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The Application of Concurrent Engineering in Infrastructure Projects

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Submission date: June 2017
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Preface

I developed an interest towards project management back when I wrote my Bachelor thesis and was therefore anxious in learning more about the social and complex aspect of leading and managing a project. Thanks to the Project Management study at NTNU I have dwelled into these aspects and enhanced my understanding of the subject. This thesis has been a large step towards my personal development, and the subject of which I am writing about, Concurrent Engineering, has shown me that even simple methods in managing people and business, can be vastly more complex than anticipated. In writing this thesis, I have developed an increased respect towards the project managers out there, and understand that some things that "on paper" is simple, can take great effort and time to realize.

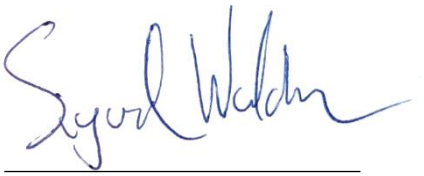
For the writing of this thesis, I want to send a special thanks to my supervisor Bjørn Andersen. His guidance this past year has been invaluable and there have been lots to learn in regard to the "world" of qualitative research. I also want to thank my contact person Erling Graarud in FoU for allowing me to join in on participating and learning with them how concurrent engineering can function in the infrastructure sector. Moreover, I want to thank the rest of the members of the research project FoU for helpful insight and on giving me an opportunity to observe their concurrent engineering work method. I also want to thank the respondents, I would not have been able to conduct my analysis without your cooperation.

I also would like to thank my friends and fellow students in debates on subjects that have been very beneficial.

Last but not least, I want to thank Alessia for her love and support in writing this thesis. You kept me motivated.

I hope you enjoy your reading.

Sigurd Wolden



Trondheim, 09.06.2017

Summary

The construction industry today is considered to be lagging competitively behind in comparison to other industries. The reason for this is thought of by many researchers to be the fragmented project process, the traditional principles and the, sometimes adversarial environment. In order to solve some of these obstacles and at the same time enhance productivity, the Norwegian infrastructure sector has recently developed an interest towards the project management method Concurrent Engineering (CE). Coupled with this and the general lack of research on CE in infrastructure projects presented a research opportunity. In fact, the Concurrent engineering method has almost exclusively been regarded as an approach that has great potential in improving project development time, increase quality and decrease cost. However, the adaptation of the method towards the construction industry, which originally was a manufacturing/production project method, has been paved with challenges, further advocating a research opportunity.

Therefore, the purpose of this thesis was to contribute to the general research field of concurrent engineering, and present findings that can substantiate the understanding of, and the utilization of the CE method in the infrastructure sector. The overarching method involved exploring the utilization of concurrent engineering within infrastructure projects in comparison to traditional project methods. The problem statements constitutes identifying effects and obstacles to the use of the method in project work sessions, called CE sessions.

In order to identify significant findings of the utilization of the concurrent engineering method, a qualitative approach was chosen, which involved the research method of interviewing a sample of 14 project managers and the observation of a CE session in the infrastructure sector.

The generalizable results of the thesis were that an increase in collaboration and communication occurred between the project team members. In addition, through the involvement of the whole project life cycle's stakeholders, the project team members understand more in-depth the elements of the project and ultimately, the team members become more quality- and problem-aware during the work sessions. The CE method however, also increased the complexity of coordinating and developing the plan. Moreover, potential obstacles to the effects identified were level of integration, particularly involving external stakeholders, low level of autonomy and insufficient preparation and practice. In addition to these identified effects and obstacles, by involving the external decision-makers on the plan early and during the plan development could potentially expedite the time to plan approval as well as increase the quality of plan.

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1 Introduction

1.1 Background and relevance

A recent interest in reducing project development time has emanated in the Norwegian infrastructure sector. Although the industry has begun to implement 3D modelling/BIM (Building Information Modelling) over the last few years, which has been proven to be highly valuable for the design process (Khanzode et al., 2008, Fanning et al., 2015, Bernstein and Jones, 2012), there is still a great potential for enhancing project efficiency (Anumba and Kamara, 2012, Morris, 2007). In fact, the majority of researches today believe that the whole construction industry is lagging competitively behind the other industries, and time-overrun are considered by many researchers a major culprit (Zidane et al., 2015a, Odeh and Battaineh, 2001, Eik-Andresen et al., 2016, Assaf and Al-Hejji, 2006, Anumba and Kamara, 2012). Common issues, which are often referred as the 'inherent' problems of the industry, lie with a fragmented project process, traditional principles and incidentally, the sometimes aggressive and adversarial environment (Anumba and Kamara, 2012, Zidane et al., 2015b).

Integrating and improving collaboration is thought of as a solution towards solving some of the issues in the industry and coincidentally improve project development time, which is why the project management method Concurrent Engineering (CE) is of particular interest today (Anumba and Kamara, 2012). Specifically, the interest lies within the high adaptability of the method and that the manufacturing industry, (which is considered to be similar to the construction industry on several aspects) (Anumba and Kamara, 2012), has achieved great reduction in project development time as well as seen other benefits (Prasad, 1996, Anumba et al., 2002).

Concurrent Engineering consists in implementing a method that integrates all contributing participants of the whole project life cycle. The method involves establishing a concurrent, cross-functional team in order to work in parallel with later phases (Winner et al., 1988, Thamhain, 2007, Prasad, 1996). The cross-functional team is the heart of the CE method, and, preferably involves the relevant project members of the whole life-cycle to gather on one spot (Anumba and Kamara, 2012). In the construction industry, the CE sessions is where work is being done concurrently with other disciplines (which is a gathering of the CE team), specifically within elements that require overlap of knowledge between them. Additionally, it is where the decisions are made for work that needs to be done concurrently at later time, and

what can be done separately before next gathering. Despite the literature elaborating several best-practices on how to manage the CE team (e.g. full-time participation and full autonomy) (Thamhain, 2007, Nicholas, 1994, Anumba and Kamara, 2012), and the success with the use of the method in manufacturing and oil and gas industries (Prasad, 1996, Zidane et al., 2015b), proper utilization in the construction industry brings about some difficulties. Several authors agree that the difficulties are related to organizational and traditional issues, but also with the parallelization of work (Park, 2001, Shouke et al., 2010, Zidane et al., 2015b, Anumba et al., 2002, Ahmad et al., 2016, Evbuomwan and Anumba, 1998).

1.2 Problem statement

The infrastructure industry in Norway is currently experimenting with CE in order to try to improve the project development. The first step towards the transition to concurrent methods involve understanding the three key aspects, (1) the CE team work, (2) involvement of project participants and (3) the concurrent work-flow. Although there is much literature on the subject, there have been minimal studies of the effects of a concurrent team in the infrastructure context. In addition, there are still issues with the utilization of CE in the overall industry, warranting further study (Anumba and Kamara, 2012, Anumba et al., 2002, Ahmad et al., 2016, Belay et al., 2016, Zidane et al., 2015b). However, despite this fact, the method has enhanced the productivity overall in the construction sector (Baiden et al., 2006, Anumba and Kamara, 2012, Shouke et al., 2010), with benefits in elements such as: improved quality of facilities relative to cost; better coordination and management of the construction process; better informed decision making; enhanced collaboration and teamwork; greater client satisfaction; improved end product quality (Anumba and Kamara, 2012). With the interest at mind, studying the effects of the cross-discipline teamwork in the infrastructure sector could contribute to the overall understanding of CE practices and, furthermore can contribute to expediting the implementation of the method in the industry sector.

Therefore, what this thesis aims to understand is what the effects of utilizing a CE team in the context of the infrastructure sector are. As mentioned, the CE session is where concurrent work is being done, which is why the emphasis is on the effects and contributing factors (such as level of integration, decision-making and structure) on this particular area. Specifically, the research questions (RQ) are:

- RQ 1: What are the effects of utilizing an integrated concurrent team as per the concurrent engineering method in comparison to more traditionally ran projects, in the context of the infrastructure sector?
- RQ 2: What are the potential obstacles (contributing factors) for such a team to work (or not work)?

In order to answer the research questions, there will be interviews conducted within the infrastructure sector as well as observation of the work method of CE. At the end of this research thesis, analysed findings will give a clear idea of these effects and obstacles and lead to a greater understanding of the implementation of CE in the infrastructure sector. In addition, it is believed that the findings of this research can contribute towards the CE literature and furthermore, be generalizable towards the construction industry.

2 Literature review

The theoretical framework will gather previous findings and theoretical views that can aid in the efforts of the analysis and develop an understanding towards the topic of this thesis. The overall focus of the literature review is to gather how the construction industry, specifically the infrastructure sector, currently operates, and connect this to the concurrent sessions' potential capabilities and effects. Starting from a generic to a more specific point of view, an overall understanding of the struggles and the modus operandi of today's construction projects will be undertaken. Next, general information about concurrent engineering and the cross-functional team will create a basis before moving on to concurrent construction projects. Here, influencing factors, theoretical effects and previous effects from a concurrent cross-discipline team, will be presented.

2.1 The traditional project method in construction

This chapter will identify the traditional project method often referred to as the serial process. In addition, literature on construction projects status quo will be presented.

2.1.1 The serial process

The construction industry involves the collaborative workings between a number of professional teams for the interest of the client's. This is required, largely, because of the fragmented state of the industry where it is necessary to interact and cooperate with many different project participants (Anumba and Kamara, 2012, Morris, 2007). Although the collaborative practice has been entrenched into the work, it has also strengthened traditional principles to such a level that, an adversarial and sometimes aggressive environment prevails, thus preventing the level of collaboration and, particularly, integration that the industry seeks (Morris, 2007, Shenhar and Dvir, 2007, Zidane et al., 2015b, Anumba and Kamara, 2012, Franz et al., 2017). In fact, a study on large construction organizations identified factors such as, excessive fragmentation, disparate project management processes and non-standardised information as hindering efficiency gains (Fulford and Standing, 2014). The fragmentation, the traditional principles and the adversarial environment has generally resulted in the construction industry being highly inefficient compared to other sectors (Anumba and Kamara, 2012, Zidane et al., 2015b). The traditional sequential process depicted in Figure 1 showcases this lack of integration often seen in the construction industry, and is commonly referred to as the *over the*

wall syndrome (Evbuomwan and Anumba, 1998, Anumba and Kamara, 2012). The figure visualizes the lack of integrated teamwork between the different processes, where work is merely being 'thrown' over to the next discipline and/or phase.

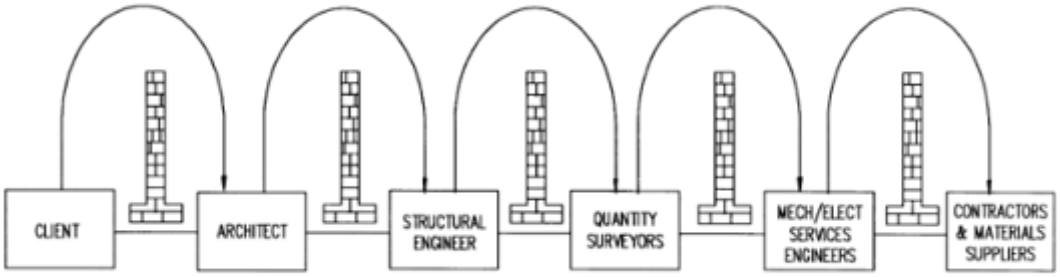

Figure 1: The 'over the wall' syndrome (Evbuomwan and Anumba, 1998).

This serial process in displays the limitations from traditional organizational standards. In fact, the construction sector's project teams exist as individual professional units within the boundaries of the organization (Baiden et al., 2006, Zidane et al., 2015b). Here, in the traditional design and construction process in Figure 1, varying degrees of integration occurs, and is determined by the adopted team practices and the agreed upon procurement approach (Baiden et al., 2006). Moreover, according to Nicholas (1994), team members that, in a fragmented setting, becomes too focus-oriented on their respective disciplines, might lose interest in the project as a whole.

2.1.2 Construction projects today

Construction projects are various in complexity and size, and usually involves unique aspects – which is (typically), having a unique supply chain and a unique design for each project. Because of this, and the normally large number of fragmented project members, contracting, terms, and conditions exert a major influence on how to work together (Morris, 2007, Baiden et al., 2006). In fact, procurement practices have been attributed to not encouraging the integration of the parties involved (Baiden et al., 2006). However, according to Morris (2007), the industry has achieved well practiced results in cost control, contract administration and value management. Despite the various issues of the industry, it has improved in the recent years. With the introduction of cross-discipline information technology like BIM (Building Information Modelling) and the transition towards new modus operandi which focuses on integration and collaboration, such as implementing Concurrent Engineering, the industry has enhanced productivity (Baiden et al., 2006, Anumba and Kamara, 2012, Shouke et al., 2010).

BIM, which is utilized more and more in the industry, can be defined as a swiftly evolving collaboration tool that offers 3D models and information. Information is the key part here, and can constitute factors such as space constraints, time, costs, materials, design and manufacturing information etc. (Bernstein and Jones, 2012). It can serve as an enabler for increased transparency, higher integration, and improved productivity (Merschbrock and Munkvold, 2015). In fact, a case study on implementing BIM on infrastructure projects found an approximate cost saving of 5-9 %, because of the reduced rework and change orders (Fanning et al., 2015). Additionally, findings by Bernstein and Jones (2012) saw a return on investment from 67 % of the users of BIM within infrastructure. Moreover, the use of BIM opens up possibilities of working more efficiently when separated geographically, which is highly valuable in such a fragmented industry (Anumba and Kamara, 2012).

2.1.2.1 The issue of delays within construction projects

A project execution time is an important aspect and one that is highly relevant for a project's success or failure (Andersen et al., 2006). Although, a product or end result can be successful despite the project development time, the majority of construction projects suffer time-overrun, and thus, increase cost/resources (Eik-Andresen et al., 2016, Odeh and Battaineh, 2001, Assaf and Al-Hejji, 2006, Arditi et al., 2017). In fact, a study of a large number of construction companies in USA by Arditi et al. (2017) resulted in a report of only 26% of the projects with no delay. Similar findings were reported from a survey in Saudi Arabia, where 70 % of the projects experienced time overruns (Assaf and Al-Hejji, 2006). What causes the delays however, seems to be dependent on a lot of factors that differ between countries. In the Norwegian context, management and coordination, and decisions issues seemed to be the most important factors for both the public and the private projects according to a study by Eik-Andresen et al. (2016). However, according to the same authors, whereas the private sector seems to lose time waiting for decisions by the client and experiencing errors and quality related delays, the public sector struggles with administration and bureaucracy and a lack of resources/capacity to move forward (Eik-Andresen et al., 2016). On the investigation of possible remedies for the delays, Eik-Andresen et al. (2016) found that the less experienced respondents wanted better or more information, better procedures, more controlled and less unnecessary meetings. Moreover, according to the same researchers, one-half of the respondents asked for simplification of procedures and the other asked for stricter and more rigorously followed procedures. A sentiment which is somewhat shared in the project management literature, and, according to Koppenjan et al. (2011) a combination of the two

procedures should be strived for, flexible and procedural. An additional contrast between the private and the public sector, in relation to remedies for delays, few from the private sector advocated the need for higher level of competence, whilst many from the public sector did (Eik-Andresen et al., 2016). Interestingly, while Arditi et al. (2017) found that organizational culture is associated with delay in the USA and India's construction projects, Eik-Andresen et al. (2016) found that most of the problem-solving lies not with organizational or resource issues, but with management issues. In fact, Eik-Andresen et al. (2016) concludes from the respondents answers that better up-front planning, and project-management and -control (particularly, procedures and project structure) can reduce delays. Furthermore, an exploratory study on generalizable project features by Andersen et al. (2006), which covered UK, France, Norway and China suggested that the managerial ability to deliver in time and at cost were early stakeholder influence and endorsement of project plans, strong project commitment and rich project communication (Andersen et al., 2006).

