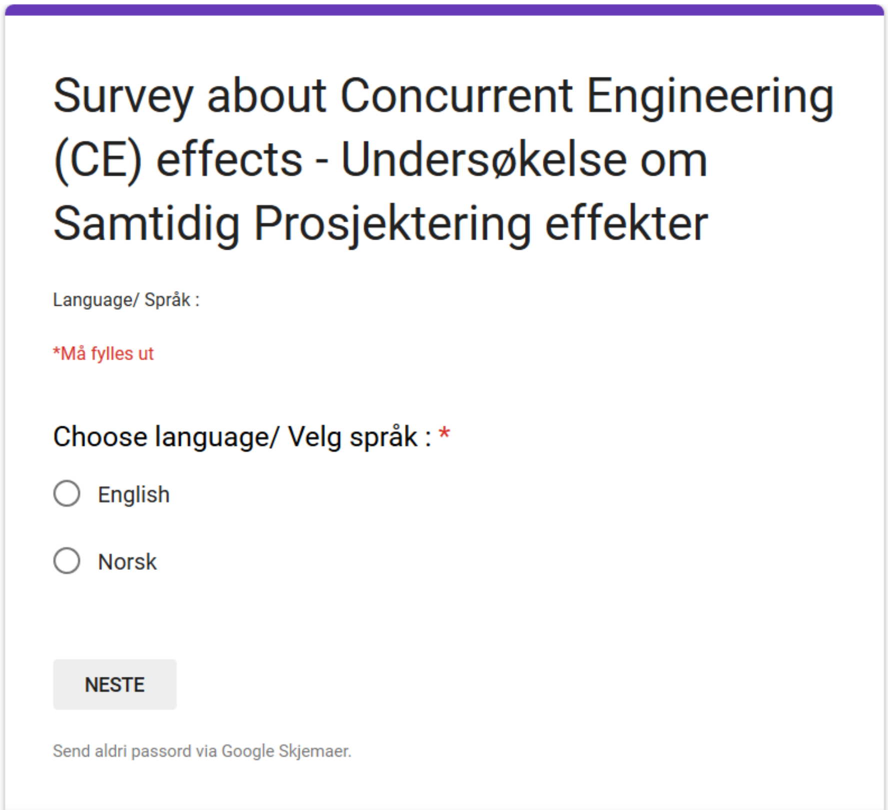

Figure 5.15: Final version of Survey Tool in this thesis.

Figure 5.16: CE web portal of SPP project.

Chapter 6

Conclusion and Future Work

The goal of this report was to create a survey tool about CE. This CE tool could be useful in the hands of the engineers of the involved companies in the SPP-project, as well as students or others that are interested in CE. The main conclusions occur from the implemented literature research and the conducted survey.

For the literature research, a vast number of articles were used in order to gain as much knowledge as possible about the following topics; CE, CE web portals and tools, surveys, and data management and extraction. This part of our research was quite thorough and the results have a solid background. However, the topics that were investigated could be of a wider range in future work. As for the results of the survey the lack of participants limits their use. Although, the content of the survey was made in a way that could give us good insights about CE, the gains from its introduction in the projects, as well as useful feedback from the participants.

The conclusions about the various aspects of CE and the content of the CE tool are analytically presented in the following sections. Finally, ideas for future work are presented.

6.1 Concerning CE

In general, our findings have shown that CE should be used by companies. That is because the aspects that were investigated in this report; flexibility, time, cost, quality, multifunctional teams and collaboration, seem to have more benefits than losses. Although, there are significant challenges, as well as paradoxes, that could exist in the implementation of CE, and have to be resolved. Thus, the strategy to cope with these issues should vary based on the type of industry. Especially, managers have a key role to try to keep the benefits balanced with the negative effects of concurrency.

It is important to understand the different aspects of flexibility in order to apply a successful CE. As it is described in theory, CE introduces flexibility mostly in the design and production phases. These phases should have related tasks and have to remain open for changes, for as long as possible and always in correlation with customer demands and environmental alterations. Although, to a certain degree, this depends on the type of company and its strategy. There is neither a formula nor a clear answer to the questions of where and for how long CE should be introduced in the product development model. Each project is identical and has to be executed in accordance with the industry's strategy. Thus, a project manager has to follow empirical regulations, based on his/her experiences, and literature research to balance between the CE benefits and challenges.

Furthermore, it is observed that with CE there is considerable time reduction in all kind of industries. The percentage of time reduction varies, based on each type of industry, but still it is always positive and notable. This is expected from CE, as its main principle is to save time by parallel processing. Although, there are matters to be considered (e.g. communication time) in the implementation of CE, in order to have the expected results.

Additionally, cost is also reduced significantly in most cases. That is because production costs are reduced as redesign time decreases due to good communication and cooperation. The investigated cases show a remarkable reduction in production costs. These reductions clearly indicate that CE is beneficial for these companies.

Concerning the quality, the identified examples in the literature review showed that there is a correlation between the quality of the product and CE. This correlation in some cases was not so obvious and it is challenging to interpret the qualitative data to quantitative. Quality is an abstract and objective term, and thus for some companies it is measured by profit or for other by the robustness of the product. However, the applied CE principles in the companies described in these examples led to improved teamwork, increased efficiency with regard to error reduction, and process improvements that led to reduced scrap.

The methodology of CE introduces the multifunctional teams in a project. It is very common in CE projects to be involved different companies that use different tools and methods, and have different policies. This makes the implementation of CE challenging. There are many methods and guidelines in literature that can support the collaboration of the multifunctional teams. A good example of these methods is the CEMET method that could help a project manager or a CE facilitator to understand better the viewpoints of the team members and resolve potential communication issues.

A good collaboration among the involved teams in a CE project is highly related to an efficient communication. The findings about how CE can benefits collaboration in a project are not clear. However, there are useful guidelines about the collaboration of teams. It is important to mention that the "7c"; collaboration, commitment, communications, compromise, consensus, continues improvement and coordination should be taken into account from the responsible project manager and CE facilitator.

On the other hand, the implementation of CE can lead to a paradox. Despite the fact that it reduces the development time in several cases, by decreasing the redesign and rework and improving the production (minimize cost and improve quality), it can easily complicate the design problem by increasing the amount of tasks, their correlations and constraints (Wu and O'Grady, 1999). On the contrary, in other cases there are delays caused by rework, and the gain from overlapping activities must be weighed against it. One reason for this is that engineers must redo part of the work, as other members make changes that affect them. In traditional engineering, processes are sequential, meaning that engineers begin with the next phase when all the changes in the previous phase are finalized.

Even though that CE tries to avoid rework, in a few cases this is inevitable. This problem is usually handled by increasing the communication time among the teams of engineers (Loch and Terwiesch, 1998). That means that they have to conduct more meetings, in order to discuss possible changes and avoid future rework. This leads to another paradox; increasing communication time, by itself, is unproductive and inefficient, because the time that would have been spent in rework is now spent in communication. The ideal solution, for this challenge, is to find the optimal combination of communication and rework time.

Hence, a development of a general CE framework in construction could be a guidance for project managers that would like to introduce and implement CE in their projects in a successful way. For this reason, a novel model under the name "Break the Wall" model was developed and presented in this report. This model transfers the CE knowledge and the empirical CE data from manufacturing to construction and tries to overcome the challenges of its implementation.

6.2 Concerning CE Tool

Web portals, with a user-friendly interface, together with e-learning offer quick and easily accessible information to the users and thus, it can increase their productivity. In addition, web portals can contain a plethora of different tools integrated as plug-ins in their main structure. One of the tools that could be included in a CE web portal could be a survey tool. This tool could collect empirical data from the CE projects, analyze and interpret their results, both qualitatively and quantitatively, and present them in a simple way to the web users. Additionally, in the future, it could create a useful database of all CE projects related to SPP. The responsible project managers or interested employees should have access to the results. Furthermore, it could help them to identify potential fails and improvements that could apply in their new projects. Moreover, these results could be used as an argumentation for the use of CE in the projects.

Different survey software such as Google forms, Survey Monkey, WordPress Survey plug-in could be used for the development of this CE tool. The final choice of the software should be taken based on different parameters such as the the type of data (qualitative/quantitative), the data analysis time, the data representation method and so on. A simple solution of a CE survey developed in Google Forms and embed in CE portal was presented in this report.

