NTNU – Trondheim
Norwegian University of
Science and Technology

Network effects and performance in construction projects

A case study of three consecutive partnering projects

Kristian Fallrø

NTNU School of Entrepreneurship
Submission date: June 2013
Supervisor: Roger Klev, IØT

Norwegian University of Science and Technology
Department of Industrial Economics and Technology Management

NTNU
Det skapende universitet

MASTERKONTRAKT
- uttak av masteroppgave

1. Studentens personalia

Etternavn, fornavn	Fødselsdato
Fallrø, Kristian	**01. mai 1988**
E-post	Telefon
kristfal@stud.ntnu.no	**90241806**

2. Studieopplysninger

Fakultet
Fakultet for Samfunnsvitenskap og teknologiledelse
Institutt
Institutt for industriell økonomi og teknologiledelse
Studieprogram
NTNUs Entreprenørskole

3. Masteroppgave

Oppstartsdato	Innleveringsfrist
15. jan 2013	**11. jun 2013**
Oppgavens (foreløpige) tittel	
Network effects and performance in construction projects	
Oppgavetekst/Problembeskrivelse	
This master thesis will investigate how relations between contractors and subcontractors construction projects affects project performance. Relevant theory will be presented and discussed. An empirical study will be conducted to investigate different forms of relations and how they influence project performance. The empirical findings will be analyzed and discussed in light of presented theory.	
Hovedveileder ved institutt	Medveileder(e) ved institutt
Førsteamanuensis Roger Klev	
Merknader	
1 uke ekstra p.g.a påske.	

4. Underskrift

Student: Jeg erklærer herved at jeg har satt meg inn i gjeldende bestemmelser for mastergradsstudiet og at jeg oppfyller kravene for adgang til å påbegynne oppgaven, herunder eventuelle praksiskrav.

Partene er gjort kjent med avtalens vilkår, samt kapitlene i studiehåndboken om generelle regler og aktuell studieplan for masterstudiet.

Trondheim 14. jan 2013
Sted og dato

Student

Hovedveileder

SAMMENDRAG

Partnerskap mellom bedrifter i byggenæringen har blitt vurdert i mange akademiske studier. Flesteparten av disse studiene viser til positive resultater, men flere forskere har stilt spørsmålstegn ved kvaliteten og objektiviteten til disse studiene.

Denne masteroppgaven presenterer en ny metode for å evaluere effekten av partnerskap i byggeprosjekter. Metoden som presenteres bygger på akademiske artikler fra fagfeltene *nettverkseffekter, læringskurvekonseptet, partnerskap i byggenæringen og ytelsesmålinger*. Målet har vært å utarbeide en praktisk, objektiv og inngående metode for evaluering av ytelse i partnerbyggeprosjekter.

Den nye tilnærmingen til partnerevaluering blir deretter brukt for å analysere tre byggeprosjekter som er gjennomført av den samme totalentreprenøren. Prosjektene er alle av samme bygningstype, og har få ulike variabler.

Prestasjonsmålinger er gjennomført av alle de involverte firmaene i prosjektene, inkludert byggherre, rådgivere, arkitekter, underentreprenører og leverandører. 107 kontrakter ble analysert på tvers av de tre byggeprosjektene. 66 kontrakter ble utført av bedrifter som ikke har erfaring fra tilsvarende byggeprosjekter med den utvalgte totalentreprenøren. 41 kontrakter ble utført av bedrifter som tidligere har levert på tilsvarende kontrakter for den samme totalentreprenøren.

En analyse av dokumenter fra byggeprosjektene avslørte 14 hendelser som negativt påvirket framdrift-, kostnad- eller kvalitetsytelsen til prosjektene. Hendelsene varierte fra mindre til større problemer og/eller uenigheter. Av 14 hendelser var 11 knyttet til bedrifter som ikke hadde tidligere erfaring fra å jobbe sammen med totalentreprenøren.

Studiet konkluderer med at bedrifter som utfører samme type kontrakt på tvers av flere like byggeprosjekter med den samme totalentreprenør presterer bedre enn firmaer som ikke har tilsvarende erfaring.

Læringskurveeffekten danner den ledende hypotesen for å forklare funnene i studiet. Ved å redusere diskontinuiteten mellom hvert enkelt byggeprosjekt, forbedres prosjektets overordnede ytelse. Funnene i studiet forventes å være bredt generaliserbart, da verken type bygg, byggeprosessen, totalentreprenør eller de andre involverte bedriftene er spesielt unike.