2.2 Concurrent engineering

Concurrent engineering has almost exclusively been regarded as an approach that has great potential in improving project development time, increase quality and decrease cost (Anumba and Kamara, 2012). However, the way towards adopting such a method in the construction industry is, according to the literature, still paved with challenges (Park, 2001, Zidane et al., 2015b, Anumba and Kamara, 2012). Because a CE team and the work (the CE session) is the centre of the concurrent engineering method, understanding and finding effects within such a session requires an understanding of the overall method. Consequently, any effects of a CE session must be understood as in the context of the overall project management method of CE. This chapter will outline the general CE method for this purpose.

Concurrent engineering is a method that involves integrating all elements of a project, including technology and tools that are used in the development process (Anumba and Kamara, 2012). The method advocates that the ultimate goal is customer satisfaction through reducing cost and time-to-market (Winner et al., 1988), and increasing product quality (Anumba et al., 2002). CE is considered to embody the key principles of early involvement of all contributing participants, teamwork and concurrent workflow (Valle and Vázquez-Bustelo, 2009, Koufteros et al., 2001, Thamhain, 2007).

The idea of CE involves having a focus on design and *getting things right the first time*. This entails the importance of integrating project participants from all phases of the project, as well as customers, suppliers and so on, in order to capture the whole life-cycle (Thamhain, 2007, Prasad, 1996). The formation of cross-functional teams arises, and work can be scheduled to occur paralleled. This integrative, communicative and collaborative environment of CE are, among others, to ensure fast information gathering on issues and work more efficiently and qualitatively (Thamhain, 2007, Anumba et al., 2002, Prasad, 1996). Summary of understanding the CE method can be seen in the Figure 2 below.

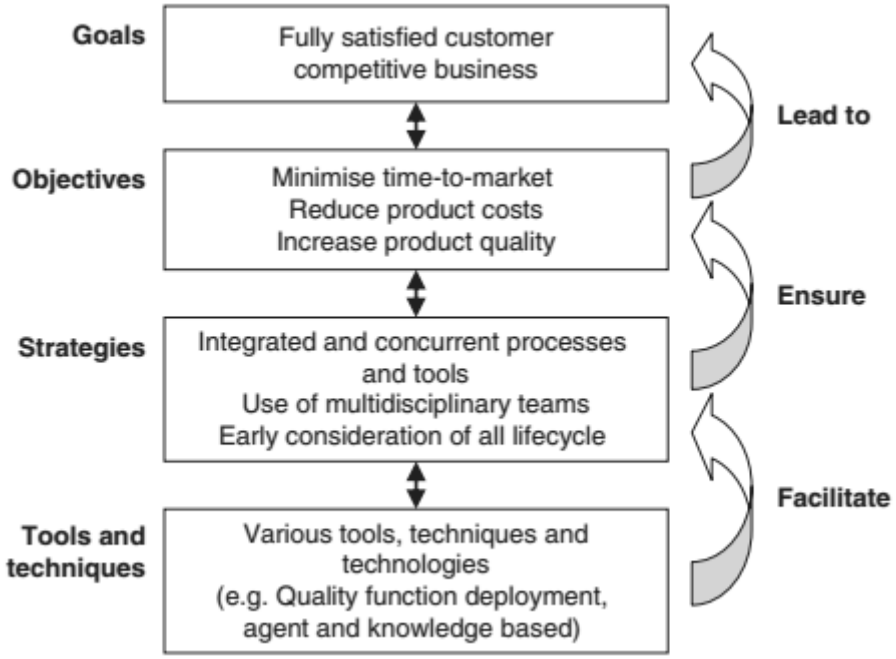

Figure 2: The CE method (Anumba and Kamara, 2012).

2.2.1 The cross-functional team (The CE team)

The concurrent team is the team responsible for developing the project. Per the literature, ideally, the team should not be hindered by organizational boundaries as well as have full autonomy on decision-making (Thamhain, 2007, Anumba and Kamara, 2012, Nicholas, 1994). Preferably, the team is co-located, if not they meet when they need to plan and/or work concurrently on overlapping discipline areas (or areas that might require input from other disciplines and/or decision makers) (Nicholas, 1994, Zidane et al., 2015b, Anumba and Kamara, 2012). This type of meeting is often called a concurrent session, and occurs in a, preferably, predetermined and prepared room (e.g. the "Big Room") (Zidane et al., 2015b, Tauriainen et al., 2016). Although the major evidence comes from the manufacturing industry; examples of

the importance of the CE team (*the multi-functional team), can be observed in Figure 3 (Prasad, 1996).

Company	Product	Best development time (months)			Major contributing factors*
		Before CE	After CE	Reduction	
ABB	Switching Systems	48	10	79%	CMS
AT & T	Phones	24	12	50%	ACM
British Aerospace	Aeroplanes	36	18	50%	MS
Digital Equipment	Personal Computers	30	12	60%	ACMS
Ford	Cars	60	42	30%	—
General Motors	Engines	84	48	43%	MS
GM/Buick	Cars	60	41	32%	MS
Goldstar	Telephone Systems	18	9	50%	CM
Honeywell	Thermostats	48	12	75%	MS
Honda	Cars	60	36	40%	—
Hewlett-Packard	Printers	54	22	59%	ACMS
IBM	–	48-50	12-15	70-75%	ACM
Motorola	Mobile Phones	36	7	81%	ACM
Navister	Trucks	60	30	50%	MS
Warner Electric	Clutch Brakes	36	9	75%	M
Xerox	Copiers	60	24	60%	ACM
Xerox	–	53	36	32%	ACM

Legend:
***M**: Multi-functional Teams
***A**: Analytical Methods and Tools'
***C**: Computer Integration
***S**: Suppliers in the Project Team

Figure 3: Savings in product development time using CE (Prasad, 1996).

2.2.2 The Concurrent Engineering process

In order to understand the integrative CE process, an example of a concurrent project phase is shown in Figure 4; here the different departments and activities are overlapping to represent the integration and cooperation that occurs. Although this figure seems straight forward, research has shown that to adopt concurrent methods, a company should be willing to change their organizational boundaries as well as be aware of the cultural shock of such a change (Zidane et al., 2015b, Portioli-Staudacher et al., 2003, Ainscough et al., 2003, Anumba et al., 2002, Park, 2001). In fact, according to the same researchers, three major generic factors that were shown to disable CE stands out. Those factors are the cultural change, the cross-functional team and management issues (Zidane et al., 2015b, Portioli-Staudacher et al., 2003, Ainscough et al., 2003, Anumba et al., 2002, Park, 2001).

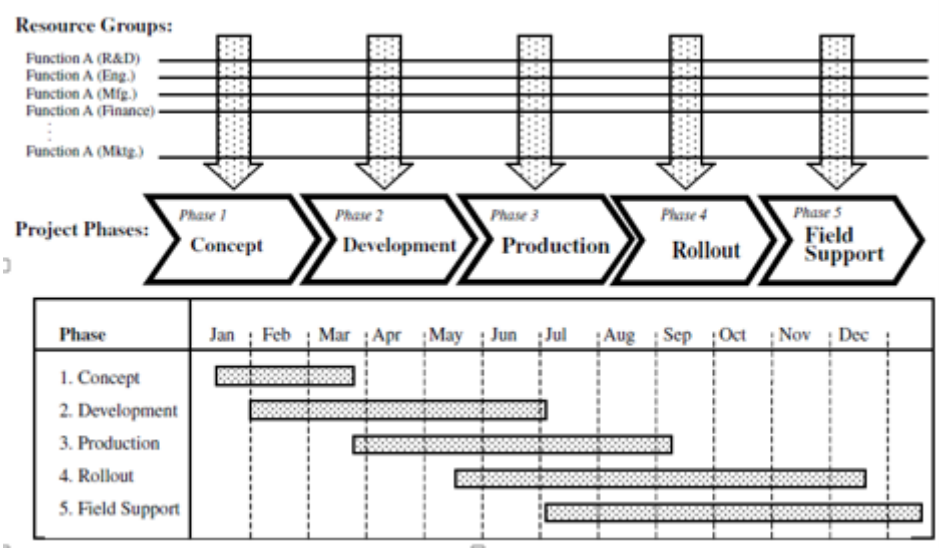

Figure 4: Example of concurrent project phase execution (Thamhain, 2007).

The manufacturing - and oil and gas – industries have adopted concurrent engineering and seem to have achieved great success in working collaboratively and cross-disciplined (Zidane et al., 2015b, Prasad, 1996). In order to align with the research questions and the topic of this thesis, the next chapter will look at the construction industry's efforts towards the adoption of the CE method.

2.3 Concurrent engineering in construction projects

The construction industry today is transitioning away from traditional modus operandi and introducing tools and techniques such as 3D modelling/BIM and Concurrent Engineering in order to improve, among others, the project development time. However, barriers and problems 'inherent' to the industry seems to stagnate the process of improvement. Problems such as the fragmented project process, the traditional principles and, often aggressive and adversarial environment (Anumba and Kamara, 2012, Zidane et al., 2015b). In order to understand more in-depth, the reasons for a concurrent session's positive or negative outcomes, a more thorough look at the current literature on the subject will be presented. In addition, because the CE sessions are supposed to be an integrated collaborative team, barriers towards such integration are examined.

Concurrent engineering and the use of information technology (like BIM) is generally seen today as the solutions to the problematic fragmented construction process (Kamara et al., 2001, Anumba and Kamara, 2012). BIM, as mentioned previously, facilitates the creation of a 3D model, thus improving the project team's capability of evaluating potential implications of the

design before construction (Fanning et al., 2015, Anumba and Kamara, 2012). In addition, BIM facilitates the collaborative workings because of the shared platform, which is important for enabling and enhancing the CE work (Anumba and Kamara, 2012, Merschbrock and Munkvold, 2015).

The reason for the motivation of adopting CE methods, is the high success that the manufacturing industry has gained from it (which is considered a similar industry on many factors), the fact that the method is highly adaptable to other industries and, that the principles of CE seems to directly address the inherent problems of the construction sector (Thamhain, 2007, Anumba and Kamara, 2012, Evbuomwan and Anumba, 1998). However, even the organizations reinventing themselves and embracing CE are struggling to see the benefits realized by the manufacturing industry, which is apparent from the continued efforts to find and present solutions to some of the problems (Anumba and Kamara, 2012, Anumba et al., 2002, Park, 2001, Zidane et al., 2015b, Landeghem, 2000, Valle and Vázquez-Bustelo, 2009, Koufteros et al., 2001, Evbuomwan and Anumba, 1998, Ahmad et al., 2016, Belay et al., 2016). Nevertheless, several authors found that there has been an increase in productivity in the construction industry by those implementing concurrent engineering (Baiden et al., 2006, Anumba and Kamara, 2012, Shouke et al., 2010).

2.3.1 Concurrent engineering utilization issues

Concurrent planning and evaluation

A common viewpoint on the struggles with the utilization of CE, is the planning of the concurrent execution of different work phases (Park, 2001, Shouke et al., 2010). This issue could cause poorly understood management and thus disruption on the construction phases (Park, 2001). A contributor to this problem is suggested to be the lack of tools befitting the dynamic state of the project (Park, 2001, Anumba et al., 2002), like for example, proper performance measurements which can be used during the project development time (Ahmad et al., 2016, Shouke et al., 2010).

Integrating the project stakeholders

The construction industry usually comprises of a distinct chosen supply chain for each project. This fact makes concurrent principles difficult to initiate early in the project and moreover, can cause relationship issues over contractual disputes (Morris, 2007, Shenhar and Dvir, 2007). As mentioned earlier, this sometimes adversarial relationship and the scattered and fragmented involvement of some of the project participants during the project causes problems with the integration necessary in concurrent construction (Zidane et al., 2015b). Some evidence regarding these issues were thought to be linked to the hierarchical and traditional nature that persists in the concurrent construction environment (Zidane et al., 2015b, Anumba et al., 2002). As previously mentioned, thoughts on changing the organizational structure for concurrent engineering to function optimally have been suggested by several researchers (Zidane et al., 2015b, Thamhain, 2007, Anumba et al., 2002, Ainscough et al., 2003, Evbuomwan and Anumba, 1998). However, the findings of Anumba et al. (2002) showed an unwillingness and disbelief that an organizational restructuring could be a way to overcome these problems. In fact, Zidane et al. (2015b) witnessed concurrent sessions as more of a hierarchical meeting rather than a collaborative work-method. For further understanding of the elements and corresponding issues involved in the construction industry, see Figure 5 below.

Elements	Oil & Gas Industry	Construction Industry
Client/ Owner/ Sponsor	The Client/ Owner/ Sponsor are the major enablers of using concurrent engineering within their projects. Thus, involve all other project participants to use the method is systematic outcome.	The Client/ Owner/ Sponsor are the major disablers of using concurrent engineering within their projects. Even some tentative from the other project participants (e.g. contractors, subcontractors, etc.) but still the method used is far to be a widespread CE method.
Operator/ Users	Operator/Users play important role in enabling the use of concurrent engineering. The reason is because they belong to the same organization as Client/ Owner or Sponsor. Thus increase the flow of needed information in the early phases of the project. So avoiding many modifications at the end of the project.	Operator/Users are almost completely absent from needs identification until the close up phase. This causes missing information in the startup of the project; therefore extend the project duration because of changes, modifications and redoing some parts of the deliverables.
Contractors	The contractor is involved in early phases before starting the implementation of the project, this gives more chance to employ properly CE method.	The contractor is involved only in the implementation of the project, after a bidding.
Subcontractors and Suppliers	Involved in the early stages, considered as partners.	Come late in the start of the planning and design phase.
Type of contract/ agreement	Most of the cases Joint venture, partnership, frame contract.	Biddings most of the cases.
Time to delivery	Extremely from very high importance, project should be delivered within or ahead of schedule	Less important comparing to oil and gas industry, or even to new product development.
HSE	Priority and key success factor	Important, not critical.
Process	Aligned and standardized in all firms.	Well defined within the contractor level.
Technology	Available in all firms.	Complete tools within the contractor level.
Concurrent sessions	More integrated, start in early project phases, they are more collaborative sessions than traditional unproductive meetings.	Scattered, unstructured, start in the implementation of the project, they have more the characteristics of hierarchical meetings than a collaborative sessions.
Readiness	All participant firms are completely ready to implement CE method (e.g. Sponsor, clients, operator, consultants, suppliers, etc.).	Except the contractors and subcontractors, no other type of firm is ready to implement CE method (client, consultants, suppliers, etc.).

Figure 5: Enablers or barriers of using CE method in oil and gas industry vs. construction industry (Zidane et al., 2015b).