6.3 Future Work

A deeper literature research about the benefits and challenges of CE could be conducted. In addition, an implementation of the developed CE framework in construction ("Break the wall" model) could check the validity of this model and improve its content.

It is of high importance also to clarify the target group of the CE tool. If this tool is intended to be used also by external stakeholders, it is crucial to integrate them in the development phase. The number of the participants in the first survey was limited. It is of high importance to get feedback from more potential users of the CE tool. Half of our responses came from ViaNova and Sweco employees and thus, there is a clear need to get equally distributed responses among the involved companies. A possible reason for this could be the lack of motivation or interest of the employees that received the survey link. A survey reward could possibly motivate them and thus, increase the responses. Furthermore, a deeper interpretation of the surveys' results could be implemented with respect to finding correlations about different aspects. Finally, it could be interesting to identify correlations among the different CE benefits such as communication, flexibility, cost and so on using statistic methods such as ANOVA and principal components analysis.

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Appendix A

Survey

Survey about Concurrent Engineering (CE) effects - Undersøkelse om Samtidig Prosjektering effekter

Language/ Språk :

* Required

1. **Choose language/ Velg språk :** *

Mark only one oval.

- English *Skip to "What is Concurrent Engineering (CE)?."*
- Norsk

Hva er Samtidig prosjektering (SPP/ICE)?

Vennligst bruk noen minutter å svare på undersøkelsen om effektene til Samtidig Prosjektering (ca. 5 min)

Hva er Samtidig Prosjektering (SPP/ICE)?

SPP er en arbeidsmetode som vektlegger parallellisering av oppgaver (dvs. å utføre oppgaver samtidig), som ofte kalles 'Intergrated Concurrent Engineering' (ICE)

Bakgrunn:

Denne undersøkelsen er en del av en masteroppgave utført av to studenter i prosjektledelse ved Norges teknisk-naturvitenskapelige universitet (NTNU). I tillegg, undersøkelsen er en del av FoU-prosjektet 'Samtidig Prosjektering', støttet av Norges Forskningsråd. Hovedmålet til undersøkelsen er å finne betydningen av samtidig prosjektering i infrastrukturprosjekter, spesielt i Norge, og forsøke å identifisere styrker og svakheter ved gjennomføringen.

Bakgrunnsinformasjon

2. **I hvilken bedrift jobber du?** *

Mark only one oval.

- Bane NOR
- Epsis
- Metier
- Multiconsult
- Nye Veier
- Rambøll
- Sweco
- Trimble
- ViaNova
- Other: ______

Bakgrunnsinformasjon

3. **Har du fått opplæring i SPP/ICE?** *
   Mark only one oval.

   - Ja
   - Nei
   - Vet ikke

4. **Har du vært med i SPP/ICE prosjekter tidligere?** *
   Mark only one oval.

   - Ja
   - Nei *Skip to question 88.*
   - Vet ikke *Skip to question 88.*

Antall prosjekter

5. **Hvor mange prosjekter vil du svare på undersøkelsen?** *
   Mark only one oval.

   - 1 *Skip to question 70.*
   - 2 *Skip to question 38.*
   - 3 *Skip to question 6.*

Prosjektinformasjon

6. **Hvilket var navnet til projektet (eller beskrivelse)?** *

7. **Hvilken var din rolle i prosjektet?** *

8. **Var du intern eller ekstern i prosjektet?** *
   Mark only one oval.

   - Intern
   - Ekstern
   - Vet ikke

9. **Deltok du på SPP møter og arbeidssesjoner (ICE møter)?** *
Mark only one oval.

- Ja
- Nei *Skip to question 88.*
- Vet ikke *Skip to question 88.*

Evaluering av SPP-implementering basert på møtene

10. **Hvor ofte møtene holdes?** *
Mark only one oval.

- Daglig
- Mange ganger hver uke
- En gang hver uke
- Noen få ganger hver måned
- Månedlig eller sjeldnere (f.eks. annenhver måned)

11. **Hvor ofte deltok du i møtene?** *
Mark only one oval.

- Daglig
- Mange ganger hver uke
- En gang hver uke
- Noen få ganger hver måned
- Månedlig eller sjeldnere (f.eks. annenhver måned)

12. **Møtene fungerte godt for å få fremdrift på aksjonspunkter/beslutningslogg** *
Mark only one oval.

	1	2	3	4	5	
Helt uenig						Helt enig

13. **Møtene hadde fokus på prosjektutfordninger og løsninger** *
Mark only one oval.

	1	2	3	4	5	
Helt uenig						Helt enig

14. **Agendaen på møtene var lik hver gang** *
Mark only one oval.

	1	2	3	4	5	
Helt uenig						Helt enig

15. **Møtene bidro til å unngå feil i prosjektet** *
Mark only one oval.

	1	2	3	4	5	
Helt uenig	◯	◯	◯	◯	◯	Helt enig

Evaluering av SPP-implementering basert på arbeidssesjonene

16. **Målsettingen for sesjonen var tydelig beskrevet og forklart** *
Mark only one oval.

	1	2	3	4	5	
Helt uenig	◯	◯	◯	◯	◯	Helt enig

17. **Arbeidssesjonen ble gjennomført iht. målsetting** *
Mark only one oval.

	1	2	3	4	5	
Helt uenig	◯	◯	◯	◯	◯	Helt enig

18. **Arbeidssesjonen fokuserte til å løse tverrfaglige problemstillinger** *
Mark only one oval.

	1	2	3	4	5	
Helt uenig	◯	◯	◯	◯	◯	Helt enig

19. **Tror du at de andre deltakerne var godt forberedt i sesjonene?** *
Mark only one oval.

	1	2	3	4	5	
Helt uenig	◯	◯	◯	◯	◯	Helt enig

Utfordringer i implementeringen av SPP/ICE

20. **Hvor vanskelig eller enkelt var å samarbeide med ansatte i andre selskaper på grunn av ulike verktøy (kompatibilitetsproblemer), arbeidsmetoder osv.?** *
Mark only one oval.

	1	2	3	4	5	
Veldig Vanskelig	◯	◯	◯	◯	◯	Veldig Lett

21. **Hvor vanskelig eller lett var å kommunisere med ansatte i andre selskaper?** *
Mark only one oval.

	1	2	3	4	5	
Veldig Vanskelig	◯	◯	◯	◯	◯	Veldig Lett

22. **Hvor mye demotivert eller motivert var du å samarbeide med ansatte i andre selskaper?** *
Mark only one oval.

	1	2	3	4	5	
Veldig Demotivert	◯	◯	◯	◯	◯	Veldig Motivert

23. **Hvor mye utilstrekkelig eller tilstrekkelig var infrastrukturen og utstyret for å lette møtene og arbeidsesjonene?** *
Mark only one oval.

	1	2	3	4	5	
Veldig utilstrekkelig	◯	◯	◯	◯	◯	Veldig tilstrekkelig

I sammenligning med tradisjonelle utførte prosjekter (f.eks. med sekvensiell prosjektering for de ulike fag), i hvilken grad har SSP/ICE hatt en positiv eller negativ påvirkning (1 = -100%, 5 = 0%, 10 = + 100%)?

24. **Kommunikasjonstid (f.eks. møter, e-post, telefonsamtaler, skype osv.)** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	+100%

25. **Overtid (arbeidstimer per person)** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	+100%

26. **Total tid brukt i prosjektet** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	+100%

27. **Total kostnad av prosjektet** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%											+100%

28. **Driftskostnader (f.eks. anleggskostnader, møteutstyr osv.)** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%											+100%

29. **Trivsel på jobben** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%											+100%

30. **Personlig motivasjon** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%											+100%

31. **Grad av omkamper** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%											+100%

32. **Tverrfaglig samarbeid** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%											+100%

33. **Allment aksepterte løsninger (for hvert involvert selskap i prosjektet)** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%											+100%

34. **Prosjektkvalitet** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%											+100%

35. **Fleksibilitet i prosjektet (tilpasningsevne til uventede hendelser)** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%											+100%

36. **Fleksibilitet på arbeidssted (f.eks. fleksibel arbeidstid, arbeid hjemmefra etc.)** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%											+100%

Åpne spørsmål

37. **Hva likte du best ved SPP/ICE i prosjektet ditt?**

Prosjektinformasjon

38. **Hvilket var navnet til projektet (eller beskrivelse)?** *

39. **Hvilken var din rolle i prosjektet?** *

40. **Var du intern eller ekstern i prosjektet?** *
Mark only one oval.