2.3.2 Benefits of CE in the construction industry

Despite the problems with the method, it has been demonstrated from many authors that CE increases project performance due to the key factors that has been clarified in the previous chapters. Documented results of the benefits in the manufacturing industry is well known (see Figure 3), but similar findings in the infrastructure sector are scarce, although an abundance of anecdotal evidence has surfaced (Anumba and Kamara, 2012). The concurrent construction benefits involve identifying associated downstream aspects and reducing or eliminating non-value activities thus producing more accurate designs, all by involving every project participants and having multi-disciplinary and cross-functional teams (Anumba et al., 2002,

Ahmad et al., 2016, Park, 2001). Potential benefits of CE in the construction industry are listed below, where some are derived from other industries, such as the manufacturing's success of the method, while others are based off anecdotal evidence from the construction industry (Anumba and Kamara, 2012):

- Improved quality of facilities relative to cost
- Reduced duration of capital projects
- Enhanced efficiency and productivity due to reduction in rework
- Better coordination and management of the construction process
- Better informed decision making and coordination, with decisions taken at the right time and by the right person(s)
- Improved competitiveness of the construction industry relative to other industry sectors
- Better project definition due to more time provision at the early project stages
- Improved integration of life-cycle considerations
- Enhanced collaboration and teamwork between members of the project team
- More robust information exchange between team members and across the stages in the project delivery process
- Improved quality of the end product – the constructed facility
- Greater client satisfaction, given the improved focus on the client's requirements and the delivery of greater value
- Waste reduction
- Reduced scope for conflicts and litigation
- Greater profits for construction companies due to the ability to control more aspects of the project, reducing overall construction time, and improved interaction with designers and other team members
- Improved safety and 'uptime' for existing operations

2.4 Concurrent work sessions

As mentioned in previous chapters, having an integrated project process and being more collaborative is seen as a possible way to increase the competitiveness within the construction industry and reduce the project development time. One way to conceive this is through a concurrent engineering approach that facilitate the integration of all elements of a project (team members, stakeholders, tools and so on) (Anumba and Kamara, 2012). Considering this thesis' focus on the multi-disciplinary teamwork in a CE session, this chapter will analyse the current

literature on concurrent teamwork, integration and collaboration, as well as the concept of the "Big Room". The purpose is to build a broader understanding of the intricacies, lessons learned and factors involved.

2.4.1 The Concurrent Teamwork

What emerged from the analysis of the literature is that one of the principal traits of the concurrent teamwork is the high diversity of project participants. This integration is the main differentiation between general project teamwork and concurrent teamwork. This integration of diverse project participants brings about a series of positive factors. In fact, many authors advocate that it can facilitate better and more stimulating discussions, as well as create more informed and accurate solutions and decision-making (Anumba and Kamara, 2012, Shelbourn et al., 2007, Nicholas, 1994). Despite this, because of the high number of diverse disciplines that have different perception of importance and interest, agreeing on decisions might be more challenging (Nicholas, 1994).

In general, achieving effective concurrent teamwork can present some challenges, and according to Nicholas (1994) the most difficult problems lie with overcoming organizational and interpersonal obstacles. The same author outlines ways to enable teamwork within three areas of considerations, the organization, the leadership and the behaviour. This is represented in Table 1 below:

Table 1: Enablers and considerations towards establishing an effective CE team (Nicholas, 1994).

Overcoming the obstacles to teamwork		
Team organization	**Team leader**	**Team behaviour**
Autonomous team	Clarify and build commitment to the team purpose	Decision making
Full-time, full-duration team	Charismatic, interpersonally competent, involved	Communication and participation
Co-located team	Facilitate teamwork	Responsibilities
Small team		Meetings
Team rewards		Conflicts
Team of doers		Gripes

Within the team organization, Nicholas (1994) advocates that the team should be autonomous, full-time and full-duration, co-located, small, include rewards for collaborating and consist of 'doers'. The author further expresses that the leader should; clarify and build commitment to the team purpose, be charismatic, interpersonally competent and involved and facilitate the teamwork. Moreover, the author outlines wanted team behaviour through guidelines within determining how decisions should be taken and who takes them, how to be heard and how to participate, determine responsibilities, meetings, conflict handling and gripes.

Furthermore, in addition to the consideration of previously mentioned obstacles with the CE method (see chapter 2.3.1), general practices towards the CE enablement and creating of an effective CE teamwork can include for example:

Table 2: A few general practices towards CE enablement.

General practices towards CE enablement	
Practices	**References**
Appropriate selection and delegation of authority to team leaders	(Anumba and Kamara, 2012, Nicholas, 1994)
The appropriateness of strategies for team formation and operation	(Anumba and Kamara, 2012, Koufteros et al., 2001, Thamhain, 2007)
Training to enable team members to fulfil their role	(Anumba and Kamara, 2012, Nicholas, 1994, Zidane et al., 2015b)
Ensuring that team members understand their role and work towards a common purpose	(Anumba and Kamara, 2012, Buvik and Rolfsen, 2015)
The use of information and communication technology that enable integration	(Thamhain, 2007, Anumba and Kamara, 2012, Koufteros et al., 2001)
Supporting policies and procedures and be adaptive to sudden changes	(Anumba and Kamara, 2012, Thamhain, 2007, Ainscough et al., 2003)

2.4.1.1 The effects of team integration and collaboration

Teamwork and integration are key words in a concurrent engineering environment. This is because the integrated teamwork is one of the most important factor for realizing the benefits of the method (Nicholas, 1994, Anumba and Kamara, 2012). In order to facilitate the creation of an integrated team, most researchers advocate a need for both organizational and technological enablers (Anumba and Kamara, 2012, Thamhain, 2007, Zidane et al., 2015b). In addition to this, there should be a consideration of interpersonal obstacles (such as lack of trust,

lack of autonomy/experience, lack of clear roles, and so on) (Nicholas, 1994, Anumba and Kamara, 2012, Erdogan et al., 2008, Buvik and Rolfsen, 2015).

Integration can be a factor for improving teamwork according to Baiden and Price (2011). The authors outline that meeting requirements of integration either complements or increases the likelihood of achieving effective teamwork. In fact, early involvement and integration positively affects performance (Valle and Vázquez-Bustelo, 2009) and create an information rich environment (Koufteros et al., 2001). Furthermore, according to a study by Franz et al. (2017), higher team integration resulted in reduced project schedule growth and increased project intensity. Moreover, integration through involving contractors improved construction schedule performance according to a case study by Song et al. (2009). However, according to Baiden and Price (2011) integration alone does not deliver all the solutions towards teamwork effectiveness. A study on the extent of team integration (as in whether it is needed to integrate all project stakeholders at all times) in construction projects concluded that, either fully integrated teams might not be necessary for effective team operations, or overcoming organizational and behavioural barriers is necessary to fully realise the benefits of it (Baiden et al., 2006). Furthermore, other researchers advocate that there should be a balance between when the teams work in isolation, and when they come together to exchange knowledge and collaborate (Garrety et al., 2004).

The collaboration in an integrated cross-discipline team requires a group of people to come together and work under, perhaps, difficult and limiting environments. In fact, (Shelbourn et al., 2007) found that effective collaboration requires three different strategies to come together, technology, business and people. A study of the Swedish construction sector by Wikforss and Löfgren (2007) also indicated that to solve the practical issues in the form of increased collaboration and integration, there should be an inclusion of information and communication technology from an organizational and management viewpoint. However, as a few researchers pointed out, some industries tend to rely too much on the technology for collaboration and lose focus or underestimating other factors, like organizational, interpersonal or management related (Erdogan et al., 2008).

2.4.1.2 The "Big Room" concept

The "Big Room" concept, which has been unnamed but known in the literature of collaborative workings for quite some time (Nicholas, 1994), involves the gathering of the project participants on one spot in order to take advantage of elements such as faster information-

gathering and more informed decision-making (Thamhain, 2007, Nicholas, 1994). Coordinating working arrangements and decision-making, and utilizing tools such as BIM are examples of how one could facilitate the collaboration between different disciplines in a "Big Room".

The "Big Room" concept can be used to ease the process of collaborative work (Jones, 2014, Tauriainen et al., 2016). A study by Jones (2014) found that most participants of a Big Room concurrent working environment, preferred the greater level of collaboration for reviewing and resolving design and construction problems compared to the more traditional construction development. In fact, Tauriainen et al. (2016) found that the usage of a Big Room was the most applicable tool for handling communication, response-time, redesign and collaboration problems.

2.5 Summary of the literature review

The construction industry is one characterized by a fragmented sector, adversarial relationships and, traditional principles (Anumba and Kamara, 2012, Morris, 2007). Because of this, integration and collaboration suffers and in return, the competitiveness is lacking in comparison to other industries (Zidane et al., 2015b, Anumba and Kamara, 2012, Odeh and Battaineh, 2001). The infrastructure industry is particularly seeing delays of project development time because of struggles with administration and bureaucracy and a lack of resources/capacity to move forward (Eik-Andresen et al., 2016). Concurrent engineering is seen today as a project management method that can be utilized for improving particularly the project development time in the construction industry. The reason for this is partly because of the success of the method in other industries and, the outcomes of CE seem to address the 'inherent' problems of the construction industry, that of integration and collaboration problems (Eik-Andresen et al., 2016, Odeh and Battaineh, 2001).

Concurrent engineering is a method that involves integrating all elements of a project development's life cycle (Winner et al., 1988). By doing so, a more informative and accurate plan can be developed and an increase in quality would occur. The majority of the benefits of CE would come from the quality of the plan, where time-to-market and reduction in cost would be mostly realized through the development of a more accurate and concurrent work plan (Anumba and Kamara, 2012). The construction industry are still trying to overcome a few obstacles towards having an effective use of the CE method (Park, 2001, Zidane et al., 2015b).

Specifically, the industry is struggling with integrating the project stakeholders and the development of the concurrent plan. In fact, for the CE method and the CE teamwork to function optimally, organizational, technological and interpersonal obstacles should be considered (Shelbourn et al., 2007, Anumba and Kamara, 2012, Park, 2001, Nicholas, 1994).

3 Research Method

This project explored the effects on the utilization of working concurrently as a multi-disciplined team, per the concurrent engineering method, versus more traditional project methods. The main and *broadest research question* of the study was (Creswell, 2013): "*What are the effects of utilizing an integrated concurrent team as per the concurrent engineering method in comparison to more traditionally ran projects, in the context of the infrastructure sector?".* To expand on this research focus and analyse the topic a little more in depth, an additional research question was added: *"What are the potential contributing factors for such a team to work (or not work)?".*

According to Bryman and Bell (2015), the broad orientation of the study is defined as the *research strategy*, which can be a *quantitative* or a *qualitative* approach. Since this study was mainly based on experiences and personal interpretations of the findings, a qualitative approach was chosen. The research method refers to the collection, analysis and interpretation of data (Bryman and Bell, 2015, Creswell, 2013). In this research the qualitative data were collected from a sample of 14 interviews and from the observation of a concurrent session (Creswell, 2013). The reason for doing an observation of CE teamwork is to corroborate the research findings (Bryman and Bell, 2015). In addition. the observation creates a setting where context can be better understood and captured, in other words, the findings from the interviews can be less obscure to the author (Bryman and Bell, 2015).

This project was connected via NTNU to the FoU project, which is supported by The Research Council of Norway. Through that connection, a questionnaire for gathering baseline data was given to the author, as well as opportunities and aids towards data collection and the observation of a concurrent session.

The findings of this research are based on a literature review, a set of interviews and, the participation and analysis of an observation of a concurrent session. The theoretical framework, which goes from a generic to a specific point of view, had a focus of researching the effects that comes from the CE method and the CE team. First, knowledge of the construction projects and the traditional project method was necessary for the overall research focus. Second, it was paramount to establish an overall understanding of the research so far on the utilization of CE and its effects, and finally understand the integrated concurrent teamwork (the CE team) in more depth. The findings from the literature review served as the knowledge basis to build the

interview process. In addition, what found from the literature was then compared with the results from the interview and with what emerged from the observation of the CE session. From this, the final findings to answer the research questions were identified and merged together.

The interviews consisted of a similar structure as the literature review, going from generic and a basic understanding to a more specific point of view. First, a basis on how the interviewees perceived the collaboration, teamwork and so on in the traditional project method. Second, more in depth towards the CE team and the effects and obstacles herein. The first part of the interview involved going through a questionnaire developed for the research project FoU. The research project's main purpose for the development of the questionnaire was to gather data on traditional project methods in the infrastructure sector. This questionnaire also served helpful for this thesis, which is why the questionnaire was adopted. In addition, contact information of the interview objects, who all are project managers in the infrastructure industry, was given to the author through the connection with FoU. After the questionnaire, specific open-ended questions were asked that were more directed towards the research questions. The development of these questions was based off the author's understanding of the literature review.

The observation consisted of one non-participant observer that wrote down events and actions occurring during a CE session in an infrastructure project. The opportunity to be present during this CE session was given to the observer through contacts with the research project FoU. The observation of the CE session was possible after the author accumulated knowledge from the literature review and the interviews. In fact, it was necessary to be aware of the CE factors, common issues, obstacles, and so on, in order to understand the effects and occurrences of the session. The structure of the observation was to have broad categories that were of great importance according to the literature or according to the responses given through the interviews. Because of the complexity of this topic, it was necessary to understand under what conditions such a session was undertaken. Some questions that seemed relevant and prepared the observer in advance of the session were:

1. What kind of tools are used?
2. How is it organized?
3. What kind of autonomy is present, and who makes the decisions?
4. How is the session structured and planned?
5. Are all the relevant stakeholders present?
6. How big or small is the project, and how complex is it?

Although the context of a concurrent session is important, this thesis primarily focuses on what effects that came out of the session and the interviews with experts, and analyse and discuss these effects relative to what was found in the literature review.

3.1 Literature review

A literature review serves an important function of a research thesis. First, to identify what is already known in the field of the research subject. last, the literature might encompass diverse observations and findings which can enhance the overall research (Bryman and Bell, 2015). The literature review, which creates the basis for the research, first established an understanding of the status quo in the construction industry. Then, an evaluation of the literature on concurrent engineering and the concurrent teamwork was conducted. The literature review consisted mainly of understanding the CE team and its effects in the construction sector, as well as the characteristics of traditional project methods. In fact, in order to have a basis for comparison of the CE method, it was necessary to consider traditional project methods in the industry. The emphasis of the review was on understanding the effects of a CE team in a concurrent session in the industry through, theoretical and expert opinionated views, and evidence from the industry and other industries. In addition, it was important to understand related elements of the CE method and the CE team, such as research on best practices and integration, as well as enabling factors.

3.1.1 Selection process

Research was conducted mostly in scientific databases like Scopus and ScienceDirect, and occasionally looking at Web of Science. First, a general understanding of the overall two topics (CE and traditional project methods in the construction industry) was necessary to build the theoretical background. Afterwards, there was a need to narrow the scope and follow-up with research specifically tailored to the problem statement. The theory of the project moves from a generic to a more specific point of view, going from CE in general and traditional project methods to the utilization of the CE project method in comparison to more traditional methods. Key search words were as follows:

- Concurrent engineering
- Traditional project method *(construction industry)*
- Traditional project method AND assessment/delay *(construction industry)*
- Construction industry (infrastructure projects) AND assessment/delay

- Concurrent engineering AND Team work
- Concurrent method/CE AND construction industry
- Concurrent method/CE AND implementation analysis/assessment

After gaining an overview of the research in the field, it was particularly important to gather data on elements that would support an analysis of why and how a concurrent team could benefit the project development in infrastructure projects, specifically on time and cost, but also any other areas of relevance that was particularly noticed. Some of the keywords were:

- Traditional construction (infrastructure projects) AND concurrent engineering/methods
- project management AND concurrent engineering LIMIT-TO construction
- Construction industry AND difficulties/concurrent engineering/assessment
- Team work AND Concurrent engineering/integration AND Construction industry
- ICE (Integrated Concurrent Engineering) AND work sessions/success factors/effects
- Concurrent method/CE AND work sessions/success factors/effects
- Integration AND Collaboration AND Project teams
- CE teamwork

The initial article sample size at 66 was selected for more detailed screening process. The major selection criteria of the samples were that they:

1. Contained elements of project/team work (traditional methods, benefits, obstacles, difficulties, integration, collaboration etc.) in the construction industry and/or…
2. Had concurrent engineering focus with related elements (particularly within project work and the construction industry).

In addition, the most relevant articles were within the sub criteria:

   a. Norwegian context and/or
   b. Infrastructure/public sector

The most significant articles comprised of both major selection criteria and was imperative to establish an understanding of how the CE teamwork can be, and has been utilized in the construction industry. Therefore, it was important to get a basis of understanding of the status quo of the industry and understand the major factors of teamwork in a CE method.