- Intern
- Ekstern
- Vet ikke

168. **Project Flexibility (adaptability to unexpected events)** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%											+100%

169. **Flexibility in the Workplace (eg. flexible working hours, working from home etc.)** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%											+100%

Open Questions

170. **What did you like the most about CE/SPP in your Project?**

Project Information

171. **What was the name of the project (or description)?** *

172. **Which role did you have in the Project?** *

173. **Were you internal or external in the Project?** *
Mark only one oval.

- Internal
- External
- I don't know

174. **Have you participated in CE/SPP meetings and work sessions?** *
Mark only one oval.

- Yes
- No *Skip to question 189.*
- I don't know *Skip to question 189.*

Degree of CE/SPP implementation based on meetings

175. **How often did the meetings take place?** *
Mark only one oval.

- Daily
- Multiple times per week
- Once per week
- A few times per month
- Monthly or less frequent

176. **How often did you participate in the meetings?** *
Mark only one oval.

- Daily
- Multiple times per week
- Once per week
- A few times per month
- Monthly or less frequent

177. **Did the meetings contribute to the project progress/decisions?** *
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree						Strongly Agree

178. **Did the meeting had their focus on project challenges and solutions?** *
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree						Strongly Agree

179. **Did the meetings have the same agenda every time?** *
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree						Strongly Agree

180. **Did the meetings help to avoid project failures?** *
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree						Strongly Agree

Degree of CE/SPP implementation based on working sessions

181. **Was the work session goal described and explained clearly? ***
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	⬭	⬭	⬭	⬭	⬭	Strongly Agree

182. **Did the work session stick to the goal? ***
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	⬭	⬭	⬭	⬭	⬭	Strongly Agree

183. **Was there a focus in resolving intedisciplinary issues? ***
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	⬭	⬭	⬭	⬭	⬭	Strongly Agree

184. **Do you think that the other participants were well prepared for the session? ***
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	⬭	⬭	⬭	⬭	⬭	Strongly Agree

Challenges in implementation of CE/SPP

185. **How hard or easy was to collaborate due to different tools (compatibility issues), working methods etc. ? ***
Mark only one oval.

	1	2	3	4	5	
Very Hard	⬭	⬭	⬭	⬭	⬭	Very Easy

186. **How hard or easy was to communicate with employees of other companies? ***
Mark only one oval.

	1	2	3	4	5	
Very Hard	⬭	⬭	⬭	⬭	⬭	Very Easy

187. **How much demotivated or motivated were you to cooperate with employees of other companies?** *
Mark only one oval.

	1	2	3	4	5	
Very Demotivated	⬭	⬭	⬭	⬭	⬭	Very Motivated

188. **How much insufficient or sufficient were the infranstructure and equipment to facilitate the meetings and work sessions?** *
Mark only one oval.

	1	2	3	4	5	
Very Insufficient	⬭	⬭	⬭	⬭	⬭	Very Sufficient

Compared with projects executed using a traditional (waterfall) structure to engineering, to which extent has CE had a positive or negative impact on (1= -100% , 5= 0% ,10=+100%) ?

189. **Communication Time (eg. meetings, e-mails, phone calls, skype etc.)** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	+100%

190. **Overtime (hours spent per person)** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	+100%

191. **Total time spent in the project** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	+100%

192. **Total Cost of the project** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	+100%

193. **Operational Cost (eg. facilities cost, meeting equipment etc.)** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	+100%

194. **Job Satisfaction** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	+100%

195. **Personal Motivation** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	+100%

196. **Conflicts** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	+100%

197. **Collaboration** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	+100%

198. **Commonly Accepted Solutions (for every involved company in the project)** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	+100%

199. **Project Quality** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	+100%

200. **Project Flexibility (adaptability to unexpected events)** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%											+100%

201. **Flexibility in the Workplace (eg. flexible working hours, working from home etc.)** *
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
-100%											+100%

Open Questions

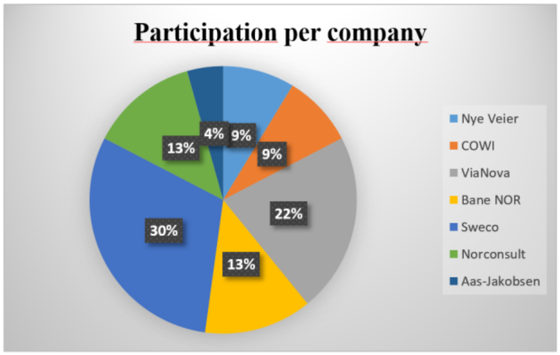
202. **What did you like the most about CE/SPP in your Project?**

203. **Are there any questions that you would like to see in this Survey? Please write your suggestions.**

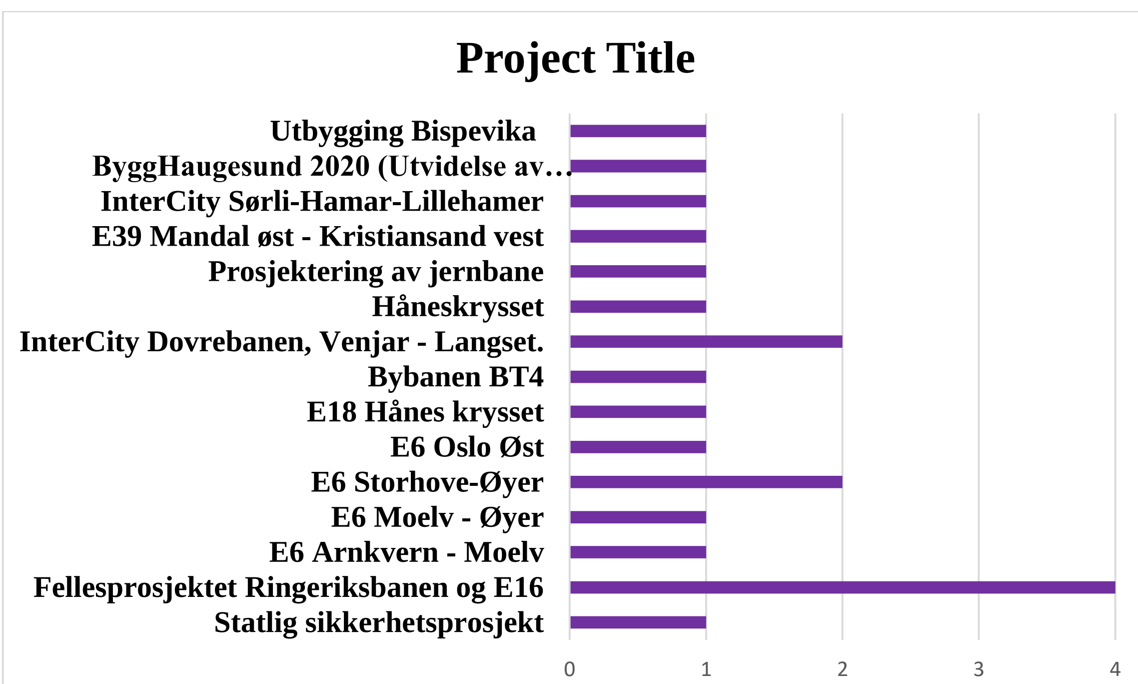
Appendix B

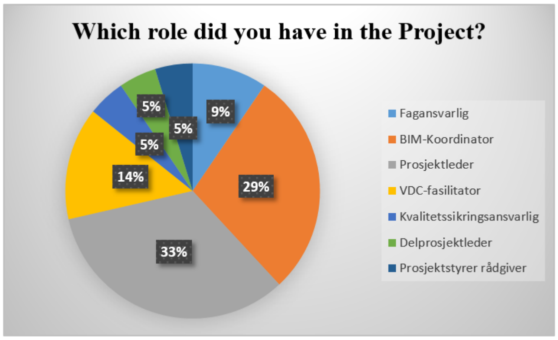
Survey Results

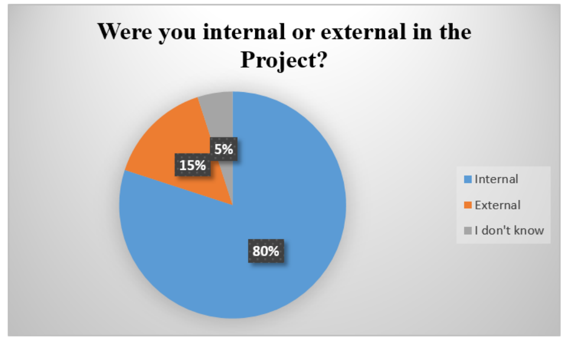
Background Information

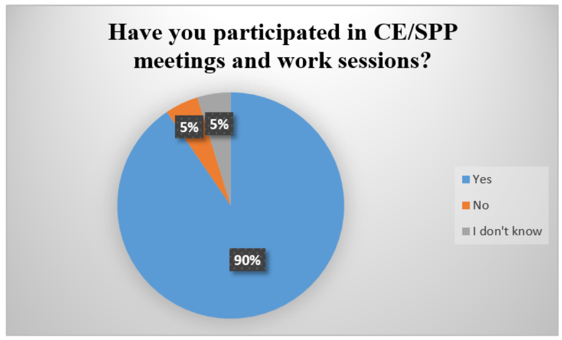


Project Information

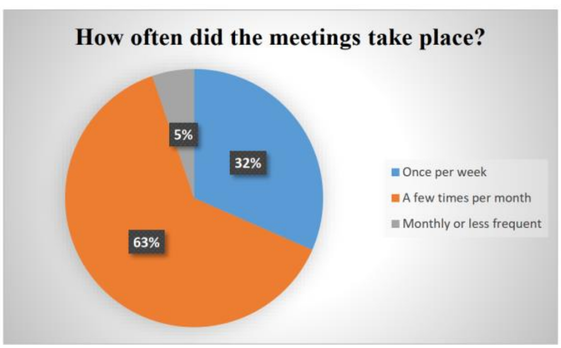


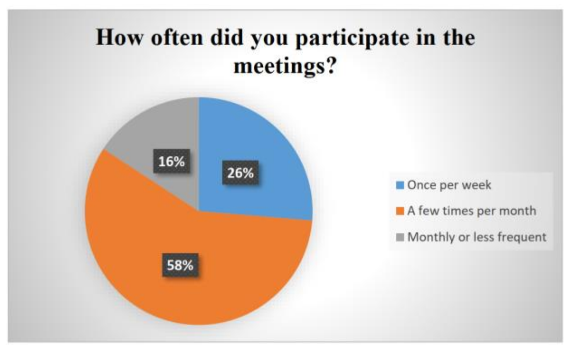


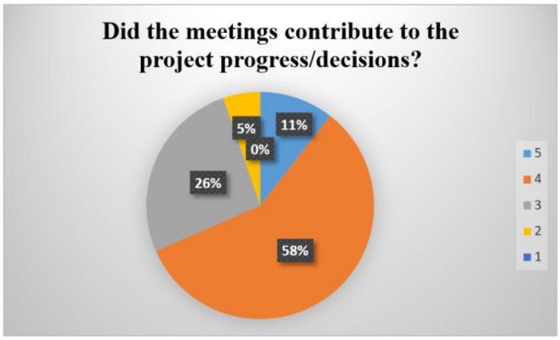


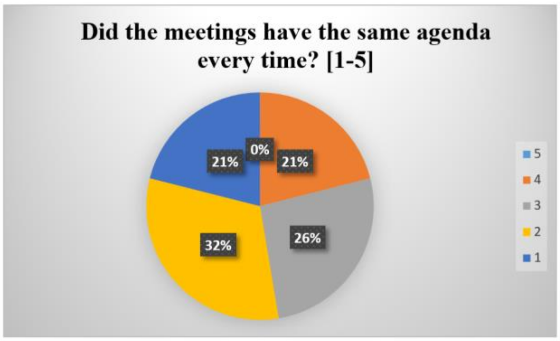


Degree of CE/SPP implementation based on meetings



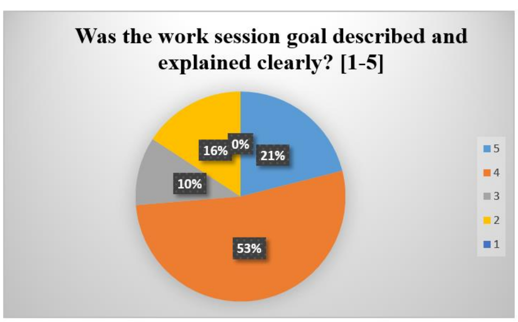


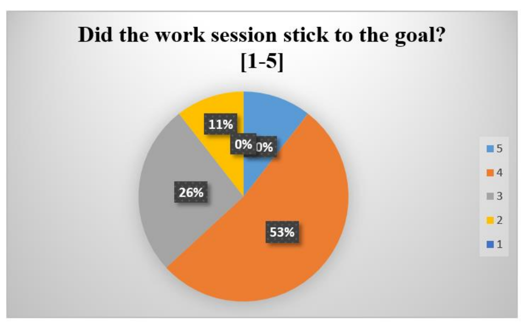


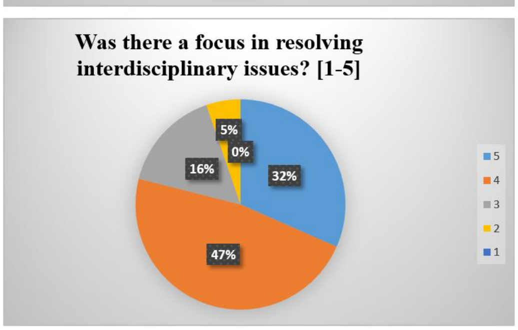


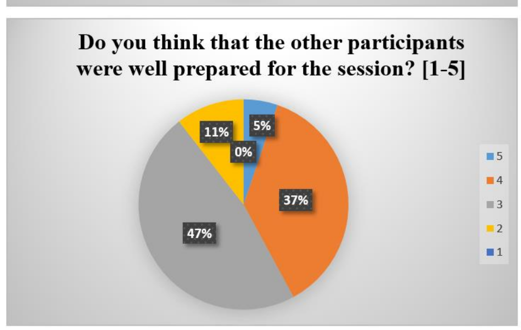
Rating	Did the meetings contribute to the project progress/decisions? [1-5]	Did the meeting had their focus on project challenges and solutions? [1-5]	Did the meetings have the same agenda every time? [1-5]	Did the meetings help to avoid project failures? [1-5]
5	*2*	*6*	*0*	*4*
4	*11*	*11*	*4*	*8*
3	*5*	*1*	*5*	*6*
2	*1*	*1*	*6*	*1*
1	*0*	*0*	*4*	*0*
SUM	*71*	*79*	*47*	*72*
Average	**3.7**	**4.2**	**2.5**	**3.8**

Degree of CE/SPP implementation based on working sessions



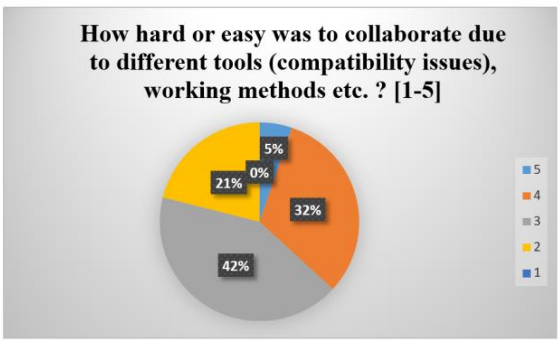


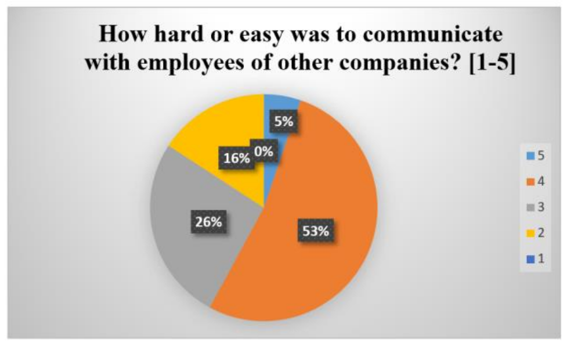


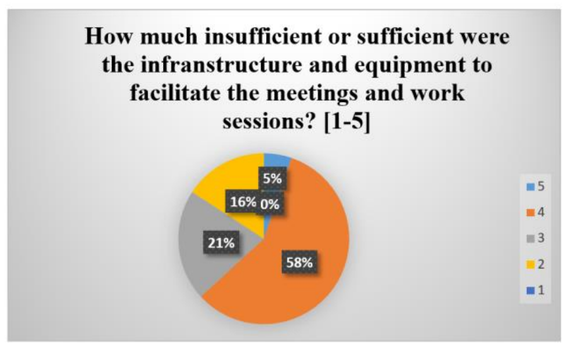


Rating	Was the work session goal described and explained clearly? [1-5]	Did the work session stick to the goal? [1-5]	Was there a focus in resolving interdisciplinary issues? [1-5]	Do you think that the other participants were well prepared for the session? [1-5]
5	4	2	6	1
4	10	10	9	7
3	2	5	3	9
2	3	2	1	2
1	0	0	0	0
SUM	72	69	77	64
Average	3.8	3.6	4.1	3.4