The selection method of the articles, if they were found to be relevant to the research, followed the steps: 1) read the abstract, 2) if the abstract were found to be relevant or contain the main

criteria then read introduction and conclusion. If the article confirmed the relevance for the research then it was necessary to 3) perform a more attentive analysis. At the end of this process, a final sample of 47 articles was chosen. The selected sample of articles were published from a wide variety of different journals, conferences papers, reports and books section. In particular, thirteen articles were published in the International Journal of Project Management, and the vast majority were published in management related journals. A few of the articles came from economics and/or social/behavioural sciences journals.

3.1.2 Analysing the theory

The finalized list of references was analysed critically and thoroughly and, it was important to have multiple sources on significant facts or theories. In addition, where various opinions and diverse findings were noticed, the references were scrutinized on finding any similarities or discordancy on the subject. Because the main topic was roughly decided in the beginning of the process, the analysis proceeded efficiently. However, because of a slow progress on finding exact problem statement, the process of analysing and finding relevant articles expanded from an initial "utilizing CE in the construction industry" to focusing on the CE teamwork in comparison to the traditional project methods. Since the project contained a limited number of articles, the need to codify or classify the relevant research seemed unnecessary.

From the literature, it emerged that in general the CE method is heavily researched. Although most CE research is connected to new product development with names such as Integrated Product Development (Thamhain, 2007), there is a wide variety of studies in relation to the method in the construction industry as well (Anumba and Kamara, 2012). A significant portion of located articles within both major selection criteria contained elements of either "best-practices" for adoption, or "challenges" with the CE method (Zidane et al., 2015b, Park, 2001, Anumba et al., 2002, Ahmad et al., 2016). Related to this, it was found that benefits of the CE method in the construction industry was surprisingly largely anecdotal in nature (Anumba and Kamara, 2012). In addition to this, no articles incorporated all of the selection criteria for this thesis. In fact, only one article contained three of the selection criteria; (1), (2) and (a) (Zidane et al., 2015b). The main reason for this aspect is the limitation of the contexts *Norwegian* and *public/infrastructure* (the sub criteria). There was a lack of research regarding both CE in Norway as well as CE in public or infrastructure projects.

The books and book sections (chapters) presented an overview of the different research areas of consideration for the thesis. Specifically, they contained general encompassing information

on CE fundamentals, CE in construction and project management in construction (Morris, 2007, Anumba and Kamara, 2012, Prasad, 1996, Shenhar and Dvir, 2007). Next was to evaluate different areas of context that involve the selection criteria, more specifically articles that looked at performance, implementation and/or effects of CE and integrated project teams in the construction industry.

3.2 Interviews

The interview process was conducted for two main purposes:

1. To gather information about the experiences that project managers had in regard to more traditional project setting, particularly, in regard to current collaboration in teamwork and overall problems in the industry/teamwork.
2. If the interviewees had experience with CE; what, in their expert opinion, obstacles and effects the method of CE and the CE teamwork brought or could bring to the project development.

The interview objects that were selected for the gathering of data are all project managers and currently involved in large infrastructure projects in Norway. The contact information of the interview objects came from the research project FoU. The majority of the data came from the client's perspective, but a number of consultants working on the engineering team on the same projects was also interviewed to get a broader viewpoint on the project development and the result. The interview process consisted of phone conversations with the interview objects and lasted approximately two months. The process consisted of a simultaneous data gathering and data coding. The interviews consisted of a questionnaire and 3-6 open-ended questions that encompassed the problem statements, with possible follow-up questions. The questionnaire (see Appendix 1: The questionnaire) was mainly developed and piloted to gather basic traditional project data for the research project FoU, however, information and data deemed valuable was kept and coded for the purpose of the research questions. The open-ended questions were chosen because it does not suggest possible answers, and furthermore are ideal for qualitative research (Bryman and Bell, 2015). This form of interview process is referred as a semi-structured approach. A semi-structured interview is according to Bryman and Bell (2015) an approach of which a set of prepared questions are asked, but adjusting this process to the interviewees' replies and flux of thoughts. This type of approach was optimal for being able to clarify answers and questions should they for example be too obscure. This type of interview

process requires high flexibility and focus from the interviewer so that information is not lost or misunderstood, and at the same time, obtain valuable findings. In addition, the different projects involved was researched through the program "Trailbase" where the KS2 reports (Quality Assessment reports) were screened. The reason for this was to gather some of the data of which the interview objects could not respond to over the phone.

The Table 3 below is a simple and anonymous rendition of the number of projects that were inquired. The table visualizes five elements: project number, which project phases that were in question, who the interviewer talked with, if a consultant was interviewed, and lastly who had experience with concurrent sessions (Client/AU on the left, and Consultant on the right). The table does not show number of consultants, because in some cases *one* consultant were involved with several projects. There were in total four consultants that were interviewed.

Table 3: The interview objects.

The interview objects and other details				
Project	**Project phase**	**Client/Awarding Authority (AU)**	**Consultant**	**Experience with concurrent sessions (Client/Consultant)**
1	D & B	Client	Yes	Na / Yes
2	D	Client	Yes	Na / Yes
3	M	Client	Yes	Yes / Yes
4	D	Client	Yes	Yes / No
5	D & B	Client	Yes	No / Yes
6	D & B	Client	Yes	Yes / No
7	D & B	Client	No	Yes / -
8	D	AU	No	Na / -
9	D	AU	No	No / -
10	D & B	Client	No	No / -
11	B	Client	No	Yes / -

Project phase nomenclature: D – Detailed plan. B – Building Plan. M – Municipality district committee plan. Na – Not applicable

A single interviewer phoned the interview objects (clients) in projects 3-7 and 9-11 as well as the consultants in projects 1-6. Project number 1, 2 (only the client) and 8 did not participate in the phone interview because they had delivered the questionnaire response in advance. The interview proceeded with the interviewer asking the questions and recording the response in

writing. Because of the semi-structured interview approach, this type of recording of data proceeded efficiently and also have increased validity because of the opportunity to probe for a deeper understanding (Bryman and Bell, 2015).

The open-ended questions (see Appendix 2: The additional open-ended questions) gave valuable insight into the collaboration and group work, both from the traditional project perspective and from their experience with CE. The first half of the open-ended questions were related to collaboration in current traditional teamwork in the industry, second half was directed to the eight interview objects that had CE experience, which encompassed questions more specifically directed to the research questions. The first question was very general regarding insight into traditional project methods and was (translated):

> *How has the group work, the collaboration, been between you and your project team members during the project phase?*

Should the question be answered simply as "good" or equivalent, the interviewer follows up with "*could you elaborate on that?"* Furthermore, after additional questions within this subject, regarding difficulties and tools for collaboration, the interview object was asked if he/she has experience with CE. If they did, additional questions were prompted:

> *How did you experience the method?*

And:

> *How was the collaboration and teamwork in comparison to traditional project method?*

Usually, this catalysed an informative round of data gathering, where much thought on the subject and related elements progressed. These questions were specific and detailed towards the research questions, thus the categorisation of the data proceeded efficiently between the interviews.

3.2.1 Analysing the interview data

The data, which was analysed simultaneously as the interviews progressed, was read and re-read in order to get a general sense of the information. This enabled an opportunity to reflect on the information's meaning (Creswell, 2013). After a few interviews was conducted, the underlying meaning behind the answers started to emerge and a list of topics was made. Thanks to the accumulated knowledge from the literature review, the underlying meaning and the preliminary list of topics proceeded efficiently. As the interview process moved on, the coding

of the data became more fluent, specific findings and new topics were noted. After the interviews were finalised and all the data was gathered, major topics and similar topics were turned into fitting broad categorisations and the data was assembled and alphabetized. After the assembly of the coded data, a preliminary analysis was conducted and some categorisations got combined and/or altered to be more fitting to the overall meaning (Creswell, 2013). A final analysis of the coded data resulted in a total of seven major categorisations that is the interview findings. The coding and analysis was performed by the single interviewer and thus, ensured consistency of the coding process. In fact, if the coding was done by more than one individual, the subjective judgement of the content might result in a lack of consistency on decisions (Bryman and Bell, 2015).

3.3 Observation: Concurrent session

The research project FoU granted the author access to early efforts of a concurrent session within an infrastructure project. This opportunity created the best context towards the research questions, but because it was an early effort, start-up problems could be more profound. These problems, identified in the literature and partly in the interviews are among others related to a lack of training and or the cultural shock in changes (Anumba and Kamara, 2012, Nicholas, 1994). In qualitative research, doing an observation adds certain strengths that can complement the qualitative interviews. Advantages such as, getting first-hand experience with the CE method, being able to record information as it occurs and unfiltered, and unusual aspects that would or could not be reported through an interview (Creswell, 2013, Bryman and Bell, 2015). Further elements that potentially could be solved from limitations of interviews are, memory problems, gap between stated and actual behaviours and others, (Bryman and Bell, 2015).

The main purpose of observing a concurrent session was to try to perceive and understand what effects, positive or negative that comes with the effort of the CE team working together. The observation of a group/individual's behaviour could reveal additional insight into how something was perceived by the interviewee regarding concurrent sessions and reported to the author through the interviews, thus potentially substantiating the findings (Bryman and Bell, 2015).

An important step to consider before observing a concurrent session is to have enough knowledge about the project method to understand both what is going on, as well as what might be important to observe and note. Furthermore, central to any observation study will be the

schedule or coding scheme. However, because the research questions are so open in regard to what effects that comes from the CE team, all and any kind of information observed might be prudent to record. Because of this, this thesis' observation was conducted as a Non-participant *unstructured observation* (Bryman and Bell, 2015). This type of observation is helpful when one wants to record as much detail as possible of a group/individual behaviour and cannot be easily categorised or scheduled.

3.3.1 The observed CE session

The session started at 09:00 and was planned to end at 13:00. It was held at the offices of "Vianova Plan og Trafikk" at the 2nd of May 2017. The session consisted of 19 participants of different disciplines and organizations, including the author as a non-participant observer. The room (see Figure 6) had six big screens (blue outlined) that could be connected effortlessly through wireless signal and cables, two big working areas with seating and a possibility to separate the two working areas with an extendable wall (the dotted line on the figure). There were two doors (black) and four tables (grey). The observer of the session sat at the orange marked chair for best visibility.

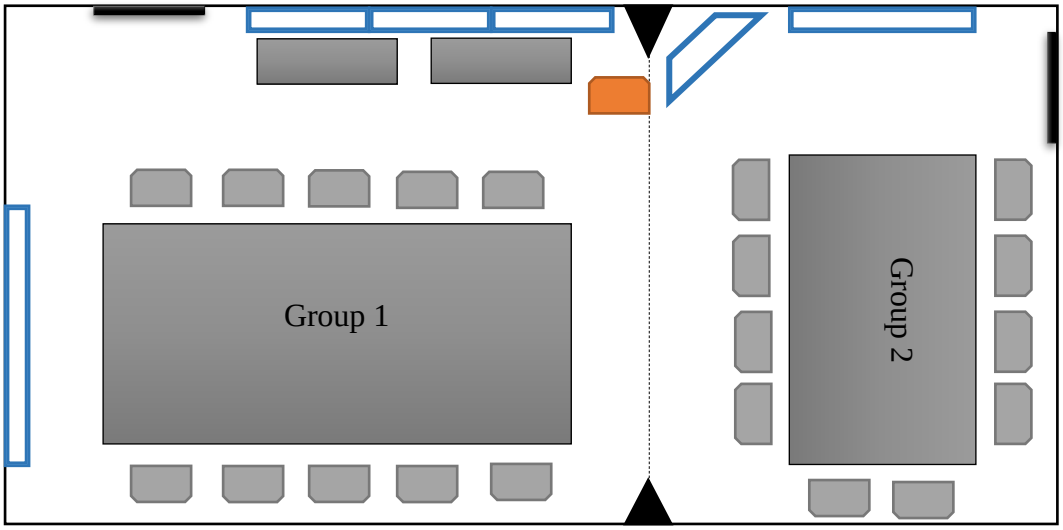

Figure 6: The concurrent session room (The "Big Room").

The 19 participants were split into two groups during the two work phases; group 1 had ten members and group 2 had nine. The observation and the concurrent session ended at 13:15. There were two group phases where work was split into the different themes/problems/actions that were to be solved. During these phases, the observer tried to keep an overall control over the major happenings but had to focus on one group at a time. This resulted in giving 3-5

minutes of focused observation on one group and then alternate between. However, being a dynamic experience, seemingly major occurrences demanded a shift of focus on the event.

The observation was recorded with as much detail about occurrences as possible on paper (see example of the observation form in Appendix 3: Observation form example). A document was prepared for the observation and consisted mainly of a time-stamp, number of participants at the action/event, a comment column, and a main area for writing down the action/event. When an event occurred, it was important to be as clear as possible, so as to not result in confusion when reading it for the analysis (Bryman and Bell, 2015). In addition, in preparation for the observation, and thanks to the interview results and the literature review, a few major elements that would be important towards the research questions were kept in mind when observing the concurrent session. These elements were:

1. Number of participants
2. Structure (work, group, communication, decision)
3. Type of tools available
4. Planning/plan
5. Autonomy (who has it, how much)
6. Integration of participants (external stakeholders, disciplines etc.)
7. Roles

It was significant for understanding the behaviours/events that occurred to try to gather information about these elements. In addition, some of the answers to these elements could shed more light on particularly what contributes positively or negatively towards the effects/behaviours seen (Anumba and Kamara, 2012, Nicholas, 1994, Park, 2001).

3.3.2 Analysing the observation data

The analysis of the observational notes started simultaneously with the observation. Notes, comments and underlying meaning from the observation was written down next to the event. The context of the sessions, including the prepared elements of categorised importance was the placeholders for some of these notes and comments. Because of the nature of the observation, it was not possible to create topics or major categorisations during the observation, but a large list of notes, memos and context of the actions were written down to give clarity for the action/event. After the observation was completed, the document was read repeatedly, jotting down additional comments and correlating the notes and events to the interview findings, trying

to create aggregated topics (Creswell, 2013). It was an emphasis on this analysis to understand the research findings more clearly and to classify them in important findings. Towards the end of the analysis, the findings were merged into broader categorisations that is the four observational findings. The data was obtained and analysed by one single observer, ensuring greater consistency on the findings (Creswell, 2013).

3.4 Reflections

This thesis presented new challenges for the author. In particular, the lack of experience in writing a qualitative research thesis resulted in much time reading, consulting experts and fellow students, and contemplating on how to analyse and work with different sources of qualitative data. Through the development of the thesis, there has been a steep learning curve on how to do interviews and observations in among others, an unobtrusive and unbiased matter. Furthermore, coming from a background that focused on quantitative research, doing qualitative research presented, in fact, a higher complexity for the author. The subjective judgement and analysis of responses and observations are a complex endeavour that simultaneously makes it challenging to repeat (Bryman and Bell, 2015). The background of the author might suggest that in the interpretation of the data, more emphasis was on elements that corresponds with the overwhelming views and/or evidence found in the literature review. Thus, perhaps not enough focus was on contrary views. However, the author focused on the holistic picture of the findings, and multiple perspectives were discussed as well as trying to identify the factors involved and that can be involved.

3.4.1 Interviews

The interview process, which lasted approximately two months, consisted of a sharp learning curve in the beginning in regard to how the infrastructure process was. This steady increase in knowledge resulted in deeper understanding of the findings. Because of this learning curve, certain questions and/or elements of the questionnaire and the open-ended questions were easier to explain, as well as the relative answers were understood. After an initial test of the open-ended questions, slight adjustment was made for clarity.