Challenges in implementation of CE/SPP

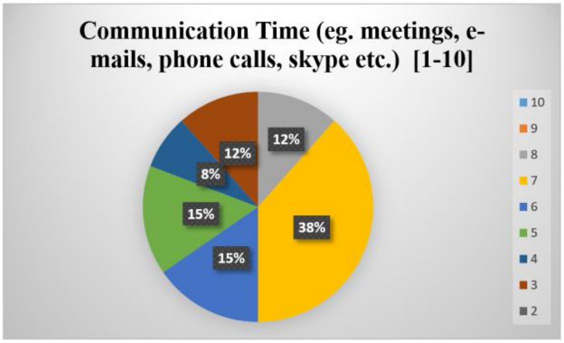


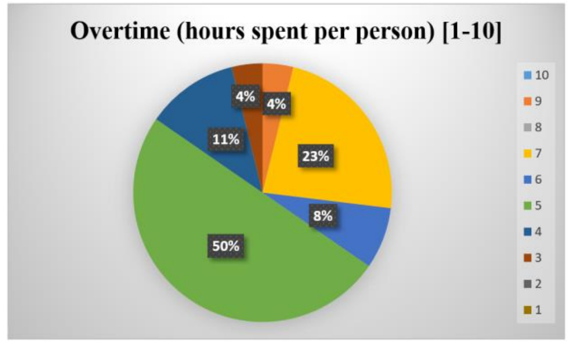


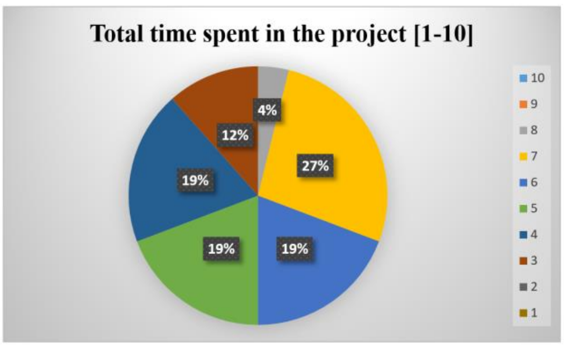


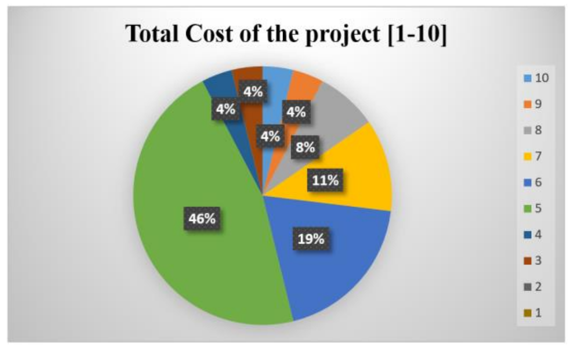
Rating	How hard or easy was to collaborate due to different tools (compatibility issues), working methods etc. ? [1-5]	How hard or easy was to communicate with employees of other companies? [1-5]	How much demotivated or motivated were you to cooperate with employees of other companies? [1-5]	How much insufficient or sufficient were the infranstructure and equipment to facilitate the meetings and work sessions? [1-5]
5	1	1	6	1
4	6	10	8	11
3	8	5	3	4
2	4	3	2	3
1	0	0	0	0
SUM	61	66	75	67
Average	3.2	3.5	3.9	3.5

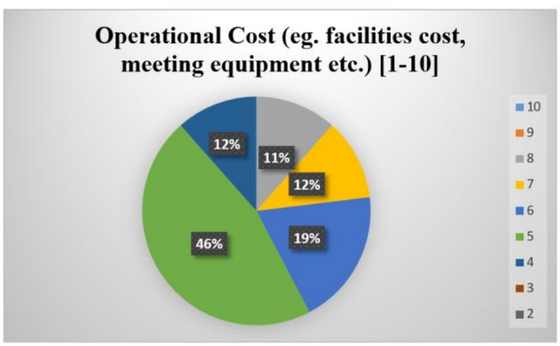
Compared with projects executed using a traditional (waterfall) structure to engineering, to which extent has CE had a positive or negative impact on (1= -100% , 5= 0% ,10=+100%) ?