Although performing a semi-structured interview seems technically easy, the process of coding and interpreting the result correctly can sometimes be a complex and time-consuming process, particularly so if the interviewer is a novice within scientific researches. In fact, Bryman and Bell (2015) outlines several obstacles that could occur during these type of approaches:

misunderstandings, intrusion of own biases and expectations, wrongly recorded data and/or other unexpected behavioural or environmental problems. This made it even more important to be focused and prepared for each interview, and ensure that the questions and the interviewer's follow-up questions did not limit the answers or create a bias.

The interview process was not audio recorded because of experienced limitations of recording over the phone (unstable, low volume, static), and moreover, face-to-face interviews was difficult because of fragmented and geographically spread interview objects. In addition, it was not deemed necessary to audio record because the semi-structured interview approach allowed for follow-up questions that ensured the notes taken from the interviewee were accurate. The problem with this method however, is to accurately reflect tone and/or underlying meaning with the answers.

The questionnaire part of the interview

The interviews consisted of having to talk with project managers about facts that they have high expertise in. This presented a challenge at the first few interviews because of the interviewer's undetailed knowledge about how processes, work-phases and hearing-processes work in the transport/infrastructure (public) industry. Although the author was aware in crude terms how the industry works, there were intricacies and special circumstances with certain phases that resulted in misunderstood data at the start. Particularly how the different parties concept of the planning phase is; which is by some interview objects considered as the whole process including the political hearing-process, and by others as only the delivery of the plan for the hearing. Moreover, in the interview process, some of the questions seemed out of place or diffuse depending on the project phase, it was quickly understood that some of the questions were not applicable or less relevant when the project was in a too early state. In addition, a few of the questions of the questionnaire were hard to answer by the interviewees because of the detail of information of which it entailed (questions like exact time of planned planning phase, cost, meetings etc.). A few questions evolved into the interviewer explaining the context up front and make sure that the interviewee understood exactly what the question was related too. This was important in order to not get skewed data. This and other intricacies made it necessary for the interviewer to evolve as to how to present and explain the questions, what to present and how to code it for the purpose of the thesis. Specifically, things like variation in naming (different companies had different names for the project phases, some had split the phases, some had combined), and also understanding how and in what form some data was given seemed important.

The open-ended question part of the interview

Because of the amount of pre-research done on CE, the interviewer already had a good understanding of the concept, potential effects and the potential problems with the method. Because of this, the open-ended questions and the follow-up questions proceeded efficiently, and the most important areas of concern was specifically context in relation to the infrastructure projects. The interviewer was aware that biases could be a problem, which is why an emphasis on the execution of the interview was to keep any follow-up questions as neutral as possible. However, the interviews were informal in nature, and questions and the sequence of them varied from interview to interview.

3.4.2 The CE session

The observation of the session presented a situation that was entirely new to the observer. Because of the scope and time of this thesis, the experience was depending on the observer to gather valuable data without having the possibility to test or pilot the observation. The attempt to prepare for the observation by gathering important elements of a CE session consisted of the author's accumulated knowledge of the subject through the literature review as well as the interview findings.

The observation itself proceeded without major complications; however, a few instances occurred in rapid succession, causing loss of small details. Observing so many people was a challenge, specifically, to manage to write down important events without losing other occurrences, hear important dialogues and rewrite them or explain them properly, and notice background events occurring. Background events are things of seemingly small importance like for example: events that are not addressed to all of the team, or experiences of individuals (such as low participation). Furthermore, as the session progressed, a greater understanding of a few elements such as, how they made decisions and who was missing/present became clearer. Because of this confusion in the start, it seems important to prepare for such an observation by establishing contextual detail beforehand, which was done in this instance during and after the observation.

3.5 Limitations

Because of the scope of this thesis, the findings should be considered from the perspective of the context it was presented. Information like work area, organizational and decision-making

structure, unknown or various degree of integration and, unknown level of experienced or non-experienced team members present, are but a few of the factors that could affect the outcome in various unknown ways. In fact, contextual elements in social studies are one of the reasons for the complication of repeating to confirm or substantiate other researchers findings (Bryman and Bell, 2015).

Although some of the methods used to find a viewpoint in this research can be investigated more thoroughly and present perhaps different interpretations, it is believed that the analysed results and the conclusions are accurate and helpful as a next step in understanding more in-depth the possibility and effects of utilizing a concurrent work method. In addition, the discussion offers some insight that can be valuable for further research.

3.5.1 The literature review

The literature review consists of no previous literature on the subject of CE in specifically the infrastructure sector. It has become clear that this part of the construction industry has some important distinctions from other sectors, such as the governmental hearing processes. Because of this, there is a possibility that some of the benefits and obstacles that have been identified in the literature review show less or more significance in this particular context. Moreover, because of this it is possible to expand the theoretical review to consider this aspect more. In addition, the theory can, perhaps positively be expanded to consider more aspects and moreover be investigated more thoroughly in regard to previous experiences and lessons learned of the method.

3.5.2 Interviews

The interview process and the findings are subject to biased and/or culturally accepted answers even when the questions are open-ended (Bryman and Bell, 2015). Problems such as the frame/reasoning for the interview, the logical steps/direction in the questions, and/or unintentional tone of the interviewer can affect the answers (Bryman and Bell, 2015, Creswell, 2013). Moreover, because the interview process was conducted over the telephone, it was not possible to engage in observation. For example, signs of unease or puzzlements on the faces of the interview objects when asked a question was not possible (Bryman and Bell, 2015).

In relation to the research questions, interviewing other project participators (not just the client and the consultants) could enhance the understanding of the effects of an integrated concurrent

session; however, it could also increase the complexity of the overall research process. Moreover, the Norwegian context limits the generalization of the findings, which could be solved by doing cross-cultural studies and interviews. Furthermore, the interview objects were not experts in the field of concurrent engineering, but they had experience with it. Finally, the interview findings in regard to traditional project method in "other findings" can and should be further investigated to elaborate on the reasoning, and moreover, should be further researched before any assumption on the matter can be generalized.

3.5.3 The concurrent session

The observational findings of the concurrent session can, in any qualitative study be open for different interpretations. In fact, findings from observational studies have many common problems concerning reliability, validity, and generalizability (Bryman and Bell, 2015). For instance, things might be perceived and/or wrongly/differently interpreted, and factors and behaviours might be lost in translation or not witnessed. Even though there are many best practices from different researchers regarding the utilization of concurrent engineering (or concurrent sessions), because of the scope and time of this thesis, these questions, factors and contexts that most certainly can affect a concurrent session, was only looked at from a discussion perspective. In addition, because this was a qualitative study, a limited number of data was available to consider generalizable importance of certain factors or context. Moreover, the observation study only consisted of one observation, which is very limited data to generalize findings from. Furthermore, the participants in the observation study can behave differently when observed, invalidating the data obtained, which normally can be solved by observing several similar situations (called the observer effect) (Bryman and Bell, 2015). Because of the limitations on the possibility to observe CE sessions in progress, and the time of the delivery of the thesis, this was not possible. Finally, observing and noting everything that occurred was impossible given the amount of participants and the number of actions (Bryman and Bell, 2015). This can also be addressed by increasing the amount of observations done (Bryman and Bell, 2015).

4 Findings and analysis

The findings of this research were found through interviews and one observed concurrent session. First, the interview findings, then the observation findings are presented and analysed. The interview findings and the observation findings are both presented according to their significance to the research questions. The research questions are:

1. What are the effects of utilizing an integrated concurrent team as per the concurrent engineering method in comparison to more traditionally ran projects, in the context of infrastructure projects?
2. What are the potential obstacles (contributing factors) for such a team to work (or not work)?

The summary of the categorised major findings can be viewed in Table 4 below:

Table 4: Summary of the major findings from the interviews and the observation.

Summary of the major findings			
	Research question 1	**Research question 2**	**Other findings**
Interviews	1. Faster process 2. Better collaboration and communication 3. Increased complexity	4. Integrating the external parties 5. Lack of autonomy 6. Lack of preparation and practice	7. Traditional project method: (1) client is happy, (2) good collaboration, (3) Delays
Observation	8. High collaboration; eagerness and involvement 9. Increased knowledge of the overall project	10. Integration problems 11. Coordination in large projects	

4.1 Interview findings

The findings from the interviews are categorised into *Interview findings RQ 1* (RQ: Research Question), *Interview findings RQ 2*, and *Other findings.* The purpose of the interview findings was two-parts; gather general work information about traditional project methods and to research effects and obstacles surrounding CE sessions. The results categorised and analysed

according to the research questions comes exclusively from the interviewees that have experience with the CE method.

4.1.1 Interview findings RQ 1:

This chapter contains findings that was perceived to have significance for research question 1. The first research question was:

> *What are the effects of utilizing an integrated concurrent team as per the concurrent engineering method in comparison to more traditionally ran projects, in the context of infrastructure projects?*

Finding 1. Faster process

Finding 1 demonstrates that because of the improved integration between project stakeholders and the overall increase in knowledge on all project phases, the (particularly external) key decision makers are now more aware of the project technicalities and thus, decision and approvals can be taken sooner and a faster process can transpire.

> According to the interviewees, because of the integration and the focus on all project phases, greater understanding is available for the tasks and more information is handed out face-to-face, which facilitates easier processing of said information. Interviewees largely believed in the method of a CE session, where they generally expressed positivity towards the method. A few of the interviewees stated that a common ownership on decision-making occurs, and because of the increase in collaboration and communication, participants were more involved, quality- and problem-aware. The fact that the external stakeholders would be more informed of the development of the plans/suggestions facilitated that a faster process could transpire, specifically within governmental hearing processes. One interviewee did in fact experience a faster hearing process (plan approval) because of the integration of the external stakeholder. One interview object specifically mentioned his disbelief that the CE session would expedite the plan process (up to the delivery for the hearing processes at governmental entities). The same interviewee believed that potential benefits lied mostly with increased quality of the plan, thus benefits towards a ‘faster process’ would only be noticeable from the later phases through a better building phase.

The literature on concurrent engineering advocates among others that the method will represent possibilities to speed up the overall project development (Valle and Vázquez-Bustelo, 2009, Anumba and Kamara, 2012). The way this is conceived is through early involvement of stakeholders of the project for a more accurate and quality-perceived plan and to construct a concurrent work-plan (Evbuomwan and Anumba, 1998). Although the CE literature substantiates that time-to-market can be reduced, it is mostly related to the later phases of a project, and does not agree that the planning phase can be expedited (Anumba and Kamara, 2012, Nicholas, 1994, Constable, 1994). In fact, by involving the major stakeholders, it is easier to assess and consider the project development's life cycle, but it will more likely increase the complexity of managing the concurrency as more factors are in play (Park, 2001, Nicholas, 1994), thus perhaps increasing the time needed for planning (Constable, 1994). In fact, what might be more likely is that by involving the stakeholders early on, decisions were taken at the right time, thus a concurrency between the hearing process (approval of plan in governmental hearings) and the plan development occurred. In fact, the CE literature does advocate that the involvement and integration ensure decisions are taken at the right time (Anumba and Kamara, 2012, Evbuomwan and Anumba, 1998, Zidane et al., 2015b), and furthermore, strengthen the information exchange across the stages in the project delivery process (Anumba and Kamara, 2012, Koufteros et al., 2001). This concurrency between stages ensure greater accuracy and understanding, thus a reduction on time-to-market can occur (Anumba and Kamara, 2012).

Finding 2. Better collaboration and communication

The majority of the interviewees believed that the CE method has potential, and that they saw an increase in collaboration and communication between the project team members in the CE session. In addition, this could bring about benefits in the form of more quality- and problem-aware team and better cross-discipline coordination between each other.

> Several interviewees stated that potential problems were detected earlier and an increased consideration of the other team members occurred, creating a more quality- and problem-aware environment. Moreover, the interviewees believed that planning and construction comes closer together and, as previously mentioned, a shared ownership feeling occurring. Several interviewees stated that the transfer of information was both easier and better because of the integration. In fact, a few interviewees said that this type of integrative session creates a better cross-discipline coordination. One interview object

however, mentioned that he did not believe the method would be an improvement as long as the project team members were experienced and experts in their fields.

The collaborative work-method of the CE session and the involvement of the whole life cycle of the project ensures increased considerations of different phases and increased knowledge of the projects phases (Constable, 1994, Evbuomwan and Anumba, 1998, Anumba and Kamara, 2012, Winner et al., 1988). Integration positively affects performance, and in this finding, an information rich environment occurs through integration and, consequently increasing problem- and quality-awareness of the team (Baiden and Price, 2011, Valle and Vázquez-Bustelo, 2009, Koufteros et al., 2001). In fact, these are outcomes that are substantiated by most CE literature, and the quality of the product is one of the major positive effects from the CE method and the CE team (Koufteros et al., 2001, Anumba and Kamara, 2012). Furthermore, Tauriainen et al. (2016) found that the use of a "Big Room", as per such a CE session, is the most applicable tool for handling communication, response-time, redesign and collaboration problems. In fact, working in an environment like a "Big Room", the CE team achieves greater level of collaboration (Jones, 2014, Tauriainen et al., 2016). The reasoning for one respondent to not believe in the method could be because of many factors: badly prepared, misunderstood approach or misunderstood purpose of the method, wrongly executed, and so on. However, perhaps the method does not reach the desired outcome in the infrastructure sector, or perhaps it will not before changes are made. After all, changes within organizational boundaries are advocated as an approach to optimizing the CE method overall in the construction industry (Anumba et al., 2002, Zidane et al., 2015b).

Finding 3. Increased complexity

Finding 3 demonstrates the interviewees opinions on the complexity in running a CE session. Specifically mentioned were elements like coordinating all the various disciplines (particularly on agreeing towards decisions) and the development of the concurrent plan.

> The interviewees experienced that it was generally complex to coordinate work between so many disciplines. One interviewee stated that it was difficult to try to coordinate the different disciplines focus of technical aspects and the overall focus of quality and collaboration between them as a project leader. Furthermore, the interviewees outlined complications of getting everyone to understand and agree on the decisions during a CE session. In fact, a few of the interviewees suggested that roles, structure and proper decision rules should be introduced for handling all the disciplines appropriately.

Related to this complication, was the challenges with the parallelization of work. Specifically, how to accommodate changes to the planned concurrency of work when problems were detected or changes were wanted. The iterations of development on the concurrent plan (before finalization), is a complex endeavour according to a few interviewees. One interviewee experienced a great challenge in this when the entrepreneurs wanted something changed and the plan had to be altered extensively because of repercussions on earlier tasks in the project.

The integration necessary for a collaborative CE session involves a large number of different disciplines. Because of this, an increase in complexity would occur, particularly within integrating the project stakeholders and the development of the concurrent work plan (Park, 2001, Shouke et al., 2010, Zidane et al., 2015b, Anumba et al., 2002). Interestingly, the element of increased complexity in coordinating work contradicts what a few other interview objects stated in finding 2 (regarding better cross-discipline coordination).

Considering this finding is from early efforts of working in an integrative CE team, start-up difficulties could be more prevalent. Elements such as personal features, status, and tenure and activity level are issues that can effect a group coming together, even beyond start-up if not considered (Nicholas, 1994). Or perhaps, as substantiated by Shelbourn et al. (2007), there are issues with the combination of three different strategies, information and communication technology, business and people. However, this finding does show relevance according to the CE literature (Anumba and Kamara, 2012, Park, 2001, Shouke et al., 2010, Nicholas, 1994), with one deviation being that the coordination difficulty seemed to not be related to the traditional and adversarial relationship, which is a common blame in the construction industry (Morris, 2007, Anumba and Kamara, 2012). The fact of the finding is that it is generally complicated to work with many different disciplines, in particular towards agreeing on solutions and developing the concurrent execution plan. In fact, according to Nicholas (1994) the CE team and its high diversity of participants and disciplines facilitates faster information-gathering and can create stimulating discussion, but it does make decision agreements more complicated. Furthermore, the project leader's struggles with the coordination and teamwork is according to Nicholas (1994) one of the obstacles to effective teamwork, further substantiating the finding.