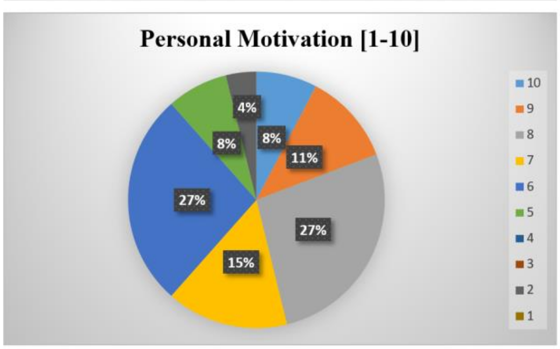


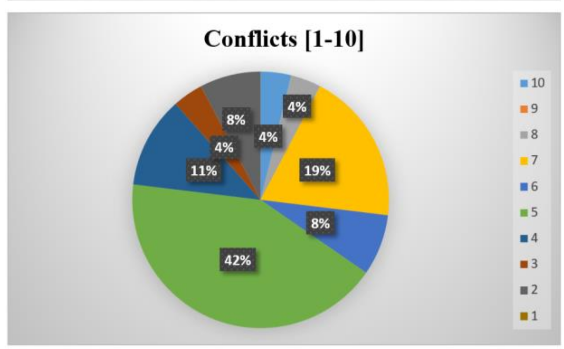


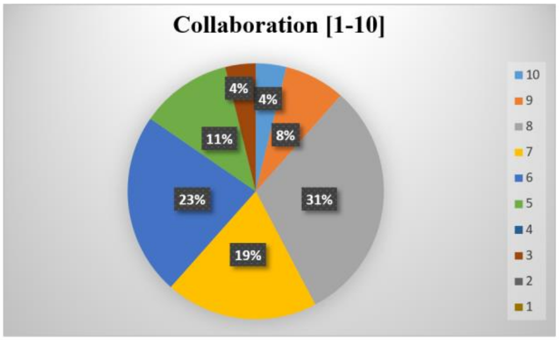


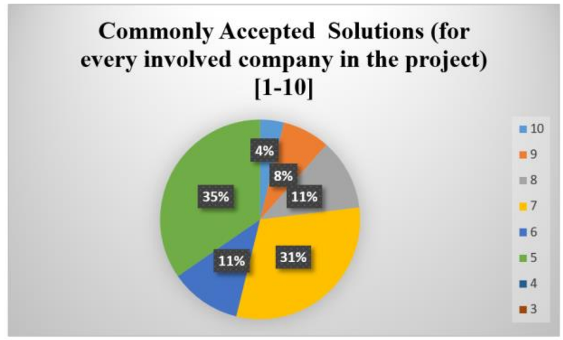


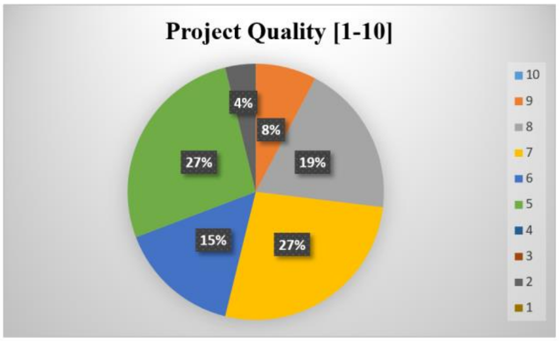


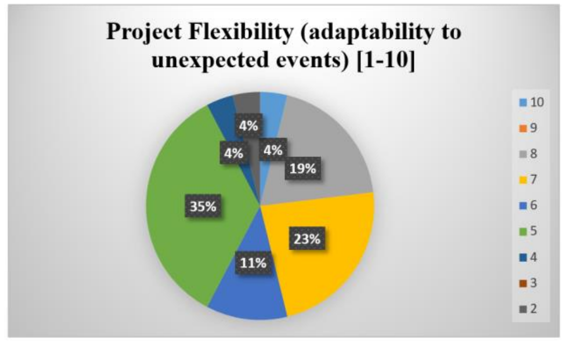


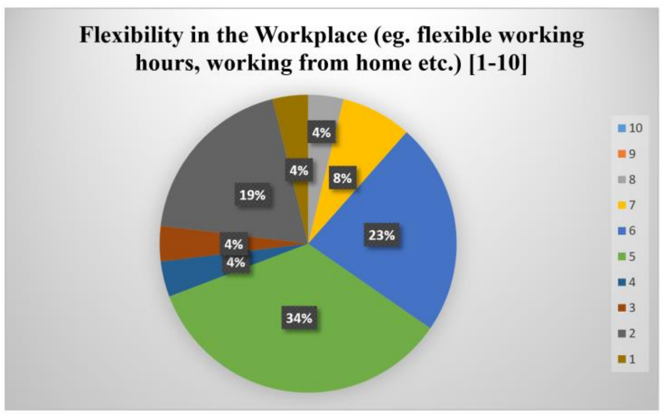



Collaboration [1-10]
4%
4%
8%
11%
23%
31%
19%
10
9
8
7
6
5
4
3
2
1


Commonly Accepted Solutions (for every involved company in the project) [1-10]
4%
8%
11%
35%
11%
31%
10
9
8
7
6
5
4
3


Project Quality [1-10]
4%
8%
19%
27%
15%
27%
10
9
8
7
6
5
4
3
2
1


Project Flexibility (adaptability to unexpected events) [1-10]
4%
4%
4%
19%
35%
23%
11%
10
9
8
7
6
5
4
3
2


Flexibility in the Workplace (eg. flexible working hours, working from home etc.) [1-10]
4%
4%
8%
19%
23%
4%
4%
34%
10
9
8
7
6
5
4
3
2
1

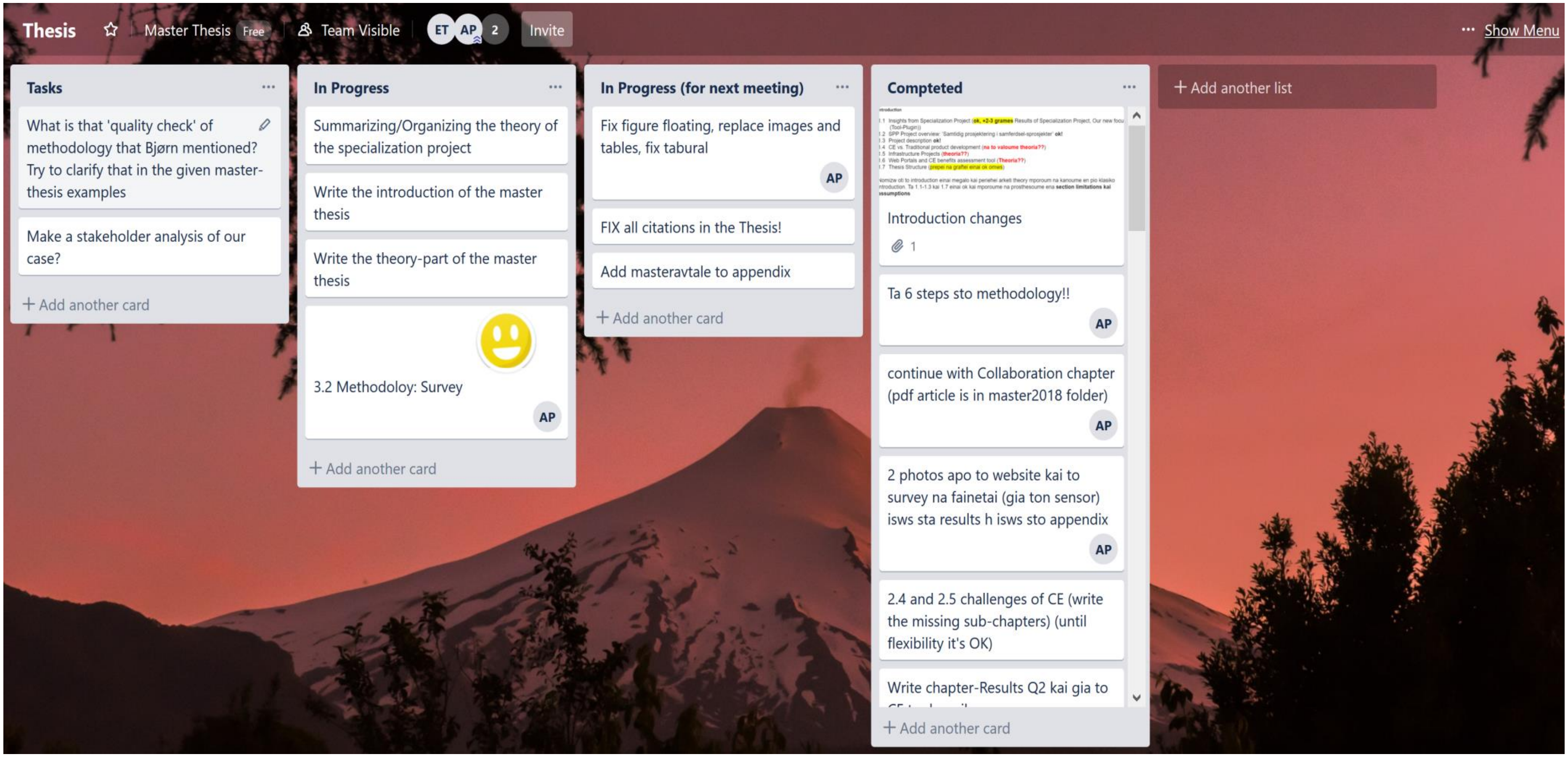
	Rating												
	1	2	3	4	5	6	7	8	9	10	**SUM**	**Average**	**Percentage**
Communication Time (eg. meetings, e-mails, phone calls, skype etc.) [1-10]	*0*	*0*	*3*	*2*	*4*	*4*	*10*	*3*	*0*	*0*	**155**	**6.0**	**21.4 %**
Overtime (hours spent per person) [1-10]	*0*	*0*	*1*	*3*	*13*	*2*	*6*	*0*	*1*	*0*	**143**	**5.5**	**11.1 %**
Total time spent in the project [1-10]	*0*	*0*	*3*	*5*	*5*	*5*	*7*	*1*	*0*	*0*	**141**	**5.4**	**9.4 %**
Total Cost of the project [1-10]	*0*	*0*	*1*	*1*	*12*	*5*	*3*	*2*	*1*	*1*	**153**	**5.9**	**19.7 %**
Operational Cost (eg. facilities cost, meeting equipment etc.) [1-10]	*0*	*0*	*0*	*3*	*12*	*5*	*3*	*3*	*0*	*0*	**147**	**5.7**	**14.5 %**
Job Satisfaction [1-10]	*0*	*1*	*0*	*1*	*4*	*8*	*4*	*6*	*2*	*0*	**168**	**6.5**	**32.5 %**
Personal Motivation [1-10]	*0*	*1*	*0*	*0*	*2*	*7*	*4*	*7*	*3*	*2*	**185**	**7.1**	**47.0 %**
Conflicts [1-10]	*0*	*2*	*1*	*3*	*11*	*2*	*5*	*1*	*0*	*1*	**139**	**5.3**	**7.7 %**
Collaboration [1-10]	*0*	*0*	*1*	*0*	*3*	*6*	*5*	*8*	*2*	*1*	**181**	**7.0**	**43.6 %**
Commonly Accepted Solutions (for every involved company in the project) [1-10]	*0*	*0*	*0*	*0*	*9*	*3*	*8*	*3*	*2*	*1*	**171**	**6.6**	**35.0 %**
Project Quality [1-10]	*0*	*1*	*0*	*0*	*7*	*4*	*7*	*5*	*2*	*0*	**168**	**6.5**	**32.5 %**
Project Flexibility (adaptability to unexpected events) [1-10]	*0*	*1*	*0*	*1*	*9*	*3*	*6*	*5*	*0*	*1*	**161**	**6.2**	**26.5 %**
Flexibility in the Workplace (eg. flexible working hours, working from home etc.) [1-10]	*1*	*5*	*1*	*1*	*9*	*6*	*2*	*1*	*0*	*0*	**121**	**4.7**	**-7.7 %**