4.1.2 Interview findings RQ 2:

The following findings from the interviews were identified as a significance to research question 2. The second research question was:

> *What are the potential obstacles (contributing factors) for such a team to work* (or not work)*?*

Finding 4. Integrating the external parties

A popular topic among the interviewees was the integration challenge in these types of infrastructure projects. Particularly, involving the municipalities, the external parties, were of great concern. The finding also demonstrates that most of the interview objects concluded that changes should be implemented for the CE session to function optimally.

> One of the interviewees referred to the challenge of involving the municipalities. In fact, efforts of this has been done previously where the outcome was positive, but generally the municipalities were unwilling to take decisions during the sessions, causing less time saved as potentially possible. Another interview object said that there might have to be changes to internal processes (with governmental entities) and contracts for successful integration and better work/decision collaboration. According to one interviewee, internal organization causes some disruption on work and decisions are fragmented. In addition, the interviewees particularly saw difficulties involving external parties and the selection and decision making in the municipalities. In fact, overall, either the interviewees said that changes had to be made, or proper integration would be highly difficult to fully achieve.

The construction industry is, despite implementing CE and various collaboration tools like BIM, struggling with proper integration between the different stakeholders (Zidane et al., 2015b, Anumba and Kamara, 2012, Anumba et al., 2002). Integrating the project stakeholders seems to be no easy process in the construction industry. In fact, several researchers have identified that the involvement of the fragmented stakeholders are among the major obstacles to the CE method (Zidane et al., 2015b, Anumba et al., 2002).

For the CE team and the CE method to function properly, integration of the relevant project participants is necessary (Anumba et al., 2002). Being one of the key elements of CE, integrating project team members and decision-makers is important for keeping a focus on the

whole life-cycle of the project during the development of the plan (Anumba and Kamara, 2012, Evbuomwan and Anumba, 1998, Anumba et al., 2002). Furthermore, there have been contributions regarding general disablers of integration. Some of which are considered the contracting and procurement practices (Morris, 2007, Baiden et al., 2006). Moreover, because of the rather unique disposition of having to await public hearings, involving certain parties that have decision-power might be very difficult to reinforce. In fact, these municipalities (and other public decision makers) might have various degree of available resources and capabilities, which further complicates the integration (Eik-Andresen et al., 2016). More so perhaps, than other sectors of construction, where resources are less likely a problem. In fact, according to the findings of Eik-Andresen et al. (2016), the public sector struggles more with administration, bureaucracy and a lack of resources.

Some evidence related to integration problems in CE teams are thought to be linked to organizational issues, and thus the organizations are suggested to change their organizational structure in order to optimize the CE method (Zidane et al., 2015b, Anumba et al., 2002, Ainscough et al., 2003, Park, 2001). An interesting finding by Anumba et al. (2002) was that the organizations were unwilling or did not believe that an organizational restructuring could be a way to overcome the problems. However, this was not a finding in this thesis.

Despite that the project leaders seemed aware of the obstacles of CE, there might be different attitudes and understanding from the top management. In fact, as mentioned by several researchers, changes need to be at or approved by the top level of management for changes to have the proper impact, and not be temporary or half-supported solutions, especially regarding integrating organizations (Thamhain, 2007, Nicholas, 1994, Anumba and Kamara, 2012).

Finding 5. Lack of autonomy

The lack of autonomy was in one way or another expressed during the majority of the interviews. In particular, concerns on the efficiency of the method was demonstrated through examples of decision-making.

> According to the majority of interviewees, a high degree of decision-making power needs to be present for the integrative CE session. Some interview-objects referred to problems with less experienced team member's unwillingness and/or lack of decision-making. Furthermore, the interviewees mentioned issues with having to check with other parties before making decisions, and if that would occur it would slow down the

process. Some interviewees advocated the necessity for high expertise in the concurrent session so that people were more confident on taking action and making decisions. Another interview object claimed the importance of determining who has the decision roles.

Having the necessary autonomy to make decisions at the right time and not be hindered by organizational boundaries on decision-making is important for the optimized utilization of the CE team (Anumba et al., 2002, Zidane et al., 2015b, Nicholas, 1994). Some of these findings can be related to having unclear roles. In fact, having clear and unambiguous roles and determining decision-making are two factors among others that are advocated as ways to overcome obstacles to teamwork and integrative efforts (Nicholas, 1994, Buvik and Rolfsen, 2015, Erdogan et al., 2008, Anumba and Kamara, 2012). In particular, having to clear decisions through other parties is detrimental to the collaboration and integrative efforts within a CE session and a CE team (Nicholas, 1994). Inexperienced team member's unwillingness to and/or lack of decision making can be related to improper training and preparation to fulfil the roles they were given, but also, as mentioned, be because of a lack of autonomy (Anumba and Kamara, 2012, Nicholas, 1994).

Finding 6. Lack of preparation and practice

Finding 6 demonstrates the interviewees belief that proper training and preparations are necessary to have the best outcome from a CE session.

> Being able to handle decisions (as mentioned in finding 5), having clear roles and knowledge of work are of high importance for a successful CE session according to several interviewees. In addition, preparing and having experience with the method facilitates these elements according to several of the interview-objects. In fact, most of the interview-objects referred to the need to practice and learn how to do it properly for the method to see best potential. One interviewee advocated that a proper decision structure should be prepared for each session. Specifically, creating alternative solutions before the session so that the session can function more as a decision platform (e.g. choose between two alternatives).

Having clear roles and to train the team members to fulfil their role in the CE team is advocated by several researchers (Nicholas, 1994, Anumba and Kamara, 2012, Buvik and Rolfsen, 2015). This finding could be a contributing factor to the unwillingness to take decisions mentioned in finding 5. Furthermore, the lack of preparation and practice with the method roughly translates

to insecurities, which could influence team member's willingness to, among others, take decisions, but also work efficiently. Furthermore, as outlined by several researchers, preparation, in the form of proper training, determining roles and responsibilities, clarification of team purpose, and deciding on participation level and so on, to name a few, are enablers of an effective CE team (Nicholas, 1994, Anumba and Kamara, 2012).

4.1.3 Other findings

These findings include the respondents that did not participate in the questions regarding CE sessions.

Finding 7. Traditional project method: (1) client is happy, (2) good collaboration, (3) Delays

The following findings were included for its value towards the discussion on the research questions and gives insight into traditional methods in infrastructure projects.

(1) Client is happy

Most of the clients reported that they were happy with the project phases.

> Clients were pleased in 13 out of 15 of the project phases (reported an average of 8/10 on a satisfaction scale).

Considering that the industry is well practiced in contract administration, cost control and value management (Morris, 2007), perhaps this creates an understanding towards the work and the limitations, and thus the clients are pleased relative to these elements. Moreover, as per the frame of the questions, perhaps the clients misinterpreted the meaning of the question and connected it to the contract with the consultants.

(2) Good collaboration

Close to none of the interview-objects expressed having problems with - or having concerns regarding collaboration of work.

> A few interviewees mentioned that there could be improvements but considering the context of the project, the collaboration between project participants was satisfactory. In addition, some of the same interviewees stated that they did not know how it could

have been better. One interviewee explained that problems with decision-making and discussions/arguments were solved thanks to the client being highly knowledgeable.

This finding could be connected to the previous finding of the clients reported being pleased with the project phases. After all, because of the fragmented project members, contracting, terms and conditions exert a major influence on how to collaborate (Morris, 2007). Therefore, results that mostly speak to a good collaboration could be related to the boundaries of the contracts.

3) Delays

From the interviews, it emerged that the planning process was generally delayed because of the dependency on a hearing process and approval from the external parties, which often took extra time and/or extra work.

> Several interviewees expressed the concern of waiting on decisions. In addition, it was mentioned to the interviewer on several occasions that the plan was delivered according to schedule but was worked with after delivery. One project manager explained that months could go before something happens (regarding waiting for the governmental hearing process). Another claimed that it took a year before a decision was taken. Various causes were thought to be the reason by the interviewees, such as, slow process and/or procedures and not enough resources available.

The construction industry today is characterized by being highly fragmented and traditional in its principles. Because of this, an adversarial environment persists and limitations on integration between project members occur (Morris, 2007, Baiden et al., 2006, Anumba and Kamara, 2012). This fragmentation seems to be the major issues regarding delays. After all, the fragmented project process is seen as one of the major obstacles for enhancing project efficiency (Anumba and Kamara, 2012, Anumba et al., 2002, Zidane et al., 2015b). In fact, early stakeholder influence and endorsement of project plans are one of the "soft" skills attributed towards delivering the project in time and at cost (Andersen et al., 2006). Moreover, according to Eik-Andresen et al. (2016), better management in the form of improving up-front planning, procedures and project structure, are where the most problem solving lies in regard to reducing delays.

4.2 Observation findings:

The observation of the concurrent session was a valuable experience. It presented an opportunity to see what effects and/or obstacles that are present in an early effort of adopting the method. Moreover, the emerged findings herein can be compared and evaluated according to the interview findings and the literature, providing an enhanced framework for the research questions.

The general elements that were thought of as important towards understanding the context of the CE session and thus for the benefit of the research questions, were noted when and if observed and is listed below:

1. Number of participants

   19 members, split into 10 and 9 when working.
2. Structure (work, group, communication, decision)

   Work: Split into predetermined work tasks (Discussion ensued, actual work was generally not done but agreed upon actions were determined and written down).

   Group: split into two group with relevant disciplines for the task.

   Communication: Seemed mostly fluid and open.

   Decision: actions put into action lists that were discussed in plenary.
3. Type of tools available

   BIM, Computers (if the participants brought themselves, which they were encouraged to do), Screens for visualization, Shared action list program.
4. Planning/plan

   Schedule for the day at the start of the session. Tasks and sub-tasks were presented. Presentation at the start of the day, motivational speech with tips and tricks.
5. Autonomy

   Responsibilities was crudely understood in the start. Decisions were taken, but a few matters had to be cleared through external contact.
6. Integration of participants (external stakeholders, disciplines etc.)

   Not all relevant stakeholders were participating in the session. Disciplines were largely present but external parties (political) were not there.
7. Roles

   An introductory round was at the start of the session. Roles seemed slightly obscure; a

few participants were much more vocal than others were. Responsibilities towards the action list was given before the session concluded.

Overall observed and noted from the CE session was that the session seemed prepared, team members crudely understood their roles, autonomy seemed to be in place, most disciplines were accounted for, and there were collaborative tools such as BIM and other IT tools. These elements, the fact that purpose and goal of the day was set, and that work groups were relatively small are all enablers of a collaborative and effective CE teamwork (Nicholas, 1994, Anumba and Kamara, 2012). With this in mind, specific observations and findings related to the research questions will now be presented.

Finding 8. High collaboration; eagerness and involvement

During the observation of the concurrent session, there was witnessed several elements of collaborative workings and eager cooperation between the project team members. The project participants were observed as active, eager and involved. In fact:

- Questions were prominent and answers accompanied them.
- Explanations were complemented by the usage of visual aids (3D model), often consisted of hand-gestures and the person explaining physically pointing to the different areas of interest.
- Discussions were not aggressive, no raised voice or attempt to talk over and suppress other individuals.
- General high attention level and interest for the subject.
- Back-and-forth discussion towards agreement.

The integrative CE session create a stimulating environment for discussion (Nicholas, 1994). There was an inclusion of information and communication technology for the work, which stimulates integration and collaboration (Wikforss and Löfgren, 2007, Shelbourn et al., 2007, Anumba and Kamara, 2012). Furthermore, the usage of the CE room (or the "Big Room") facilitates collaboration and communication (Tauriainen et al., 2016). In addition, as mentioned in finding 2, the observer witnessed that people were considerate to each other, and by being involved and active, they showed interest towards the other disciplines. This observational finding is therefore connected to an increase in collaboration in comparison to traditional project methods. Thus, the finding can substantiate finding 2, and vice versa, and is answering to research question 1.

Finding 9. Increased understanding of the overall project

This finding demonstrates that the team members understood other disciplines more clearly, and thus a better understanding of the other parts of the process ensued. The cross-discipline interaction seemed to bring about technical questions specifically with regard to relating elements.

> Because of the cross-disciplinary collaboration, an increase in understanding occurs, specifically what impact, or certain technical aspects, different solutions or actions would cause. Observed several occasions of questions being asked about some potential issues or calculations, where the question was rather quickly answered. Example of this: An event regarding the roads guardrails involved various disciplines and experts in a stimulating discussion where certain ideas were in unison, and others were discontinued because of implications. If discussions were too long or actions could not be decided at that point, they were written down in the action list for follow-up work after the completion of the session.

As stated by Nicholas (1994), the different disciplines coming together creates stimulating discussions, but decision agreement might be more challenging. Both of which was observed occurring in this finding. In fact, the increased collaboration and the stimulating discussions from the integrated environment facilitates creative solutions and more accurate and informed decision-making (Nicholas, 1994, Anumba and Kamara, 2012, Shelbourn et al., 2007). The observations here correlate with the interview findings, where decisions might be more challenging, but project team members are more considerate and know/understand more of the project. This finding is connected to research question 1.

Finding 10. Integration problems

This observation finding exemplifies issues that can be related to a lack of integration.

> The observed session initially begun without seemingly any integration-issues, and decisions and tasks were promptly created/made. However, there were a few instances where either the client (or other decision-makers) and other disciplines (that were not present) had to be questioned before any decision could go forward. In addition to this,

> a fully and integrated team was not present during the session, specifically the municipalities and other political decision-makers were not there.

These instances of decision making that required follow-up to other parties and/or the clients demonstrates clearly the loss of efficiency in the CE team. Worst case under such circumstances is if the decision is paramount for the completion of tasks currently planned for the session. This would be a loss of voices that potentially could have an impact on certain areas/phases. In fact, missing relevant parts of the project life cycle is a disabler for the CE method (Evbuomwan and Anumba, 1998, Anumba et al., 2002, Zidane et al., 2015b). Furthermore, this observation adds to the demonstrated interview findings regarding the difficulty of integrating the external parties.

Finding 11. Coordination in large projects

This finding is related to observed complications of coordination. An open and unstructured conversations was observed (barring thematic/problem), and the room size seemed to already have reached its capabilities.

> The observed session had 19 participants, which almost maxed out the room's capabilities. In addition, there was a lack of certain disciplines as well as some external/political decision-makers. The structure of, and the coordination present, suggest that having all stakeholders in the same room might cause problems. In addition to this, there was not observed any structure in communication (other than thematic overall problem) and it was mostly fluid and loose towards the problem statements. This approach seemed to work quite well in this circumstance however. Moreover, there were one instance during the group work (when the CE team was split into two groups) that something had to be confirmed by one team member on the other group.

The finding entails the importance of the environment and context during a session as well as the structure of said session. There seem to be some relative problems related to the size of the room and the number of participants. In this particular session, it emerged that some stakeholders, particularly political ones were not present. However, the total number of participants was as high as nineteen. Because of the room's capabilities, adding more team members would probably create coordination difficulties, which would add to *finding 3* and the coordination difficulties that was perceived by the project leaders. Despite this, the CE teamwork proceeded efficiently, perhaps because of the division into groups of two. In fact, according to Nicholas (1994) teamwork is enhanced by a small team size and a group of 8-12

members should cover most disciplines, which seemed to be true for this observed session barring one specific instance (where one team member had to approach the other group for some answers). Whether or not this specific instance was an obstruction of the task was not clear. However, it seems natural that a CE team split in such a way could end up having one specific expert or veteran, and arguably, it is even advocating the importance of having the right stakeholders/disciplines at the CE session. In fact, this further substantiates *finding 2. Better collaboration and communication* as well as the CE literature on having an information rich environment and the benefits thereof (Koufteros et al., 2001, Anumba and Kamara, 2012).