Open Questions

Solutions and Decisions		**Meetings**	**Projects**	**Working Environment**
● More focus on the solutions	● Concrete problem statements	● Better prepared participants in the meetings	● Clarifies the central challenges of the project in the agenda	● The pressure and the dynamics of interdisciplinary working environment
● Clearer interdisciplinary solutions	● The client was involved in all meetings, which led to well accepted and well grounded solutions.	● No planning in the meetings, just decisions on the terms and deadlines	● Knowledge acquired about the big changes of the project in the planning and building phases	● The knowledge sharing and the knowledge acquired for other subjects and their prerequisites.
● Common understanding for solutions	● Clearly defined what should be done	● Higher focus on the planning of the meetings	● The methodology was tested in the planning phase	● Early interdisciplinary work
● Mutually agreed solutions	● Better focus on a good interdisciplinary solution		● Overview planning	● Interdisciplinary work
● Effective method to understand quickly the project problem description, challenges, and have good solutions	● Better understanding of the challenges		● As a Manager, had the chance to plan, facilitate and work with the goals	● That all the managers meet in person
●Decision oriented method	● Consensus with regard to quick decisions			● Better awareness, among the subjects, for their influence in the project and their impact on each other
● Work with specified goals				

Appendix C

Trello



Thesis
Master Thesis
Free
Team Visible
ET
AP
2
Invite
Show Menu
Tasks
What is that 'quality check' of methodology that Bjørn mentioned? Try to clarify that in the given master-thesis examples
Make a stakeholder analysis of our case?
+ Add another card
In Progress
Summarizing/Organizing the theory of the specialization project
Write the introduction of the master thesis
Write the theory-part of the master thesis
3.2 Methodoloy: Survey
AP
+ Add another card
In Progress (for next meeting)
Fix figure floating, replace images and tables, fix tabural
AP
FIX all citations in the Thesis!
Add masteravtale to appendix
+ Add another card
Competed
Introduction changes
1
Ta 6 steps sto methodology!!
AP
continue with Collaboration chapter (pdf article is in master2018 folder)
AP
2 photos apo to website kai to survey na fainetai (gia ton sensor) isws sta results h isws sto appendix
AP
2.4 and 2.5 challenges of CE (write the missing sub-chapters) (until flexibility it's OK)
Write chapter-Results Q2 kai gia to
+ Add another card
+ Add another list

Appendix D

Contracts

NTNU

Masteravtale

Sist oppdatert 29. juni 2018

Fakultet	**IV - Fakultet for ingeniørvitenskap**
Institutt	**Institutt for maskinteknikk og produksjon**
Studieprogram	**MSPROMAN**
Emnekode	**194 _TPK4920_ 1**

Studenten

Etternavn, fornavn	**Polonyfis, Athanasios**
Fødselsdato	**23.09.1988**
E-postadresse ved NTNU	**athanasp@stud.ntnu.no**

Oppgaven

Oppstartsdato	**15.01.2019**
Leveringsfrist	**11.06.2019**
Arbeidstittel	**A digital handbook of CE for infrastructure projects in Norway**
Problembeskrivelse	**In this master thesis we will use our findings from the specialization project to develop a web portal about concurrent engineering in norwegian infrastructure projects.**

Tilknyttede ressurser

Veileder	**Bjørn Andersen**
Eventuelle medveiledere	
Eventuelle medstudenter	**Evangelos Tyflopoulos**

Eventuelle emner som skal inngå i mastergraden

Retningslinjer - rettigheter og plikter

Formål

Avtale om veiledning av masteroppgaven er en samarbeidsavtale mellom student, veileder og institutt som regulerer veiledningsforholdet, omfang, art og ansvarsdeling

Masterstudiet og arbeidet med masteroppgaven er regulert av Universitets- og høgskoleloven, NTNUs studieforskrift og gjeldende studieplan for masterprogrammet.

Veiledning

Studenten har ansvar for å

- Avtale veiledningstimer innenfor de rammene avtalen gir
- Utarbeide framdriftsplan for arbeidet i samråd med veileder, inkludert plan for når veiledningen skal finne sted
- Holde oversikt over antall brukte veiledningstimer sammen med veileder Gi veileder nødvendig skriftlig materiale i rimelig tid før veiledningen.
- Holde instituttet og veileder orientert om eventuelle forsinkelser.

Veileder har ansvar for å

- Avklare forventninger om veiledningsforholdet og hvordan veiledningen skal foregå Sørge for at det søkes om eventuelle nødvendige godkjenninger (etikk, personvernhensyn).
- Gi råd om formulering og avgrensning av tema og problemstilling, slik at arbeidet er gjennomførbart innenfor normert eller avtalt studietid.
- Drøfte og vurdere hypoteser og metoder.
- Gi råd vedrørende faglitteratur, kildemateriale/datagrunnlag/dokumentasjon og evt. ressursbehov
- Drøfte framstillingsform (disposisjon, språklig form mv.).
- Drøfte resultater og tolkningen av dem.
- Holde seg orientert om progresjonen i studentens arbeid i henhold til den avtalte tids- og arbeidsplan, og følge opp studenten ved behov.
- Sammen med studenten holde oversikt over antall brukte veiledningstimer.

Instituttet har ansvar for å

- sørge for at avtalen blir inngått.
- finne og oppnevne veileder(e).
- inngå avtale med annet institutt/ fakultet/institusjon dersom det er oppnevnt ekstern biveileder.
- i samarbeid med veileder holde oversikt over studentenes framdrift, oversikt over antall brukte veiledningstimer, og følge opp dersom studenten er forsinket i henhold til avtale.
- oppnevne ny veileder og sørge for inngåelse av ny avtale dersom:
  - veileder blir fraværende på grunn av forskningstermin, sykdom, reiser o.a., og om studenten ønsker det. o student eller veileder ber om å få avslutte avtalen fordi en av partene ikke følger den.
  - andre forhold gjør at partene finner det hensiktsmessig med ny veileder.
- gi studenten beskjed når veiledningsforholdet opphører.
- informere veiledere om ansvaret for å ivareta forskningsetiske forhold, personvernhensyn og veiledningsetiske forhold.

Blir veiledningsforholdet problematisk for en av partene, kan student eller veileder be om å bli løst fra veiledningsavtalen. Instituttet må i et slikt tilfelle oppnevne ny veileder.

Avtaleskjemaet skal signeres når retningslinjene er gjennomgått.

Signaturer

Institutt	Veileder	Student
		Trondheim, 06.02.2019
sted og dato	sted og dato	sted og dato

NTNU

Masteravtale

Sist oppdatert 29. juni 2018

Fakultet	IV - Fakultet for ingeniørvitenskap
Institutt	Institutt for maskinteknikk og produksjon
Studieprogram	
Emnekode	194_TPK4920_1

Studenten

Etternavn, fornavn	Tyflopoulos, Evangelos
Fødselsdato	13.04.1983
E-postadresse ved NTNU	evangelos.tyflopoulos@ntnu.no

Oppgaven

Oppstartsdato	15.01.2019
Leveringsfrist	11.06.2019
Arbeidstittel	A digital handbook of CE for infrastructure projects in Norway
Problembeskrivelse	In this master thesis we will use our findings from the specialization project to develop a web portal about concurrent engineering in norwegian infrastructure projects.