Moreover, the scope of the work and the number of stakeholders are high in these types of infrastructure projects. Which roughly translates into, the larger the project, the more effort lies with the collaboration and coordination, specifically because of the number of stakeholders and/or number of disciplines. This could theoretically support *finding 3. Increased complexity.* The challenge to plan the parallelization of work is not only affected by the number of team members, but also, it is arguably interrelated to the general challenge of coordination and collaborating on a complex and large project. In fact, the planning of the concurrent execution of different work phases is a common viewpoint of utilization issues with CE (Park, 2001, Shouke et al., 2010). The increased complexity through number of participants, the considerations on communication structure and the room capabilities, as well as the problems with decision making that comes from this diversity, are a few of the challenges with a CE team (Nicholas, 1994, Constable, 1994, Anumba and Kamara, 2012), which is why this finding is connected to research question 2.

Categorised observation findings

- *Finding 8. High collaboration; eagerness and involvement* are positive effects observed in the CE session and is therefore related to **research question 1**.
- *Finding 9. Increased knowledge of the overall project* is a positive effect connected strongly by the eagerness and involvement observed in finding 8. This finding is a positive effect related to **research question 1**.
- *Finding 10. Integration problems* are factors that might contribute to the effects of a CE session, thus it is related to **research question 2**.
- *Finding 11. Coordination in large projects* is a possible contributor to problems with the CE session and can be categorised into **research question 2**.

A summary of the relations the observational findings have to the research question can be seen in Table 5.

Table 5: The analysed observation findings according to the research questions.

The observation findings and their relation towards the research questions			
	Research question 1	**Research question 2**	**Other findings**
Observation	8. High collaboration; eagerness and involvement 9. Increased knowledge of the overall project	10. Integration problems 11. Coordination in large projects	

5 Discussion

Up until now, it has been established that the construction industry, which is supposed to work collaboratively between many various professional teams, is not doing this at an adequate competitive level. In fact, according to Fulford and Standing (2014), excessive fragmentation, disparate project managements processes and non-standardised information are hindering the potential efficiency of the industry. The literature review identified these characteristics and at the same time advocated for a higher integration as a step towards improving the industry's competitiveness (Anumba and Kamara, 2012, Shelbourn et al., 2007). The attempt towards this integration is the inclusion of the concurrent engineering method (Anumba and Kamara, 2012).

In order to see the effects and obstacles of the CE teamwork, certain major thematic aspects will be discussed that substantiate or show discordancy towards the CE method. This chapter will first go through the observation findings in order to correlate and discuss the findings and related elements more thoroughly. Next, the thematic subjects of, traditional project method, delays in the project and integration will be discussed according to the findings and the literature. Finally, a general discussion will cover the major outcomes from all the analysis and discussion.

5.1 The observation findings

Finding 8. High collaboration; eagerness and involvement is a result that can substantiate the reports from the interview *finding 2. Better collaboration and communication*. The observer witnessed almost exclusively a healthy atmosphere where the participants were active, eager and involved. It was not observed any large issues with the collaboration, other than the lack of a few stakeholders. *Finding 8* and *finding 9. Increased knowledge of the overall project* is interrelated and has significance as an advocator for the CE method. The integrative and collaborative environment has seemingly resulted in increased and better information gathering and, thus an environment where better decisions can be made is achieved. These two related findings show significance as positive outcomes of a CE method and has grounding in the literature as well as in the interview findings 1 and 2 (Anumba and Kamara, 2012, Prasad, 1996, Thamhain, 2007).

One interesting outcome of the observation findings was the lack of the presence of the coordination issues of work found in interview *finding 3. Increased complexity*. The reasons for this could be various, but are not limited to the following:

1. the observer was not aware, as a non-participant, that there were coordination problems between disciplines, or that the project leader failed/struggled to facilitate the coordination
2. the observer did not witness it directly,
3. the observer witnessed it but did not perceive it as noteworthy,
4. the sessions could have been more complicated by those interviewees that experienced an increase in complexity through coordinating work,
5. integration, context, environment, tools, preparation, etc. might have played a role that facilitated better coordination in this particular session.
6. The observer was biased towards the method being positive

The CE literature however support that achieving good collaboration might be challenging (Anumba and Kamara, 2012, Nicholas, 1994). Particularly, because of the increased complexity in concurrent planning and/or integration problems (Park, 2001, Anumba et al., 2002, Shouke et al., 2010, Zidane et al., 2015b). *Finding 10. Integration problems* and *finding 11. Coordination in large projects* further exacerbates these issues. Observation f*inding 10* demonstrates clearly what the literature and the interview findings states, in that decisions and problems have to be decided at a later point in time, thus less efficiency is achieved.

Although, integration problems might catalyse decision issues, arguably, what is important, is that there have been and is an ongoing integrated and collaborative understanding of the project's whole life cycle for the accuracy of the plan (Anumba and Kamara, 2012). Although the literature generally advocates a full-time, fully autonomous and co-located team (Thamhain, 2007, Nicholas, 1994), doing this in practice, particularly within the construction industry, seems with the current state an incredibly challenging task. If this is to be achieved, which will not necessarily be beneficial, large changes not just within the organization, but also by the supply chain and the client(s) to that organization would probably be necessary. The perhaps biggest reason against a fully integrated, co-located, full-time team is the loss of important resources to one particular project when there are other projects in development. Causing a company to, for instance having to either increase its resource pool or have fewer resources elsewhere, both of which might be negative for the company. Despite this, under some circumstances, on perhaps important and expensive projects, having a fully autonomous, co-located and full-time team should, and will according to the CE literature, result in a more efficient and accurate project plan (Anumba and Kamara, 2012, Thamhain, 2007, Prasad, 1996). Thus, reducing time-to-market, increasing quality and design, and reduce cost among others

(Evbuomwan and Anumba, 1998). In addition, the possible benefits could result in an overall positive and cost-effective use of resources if the project is large and important enough. Thus, these things need to be weighed accordingly.

5.2 The Traditional Project Method

The construction projects today are not necessarily considered unsuccessful. In fact, according to the *finding 7. (1) Client is happy* the client rates on average 8/10 pleased with the project phases. In fact, possibly related to these findings are the adoption of BIM on infrastructure projects, which has resulted in cost savings in reduced rework and change orders of up to 9% (Fanning et al., 2015). In fact, the utilization of BIM, which facilitates in the collaboration and integration between project team members, might be a contributor to the positive findings in *finding 7, (1) and (2)* (Bernstein and Jones, 2012, Merschbrock and Munkvold, 2015, Anumba and Kamara, 2012).

The findings related to traditional project method in the infrastructure sector are projects that have good collaboration and a generally very pleased client according to *Finding 7, (1) and (2).* Close to no interviewees expressed concern with the collaboration of teamwork, which is contradicting the general literature on problems within the construction industry (Eik-Andresen et al., 2016, Anumba and Kamara, 2012, Andersen et al., 2006). Either this finding is true or, it is a relative response to the limitations they perceive, and more importantly, accept. In fact, almost contradictive to this response is the fact that most interviewees' responses claimed that they achieved better collaboration and communication with the CE session. Perhaps the element of increased collaboration should have been more evaluated and/or defined for *finding 7, (1) and (2).* However, on the basis of in comparison to traditional project methods, the findings almost exclusively stated that an increase in collaboration occurred. Why however, that most of the interviewees simultaneously were happy with the collaboration in traditional projects should be more investigated.

5.3 Delays in the Project

Despite the happy client, delays are a problem that is encompassing most construction projects and thus, because of a longer planning and development time, cost or resources might increase. Interestingly, from *finding 7. (3),* the delays seem to be connected mostly to an extensive hearing process when the plan has been delivered to the external decision-makers. However, the finding did identify that very often, more work or other types of work would be continued

after delivery, but for the most part the consultants that developed the plan delivered what they were supposed to on time. Considering this occurs after delivery suggests that the external decision makers more often than not realize what extra work they want/need because of the information provided by the delivered plan. Theoretically, this seems like a significant advocator for integrating these decision-makers so that this work can be realized sooner. Also, within infrastructure/public projects, this substantiates *finding 1. Faster process.* However, the effects of increased complexity *(finding 3),* particularly in coordinating work and planning the parallelization might increase the overall process time, perhaps even offsetting the time saved with the concurrent decision-making. From the CE literature, these identified effects are notable because they further advocate effects that could be derived from a better planning process, like increased plan-quality and thus a reduction on the projects overall cost- and development-time (Anumba and Kamara, 2012, Park, 2001).

The literature review however, found some division on the reasons for delays. One research identified a need for better up-front planning and project – procedures and - structure (Eik-Andresen et al., 2016), another advocated a need for an organizational structure that emphasised project work (Arditi et al., 2017). In a way, one could argue that both findings have some truth. For example, the studies within concurrent engineering in the construction industry has identified several reasons for a non-optimal use of the method. Among a few of the more emphasized is the involvement of all the stakeholders early to capture the whole life cycle and changing their organizational boundaries so that an autonomous and collaborative environment prevails (Anumba and Kamara, 2012, Thamhain, 2007, Anumba et al., 2002). Interestingly, there seems to be great similarity between the research on remedies for delays in the construction industry and the identified "best-practices" on utilizing the concurrent engineering method. In fact, the early stakeholder influence and endorsement of the plans was found to be related to the managerial ability to deliver in time and at cost according to Andersen et al. (2006). However, this correlation might not be surprising, considering that, most studies advocate concurrent engineering as a way of overcoming the industry's inherent difficulties and, the method does claim to reduce cost and time-to-market (Evbuomwan and Anumba, 1998, Anumba and Kamara, 2012). From the perspective of the manufacturing industry, this is certainly true. The manufacturing industry enjoyed major reduction on development time using concurrent engineering and the multi-functional team was in fact, one of the major contributing factors for this (Prasad, 1996).

5.4 Integration

The utilization of the CE method in the construction industry is strongly advocated by the majority of researchers, and a large amount of, although mostly anecdotal, evidence have emerged from the use of CE (Anumba and Kamara, 2012, Park, 2001). Considering the literature on CE, and *finding 1* and *2*, an integrated concurrent team in the construction industry seems likely to bring about positive effects. However, as one notices from the manufacturing industry's development, these effects might vary considerably (Prasad, 1996). Perhaps because of various degrees of integration, various degree of autonomy and/or differences in complexity, environment/context and competence, which all seemed as possible contributors and factors according to both the literature and the findings (Anumba and Kamara, 2012, Nicholas, 1994). Nevertheless, what emerged from the findings suggests that CE sessions, thus the CE teamwork, will contribute in better collaboration and communication, which could bring about more quality- and problem-aware attitudes and possibly result in a faster overall process because of increased integration and understanding.

However, increased integration also seems to bring about a more complex way of working. A situation where more decision-makers and stakeholders get a say on the matter early on during a CE session has its benefits through increased accuracy and quality of plan (Anumba and Kamara, 2012), but also makes the plan in development more interactive, thus, challenges might arise. Challenges that, according to both the findings and the CE literature is particularly related to the planning of the concurrency of work (Park, 2001). Contrarily, perhaps the findings do not entail the challenges of increased complexity because of integration (as in larger involvement of stakeholders), but rather that challenges occur because of a lack of embracing the collaborative integrative environment necessary for the CE method as stated by Zidane et al. (2015b), thus missing the level of integration and collaboration needed. In fact, improving teamwork is according to several researchers catalysed by integration (Valle and Vázquez-Bustelo, 2009, Baiden and Price, 2011, Franz et al., 2017). A belief shared by the majority of the interviewees, who experienced an easier and better transfer of information, and additionally believed a better cross-discipline coordination occurred. Of course, perhaps the use of tools such as BIM and the concurrent working environment for the facilitation of collaboration aided in this perception (Tauriainen et al., 2016, Jones, 2014).

On the other side, studies by Baiden et al. (2006) found that regarding effective teamwork, fully integrated teams might not be necessary. However, the authors did state that perhaps one has to

overcome organizational boundaries in order to realize the benefits of full integration. In fact, in *finding 4* the interviewees promoted that changes were most likely necessary for the level of integration needed for optimization of the method. A sentiment shared by Zidane et al. (2015b) and Anumba et al. (2002), but in regard to optimizing CE. Specifically, the interviewees saw difficulties in involving the external parties, and a few even advocated that contracts and internal processes might have to change. A similar solution that the research of Baiden et al. (2006) found, who attributed procurement practices to not encouraging the integration of parties involved. In fact, contracting and terms and conditions exert a major influence on how to work together(Morris, 2007).

The level of awareness on integration problems the interviewees had in this thesis is an interesting misalignment with the findings of Anumba et al. (2002) who found that the organization showed an unwillingness and disbelief that such a restructuring could present improvements with the CE method in the construction industry. However, it is only natural to think opinions and knowledge changes over the years. Furthermore, despite some ambiguous understanding of the integration and the complexity of collaborative workings, the findings from Zidane et al. (2015b), which stated that the Norwegian construction industry's concurrent sessions proceeded more as hierarchical meetings rather than a collaborative work-environment was not found in this research. In fact, other than a lack of a fully integrated team during the observed CE session, the session did, in the eye of the observer, function collaboratively. Although, projects and organizations naturally create variations, it is curious that such a difference in findings would occur. However, the interest of CE has elevated in Norway, and much research and preparation have been done up to the point of this thesis, which might explain the variation.

On the topic of integration, considering the above-discussed subjects, it is arguably more beneficial for a project to be fully integrated when the project is young and insecurities are plenty. Arguably, at later phases and/or time in the project, although some elements might be dependent on certain stakeholders for optimal information gathering and processing, always being in a fully integrated position might be a waste of resources, even if the planning process would be slightly expedited. Despite this, it is imperative to have established an information base of the whole life cycle of the project through integrative efforts, if this is not considered, much of the major benefits of CE will get lost (Anumba and Kamara, 2012, Prasad, 1996, Thamhain, 2007). Thus, should some CE sessions not consist of the stakeholders necessary to consider the whole life cycle, then the tasks in the CE sessions should preferably be tasks that

will not affect later phases/those areas of lacking disciplines/decision makers. At least if the effectiveness of the method wants to be preserved. Considering that the empirical data are from early efforts of the CE method, these things could be more fully understood and optimizations could be found after some experimenting of the method.

5.5 General discussion

The effects of a concurrent session are rather difficult to generalize. Particularly considering the uniqueness of projects and the varying context and complexity of it (Shenhar and Dvir, 2007). However, despite the observed session and the interviewees' statements was from early execution of the method in the infrastructure sector, the method seems to bring about a higher understanding and a better collaboration of work. Through these effects, a higher quality plan with accurate concurrent work-phases should be the results. Thus, cost and time might be saved on the project development (Anumba and Kamara, 2012, Prasad, 1996). The effects of increased complexity could be because of this being early efforts of concurrent sessions, and could ultimately be resolved when the parties are more experienced with the method and (if) the proper adjustments have been executed for the benefit of the integration. However, it is natural to believe that increased complexity would occur when more people have to be reactively considered during the development of the plan, particularly with how changeable and interactive the execution of concurrency would have to be. Furthermore, a lack of autonomy, which was identified as obstacles with CE from the findings and the CE literature, could bring about several problems regarding efficient and collaborative teamwork (Nicholas, 1994, Anumba and Kamara, 2012). Related to this, what emerged from the findings was that decision-making would be problematic when inexperienced team members or people with lacking autonomy was present. Moreover, if this occurs, arguably, the collaborative environment fails and information and problems would not be solved in a cross-discipline integrative matter, but from a hierarchical point of view given with second-hand information. In fact, decisions could be taken without ample considerations of the whole life cycle, which then could result in delays of the development when this information reaches the rest of the team members and resulting in a back-and-forth exchange (Anumba and Kamara, 2012). Should such a situation occur, the process of handling information would increase and it would affect the overall collaboration from the integrated team members. It is clear from the findings that this is a subject of importance by the interviewees as well. Remedies in regard to a lack of autonomy and the issues that might occur from and to it were thought by the interview-objects to be changing internal

processes, contracts and the organizational structure. In addition, they advocated a need for, high expertise in the CE sessions, determining roles and, proper focused decision structure. Despite autonomy being of importance, the core of the CE session is still integrating the project stakeholders for increased knowledge of the whole project life cycle. Without the necessary integration for an informed CE team, proper decision-making has a risk of being false or less optimal and furthermore, would result in a slower overall process.

The analysed findings of this research contribute in the overall understanding of the specific CE session in the infrastructure process. In order to understand what was discussed, a concept model of the effects is depicted in Figure 7. The model, which serves an explanatory function, must not be confused with being fully generalizable or even complete. Meaning, it can be expanded upon. The model, which can be a starting point for further work and research, is the authors scrutinized findings of the research questions:

1. *What are the effects of utilizing an integrated concurrent team as per the concurrent engineering method in comparison to more traditionally ran projects, in the context of infrastructure projects?*
2. *What are the potential obstacles (contributing factors) for such a team to work in the context of infrastructure projects?*

The CE session consists of a cross-discipline environment where information and understanding of the whole life cycle of the project creates a more collaborative process that ensures greater detailing and a better plan for the work (Anumba and Kamara, 2012). It is also the platform where decisions can be made that increases the accuracy of the concurrent work. In fact, barring the development and execution of concurrent work, the model consists of two of the three key elements that embody the CE method, which is integration and the CE teamwork (The CE session) (Winner et al., 1988, Anumba et al., 2002). The model shows accuracy by being supported by the CE literature (Nicholas, 1994, Anumba and Kamara, 2012).

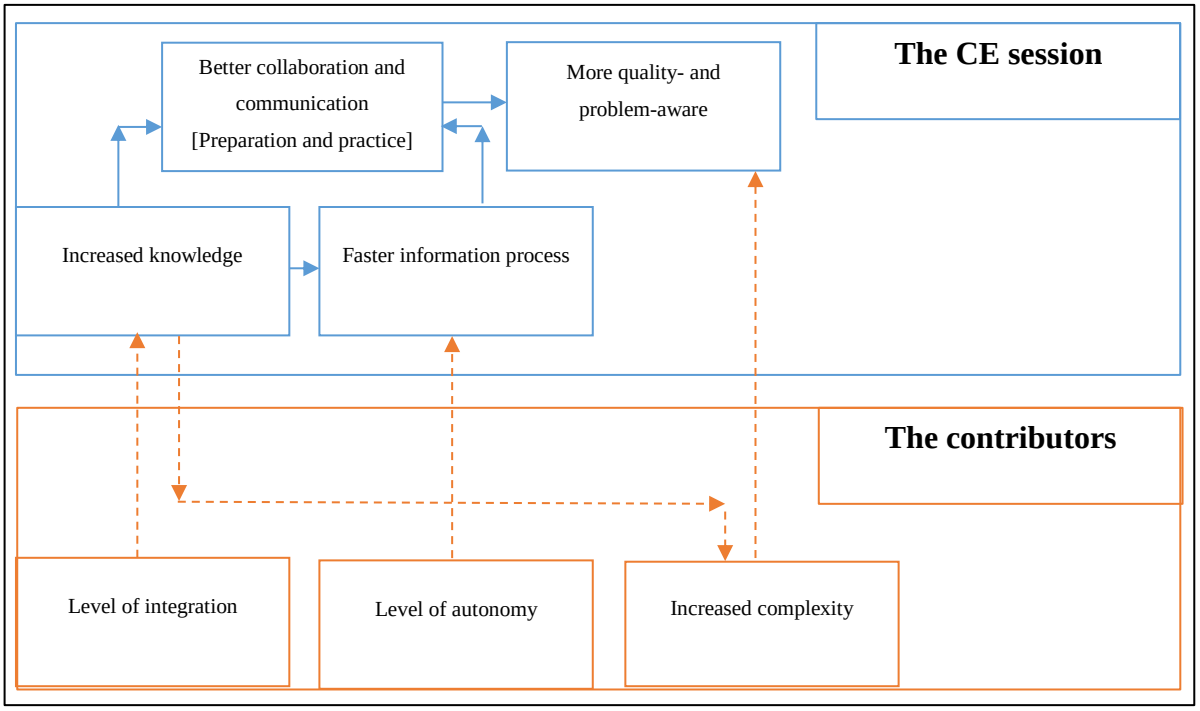

Figure 7: Explanatory model of analysed findings.

The model consists of the major effects that came out of a CE session according to the analysed findings. The model consists of two blocks, *the contributors* and *the CE session*. *The CE session* contains the findings from research question 1 split into fitting factors/elements for greater understanding. *The contributors* are largely research question 2, except for increased complexity, which is both a consequence/effect of the CE session and a negative contributor. In addition, lack of *preparation and practice* was also considered as a potential obstacle for teamwork according to the findings in research question 2, but is in the model embedded with *better collaboration and communication*. The reason for this is the fact that preparing and having experience with CE sessions is adamant for not just the overall CE session but also for handling the complexity better, involving the right amount of stakeholders and having the right level of autonomy. Because of the encompassing attribute of *preparation and practice*, it was placed as a facilitator for *better collaboration and communication*.

The *level of integration*, as previously mentioned, is highly important for the CE session. In the model, this is visualized by having the level of integration as a contributor to *increased knowledge*. The outcome of this increased knowledge is depicted in the model as increasing the complexity, enabling faster information process and better collaboration and communication. As the findings stated, complexity increases when more disciplines are present. Specifically, the planning of the concurrency and the coordination between them. The reason for the

connection between *increased knowledge* and *increased complexity* is that the coordination and handling of information from the whole life cycle naturally makes the CE session more complex. Where in other circumstances, like more traditional projects, some of the information would be handled at a later time in development and/or handled sequentially. However, now it is handled concurrently, where all other disciplines can provide information on a work-task and it can be evaluated according to the whole life cycle. The increase in complexity affects the overall ability of the CE session, thus it is connected to the immediate effect of the participants being more quality- and problem-aware. The last contributor is that of the *level of autonomy*. *Level of autonomy* is visualized as increasing the information process, more specifically however, it enables concurrent decision making and the execution of decisions at the right time. More importantly, in the context of infrastructure projects, it enables especially the external decision makers (like the municipalities) to be involved and take decisions more paralleled with the plan development, instead of the normally sequential process that demanded (sometimes, a lot of) waiting. The main effects inside the CE session shows that the increase in knowledge and the faster information process creates a better collaboration and communication. This greater understanding of collaboration ensures higher level of quality- and problem-awareness of the project. Moreover, *faster information process* is enabled by *increased knowledge* because the lack of team members would lessen informed decisions, and perhaps cause less optimal or incorrect choices and, additionally, the integration results in faster information gathering.

6 Conclusion

To understand the complicated matter of what effects a CE session in infrastructure projects can have in comparison to traditional projects, it is necessary to see not just the other side of the coin, but *where* the coin is. Context is probably the most important addition to any findings. Very little meaning can be found without it. Ironically, context in a social research are as the projects are, unique, therefore, it is difficult to generalize findings from such experiences (Bryman and Bell, 2015). It is however, possible to make assumptions about the circumstances that have the most impact, and thus, make CE sessions more understood. By finding patterns and correlations, the results can at the very least strengthen previous findings and literature, thus increasing the collective understanding of the method. Moreover, considering the lack of research in public/infrastructure project and the Norwegian context, this thesis contributes to this field.

6.1 Answering research question 1

What are the effects of utilizing an integrated concurrent team as per the concurrent engineering method in comparison to more traditionally ran projects, in the context of infrastructure projects?

The **immediate effects** from a CE team working collaboratively in a CE session are:

1. Increased collaboration and communication
    a. More quality- and problem-aware
2. Increased knowledge of the whole life cycle of the project
3. Increased coordination- and plan-complexity

Both from the analysed interviews and observation findings, increased collaboration and communication and increased knowledge of the project were effects that were identified. In addition, a connected effect to the increased collaboration is that the team is more quality- and problem aware. Increased coordination and plan complexity was identified from the interviews but only coordination problems were noticeable from the observation findings. All three of the effects plus sub effect 1.a shows relevance by being supported by the CE literature (Anumba and Kamara, 2012, Park, 2001, Ahmad et al., 2016, Nicholas, 1994).

The immediate effects seem to be related strongly to the integration and involvement of the project stakeholders. Particularly, in the infrastructure projects, this integration can expedite the overall planning process. Specifically, by the involvement of external decision parties that normally would oversee the project plan in a sequential project process. Thus, concluded from the analysis, **delayed probable effects** in the infrastructure sector are:

4. Expedited overall planning process
5. Increased quality of the plan

Expedited overall planning process comes from a possibility that some decisions can be done concurrently and earlier in time, specifically towards extra work or change in work. Moreover, the external parties might have an increased understanding of the project, thus more easily can make decisions and move forward when the project plan has been delivered for review. The increased quality of the plan derives from these elements as well, where the project plan benefits from an increased intake of information that is more accurate according to the whole project life cycle. In addition, it is derived from the increase in collaboration and communication and the increase in knowledge that seem to be the major immediate finding of the CE method.

6.2 Answering research question 2

What are the potential obstacles (contributing factors) for such a team to work (or not work)?

The analysed contributing factors for the CE team to work are:

1. Integration
2. Autonomy
3. Preparation and practice

All of these three factors show significance according to the analysed findings and the literature review (Nicholas, 1994, Valle and Vázquez-Bustelo, 2009, Constable, 1994, Anumba and Kamara, 2012). Moreover, factor 1 and 2 becomes significant obstacles to the efficiency of the CE method should they not meet the necessary level. In addition, the integration of external decision makers was identified as the main difficulty in the infrastructure sector. Factor 3 entails the obstacles with the effectiveness of the method if preparation and practice is at an insufficient level.

6.3 Generalizability

Although there is a lack of research in public/infrastructure projects in regard to CE, the findings stated in this conclusion is strongly supported by the general literature on CE in the construction industry. In fact, only **delayed probable effect 4 (Expedited overall planning process)** is not specifically mentioned in the literature. This finding is strongly connected to the context of having public hearings/decision makers. If one considers the general CE literature however, which states that the reduction on the overall project development is possible through concurrent work and a development of an accurate plan (Prasad, 1996, Anumba and Kamara, 2012), it is likely that the governmental process of approving the plan might be expedited. In conclusion, this delayed effect might be generalizable towards public projects, but would need more supportive research.

6.4 Further research

Regarding the level of integration and autonomy, it seems unquestionable that these are major contributing factors for the CE teamwork to function more effectively. However, how much integration and autonomy really is needed in the infrastructure projects and at what point in time of the project, should be further researched. The reason for this is in particular the extra complexity in involving the governmental entities, but also that research of CE in the infrastructure sector is lacking.

Research that emphasizes the processes that occur because of governmental procedures should be further studied so that potential disablers or enablers can be identified more clearly concerning the utilization of a CE team. Furthermore, more in-depth analysis of how the infrastructure sector currently operates (in regard to project development time, project cost, and so on) might reveal additional understanding. In addition, to expand on the benefits of the CE method and the utilization of the method in the construction industry, more data should be gathered. In particular, data that compares project development time, cost, and number of reworks on each project phase between normal project method and the CE method. In addition, more research can be done within specifically how the infrastructure process and projects are done, for the benefit of the investigation of the traditional project method findings.

To validate further some of the findings in this thesis, it is suggested to increase the amount of observations, and furthermore, perform more qualitative interviews with a more diverse amount of members of a CE session for an enhanced opinion on all the aspects of CE work.

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Appendix 1: The questionnaire

Prosjektnavn:

Denne besvarelse er levert av	Byggherre/oppdragsgiver	
	Rådgiver	

Med forståelse for at det kan være vanskelig å fremskaffe alle data tabellen under etterspør, ber vi om at så mange som mulig av datapunktene registreres.

Om prosjektet:

Prosjektnavn		
Beliggenhet/kommune(r)		
Prosjekteier (organisasjon)		
Prosjektstart/-slutt (måned/år)	Start:	Slutt:
Prosjektfase (dette skjemaet gjelder)	Utredning/KVU	
	Forstudie	
	Kommunedelplan	
	Reguleringsplan	
	Byggeplan	
Gjeldende prosjektfases start/-slutt (måned/år)	Start:	Slutt:
Var prosjekteringsleverandørene hovedsakelig samlokalisert under prosjektet?		
Kontraktsform for plan eller prosjektering		
Var det incentiver for forsert fremdrift? I så fall hvilke?		
Ble det hovedsakelig benyttet tegningsbasert eller modellbasert prosjektering?	Tegningsbasert	
	Modellbasert	

Kontrakt og gjennomføring:

Planlagt varighet gjeldende planfase (måneder)		
Planfasens faktiske varighet (måneder)		
Planlagt timeomfang gjeldende planfase (kontraktsavtalt timeomfang)		
Plan / prosjekteringens kostnad for fasen		
Planfasens faktiske utførte timeomfang		
Omfang av tilleggsarbeider (timer)		
Antall deltakere som deltok i plan / prosjekteringen	Firma	stk
	Fagområder	stk
	Personer	stk

Planarbeid og grunnlag:

Opplevde du at prosjekteringsbeslutninger ble tatt	Før planlagt	
	Ihht. Plan	
	Senere enn planlagt	
Antall møter	Prosjekteringsmøter (inkl. oppdragsg.)	
	Fagmøter (internmøter konsulenter).	
Antall endringer av tekniske forutsetninger som lå fra forrige planfase		
Antall endringer av formelle/politiske valg/forutsetninger som lå fra forrige planfase		
Kostnadsendring	Kostnad forrige fase:	
	Kostnad denne fase:	

Vurdering:

Grad av problemstillinger som burde vært avdekket i foregående planfase, men ikke avklart	Skala Svært lite, lite, middels, høyt, svært høyt 1-5
Grad av feil og mangler i prosjekteringsunderlag som ikke ble avdekket i gjeldende planfase	Skala Svært lite, lite, middels, høyt, svært høyt 1-5
Byggherres generelle fornøydhet med prosjekteringsarbeidet (skala fra 1-10, 10 mest fornøyd)	1-10
I hvilken grad var byggherre aktivt involvert i løsningsvalg underveis i prosjektet?	Skala Svært lite, lite, middels, høyt, svært høyt 1-5

Appendix 2: The additional open-ended questions

For all the interview objects:	
1	Hvordan har gruppearbeidet, samarbeidet vært mellom dere og partene under prosjektet?
2	Noen tanker rundt problemer i forbindelse med gruppearbeidet/samarbeidet?
3	Hvilke hjelpemidler ble brukt og hva ble gjort for å opprettholde et godt samarbeid?

If they were involved in Concurrent engineering:	
1	Hvordan opplevde du denne arbeidsmetodikken?
2	Hvordan var samarbeidet og gruppearbeidet i forhold til tradisjonell prosjektering?
3	Hva fungerte, hva var bra, hva var dårlig osv.? Særlig i forbindelse med sesjonene?

Appendix 3: Observation form example

Observasjonspunkter som skal noteres

Hvordan observere: skriv ned tid, handling (om mulig) og hva som ble gjort (observert), ant. deltakere, andre kommentarer.

Informasjon	Handling/observert	Andre kommentarer
Kl: _____ Ant deltakere _____		
Kl: _____ Ant deltakere _____		
Kl: _____ Ant deltakere _____		