Tilknyttede ressurser

Veileder	Bjørn Andersen
Eventuelle medveiledere	
Eventuelle medstudenter	Athanasios Polonyfis

Eventuelle emner som skal inngå i mastergraden

Retningslinjer - rettigheter og plikter

Formål

Avtale om veiledning av masteroppgaven er en samarbeidsavtale mellom student, veileder og institutt som regulerer veiledningsforholdet, omfang, art og ansvarsdeling

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- Holde oversikt over antall brukte veiledningstimer sammen med veileder
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- informere veiledere om ansvaret for å ivareta forskningsetiske forhold, personvernhensyn og veiledningsetiske forhold.

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Avtaleskjemaet skal signeres når retningslinjene er gjennomgått.

Signaturer

Institutt	**Veileder**	**Student**
	Trondheim, 23.01.2019	Trondheim, 05.02.2019
sted og dato	sted og dato	sted og dato

NTNU

Fastsatt av Rektor 20.01.2012

STANDARDAVTALE

om utføring av masteroppgave/prosjektoppgave (oppgave) i samarbeid med bedrift/ekstern virksomhet (bedrift).

Avtalen er ufravikelig for studentoppgaver ved NTNU som utføres i samarbeid med bedrift.

Partene har ansvar for å klarere eventuelle immaterielle rettigheter som tredjeperson (som ikke er part i avtalen) kan ha til prosjektbakgrunn før bruk i forbindelse med utførelse av oppgaven.

Avtale mellom

Student: **Tyflopoulos, Evangelos** / Polonyfis, Athanasios	født: **13.04.1983** / 23.09.1988

Veileder ved NTNU: **Bjørn Andersen**

Bedrift/ekstern virksomhet: **ViaNova**

og

Norges teknisk-naturvitenskapelige universitet (NTNU) v/instituttleder

om bruk og utnyttelse av resultater fra masteroppgave/prosjektoppgave.

1. Utførelse av oppgave

Studenten skal utføre masteroppgave i samarbeid med

ViaNova

bedrift/ekstern virksomhet

15.01.2019 - 11.06.2019

startdato – sluttdato

Oppgavens tittel er:

A digital handbook of CE for infrastructure projects in Norway

Ansvarlig veileder ved NTNU har det overordnede faglige ansvaret for utforming og godkjenning av prosjektbeskrivelse og studentens læring.

AA

2. Bedriftens plikter

Bedriften skal stille med en kontaktperson som har nødvendig veiledningskompetanse og gi studenten tilstrekkelig veiledning i samarbeid med veileder ved NTNU. Bedriftens kontaktperson er:

Erling Graarud, erling.graarud@vianova.no

Formålet med oppgaven er studentarbeid. Oppgaven utføres som ledd i studiet, og studenten skal ikke motta lønn eller lignende godtgjørelse fra bedriften. Bedriften skal dekke følgende utgifter knyttet til utførelse av oppgaven:

The purpose of completing the academic work is academic training for the student. The academic work is part of a student's course of study and the student is not to receive wages or similar compensation from the organization. The organization agrees to cover the following expenses that are associated with carrying out the academic work of 'TPK4920 - Project and Quality Management, Master's Thesis'

3. Partenes rettigheter

a) Studenten

Studenten har opphavsrett til oppgaven. Alle immaterielle rettigheter til resultater av oppgaven skapt av studenten alene gjennom oppgavearbeidet, eies av studenten med de reservasjoner som følger av punktene b) og c) nedenfor.

Studenten har rett til å inngå egen avtale med NTNU om publisering av sin oppgave i NTNUs institusjonelle arkiv på internett. Studenten har også rett til å publisere oppgaven eller deler av den i andre sammenhenger dersom det ikke i denne avtalen er avtalt begrensninger i adgangen til å publisere, jf punkt 4.

b) Bedriften

Der oppgaven bygger på, eller videreutvikler materiale og/eller metoder (prosjektbakgrunn) som eies av bedriften, eies prosjektbakgrunnen fortsatt av bedriften. Eventuell utnyttelse av videreutviklingen, som inkluderer prosjektbakgrunnen, forutsetter at det inngås egen avtale om dette mellom student og bedrift.

Bedriften skal ha rett til å benytte resultatene av oppgaven i egen virksomhet dersom utnyttelsen faller innenfor bedriftens virksomhetsområde. Dette skal fortolkes i samsvar med begrepets innhold i Arbeidstakeroppfinnelsesloven[1] § 4. Retten er ikke-eksklusiv.

Bruk av resultatet av oppgaven utenfor bedriften sitt virksomhetsområde, jf avsnittet ovenfor, forutsetter at det inngås egen avtale mellom studenten og bedriften. Avtale mellom bedrift og student om rettigheter til oppgaveresultater som er skapt av studenten, skal inngås skriftlig og er ikke gyldig inngått før NTNU har mottatt skriftlig gjenpart av avtalen.

[1] Lov av 17. april 1970 om retten til oppfinnelser som er gjort av arbeidstakere
http://www.lovdata.no/all/hl-19700417-021.html

Dersom verdien av bruken av resultatene av oppgaven er betydelig, dvs overstiger NOK 100.000 (kommentert i veiledningen[2] til avtalen), er studenten berettiget til et rimelig vederlag. Arbeidstakeroppfinnelsesloven § 7 gis anvendelse på vederlagsberegningen. Denne vederlagsretten gjelder også for ikke-patenterbare resultater. Fristbestemmelsene i § 7 gis tilsvarende anvendelse.

c) NTNU
De innleverte eksemplarer/filer av oppgaven med vedlegg, som er nødvendig for sensur og arkivering ved NTNU, tilhører NTNU. NTNU får en vederlagsfri bruksrett til resultatene av oppgaven, inkludert vedlegg til denne, og kan benytte dette til undervisnings- og forskningsformål med de eventuelle begrensninger som fremgår i punkt 4.

4. Utsatt offentliggjøring

Hovedregelen er at studentoppgaver skal være offentlige. I særlige tilfeller kan partene bli enig om at hele eller deler av oppgaven skal være undergitt utsatt offentliggjøring i maksimalt 3 år, dvs. ikke tilgjengelig for andre enn student og bedrift i denne perioden.

Oppgaven skal være undergitt utsatt offentliggjøring i

Ikke aktuelt

Behovet for utsatt offentliggjøring er begrunnet ut fra følgende:

De delene av oppgaven som ikke er undergitt utsatt offentliggjøring, kan publiseres i NTNUs institusjonelle arkiv, jf punkt 3 a), andre avsnitt.

Selv om oppgaven er undergitt utsatt offentliggjøring, skal bedriften legge til rette for at studenten kan benytte hele eller deler av oppgaven i forbindelse med jobbsøknader samt videreføring i et doktorgradsarbeid.

5. Generelt

Denne avtalen skal ha gyldighet foran andre avtaler som er eller blir opprettet mellom to av partene som er nevnt ovenfor. Dersom student og bedrift skal inngå avtale om konfidensialitet om det som studenten får kjennskap til i bedriften, skal NTNUs standardmal for konfidensialitetsavtale benyttes. Eventuell avtale om dette skal vedlegges denne avtalen.

Eventuell uenighet som følge av denne avtalen skal søkes løst ved forhandlinger. Hvis dette ikke fører frem, er partene enige om at tvisten avgjøres ved voldgift i henhold til norsk lov.

[2] Veiledning til NTNUs standardavtale om masteroppgave/prosjektoppgave i samarbeid med bedrift http://www.ntnu.no/studier/standardavtaler

ff

Tvisten avgjøres av sorenskriveren ved Sør-Trøndelag tingrett eller den han/hun oppnevner.

Denne avtale er underskrevet i 4 - fire - eksemplarer hvor partene skal ha hvert sitt eksemplar. Avtalen er gyldig når den er godkjent og underskrevet av NTNU v/instituttleder.

Trondheim, 05.02.2019		
sted, dato	studenter	

Trondheim, 23.01.2019	Bjørn Ark	
sted, dato	veileder ved NTNU	

sted, dato	instituttleder, NTNU	institutt

Sandvika, 25/1-19		
sted, dato	for bedriften/institusjonen stempel og signatur	VIANOVA ViaNova Plan og Trafikk AS