ABSTRACT

Partnering in construction has been evaluated in a myriad of studies. The majority of these studies indicate positive outcomes by introducing the concept. However, several researchers have questioned the quality and objectivity of these studies.

This thesis presents a novel approach to partnering evaluation in construction projects. The method presented is based on research articles concerned with *network effects, the learning curve concept, partnering in construction and performance measurements*. The objective has been to develop a practical, objective and in-depth method for evaluating the performance of partnering projects.

The novel approach to partnering evaluation is applied in a case study of three construction projects conducted by the same main contractor. The three projects present a low degree of variation and are all the same type of building.

Performance measures are conducted of all involved firms in the projects including engineers, architects, sub-contractors and suppliers. 107 contracts were analysed across the three projects. 66 of these contracts were fulfilled by firms without previous working experience with the main contractor. 41 contracts were fulfilled by firms that had delivered on a similar contract in a previous construction project with the main contractor.

An analysis of construction project documentation identified 14 events that affected time, cost and quality performance. The events ranged from minor to major issues and/or disputes. Of these 14 events, 11 were related to firms without previous working experience with the main contractor.

The case study concludes that firms fulfilling the same type of contract across several similar projects with the same main contractor performs better than firms without previous experience in a related project type.

The learning curve effect forms the leading hypothesis for explaining the study findings. By reducing the discontinuities between each project, the overall project performance is improved. The results of this study is expected to be broadly generalizable, as neither the construction type and process nor the main contractor and other firms involved in the study are particularly unique.

Table of Contents

List of Tables

List of Figures

Acknowledgements

The author wishes to express sincere appreciation to Adjunct Associate Professor Roger Klev whose guidance was invaluable in the preparation of this thesis. Additionally, a special thank-you to the employees of the main contractor in this study who took time from their busy schedules to assist in this research. Heart-felt thanks are also extended to my parents, Siri Stokseth and Per-Johan Fallrø who were continual sources for motivation and valued sparring partners. Finally, lots of appreciation is expressed to my co-workers at Rendra, you're the best bunch of entrepreneurs in the world!

Chapter I: Introduction

The state of the construction industry

The construction industry is frequently described as large, fragmented and complex. The Norwegian construction industry had an annual turnover of roughly BNOK 600 in 2009, accounting for 13% of the Norwegian GDP. Despite a steady growth in turnover, contract value per work hour has declined more than 20% between 2000 and 2010 in Norway (Stortingsmelding 28, 2012).

These findings are not unique to Norway, and over the recent decades, huge efforts have been made to *'stimulate radical improvements in the construction industry in terms of value for money, profitability and reliability'* (Beach *et al.*, 2005). These efforts is a reaction to several comprehensive analyses of the current conditions in the US and UK construction sectors (CII, 1991; Latham, 1994; Egan, 1998).

The underlying reason for these efforts seems to be the general opinion that the industry is characterized by *'inefficient business processes which feed through as overheads to total project costs'* (Brensen and Marshall, 2000). The academic findings got widespread attention and resulted in global efforts to promote significant improvement in the industry (Brown et al., 2001).

One of the main ambitions of this reorientation was to apply practices that successfully had been implemented in other industries. Many have been suggested and tested, from applying *'radically different approaches to procurement'* (Wood and Ellis, 2005) to *'changing traditional relationships to a shard culture without regard to organisational boundaries'* (CII, 1991).

Despite great academic, industry and political attention, the overall productivity in the construction industry has declined during the latest years. However, as firms in the industry investigate new approaches to the industry challenges, some variations are bound to be more efficient and provide better value than others.

The main contractor

***Notice**: The main contactor in this thesis has been anonymized as firm and project specific sensitive data is presented throughout the analysis. The firm asked to be presented anonymously to preserve the identity of the other parties involved in the analysed projects.*

The main contractor, hereafter called MC, is one of the largest civil contractors in its operational region and delivers project development services and turnkey contracts within the market areas of civil construction, infrastructure and transportation.

Six similar construction projects

MC has won contracts for six similar types projects in the same county since 2002. The first projects were both lower secondary schools. Often referred to as 'twin projects', the schools were designed and built to be as similar as possible. The contract for both schools was won in 2002. The next school project was another lower secondary school. This contract was won in 2005, followed by a fourth lower secondary school won in 2008. In 2011, MC won the contract for an upper secondary school. MC won the contract for another upper secondary school in 2012.

All contracts have been won with the same architectural firm as a partner. In addition, many firms providing engineering services, supplies or sub-contracting services has fulfilled the same contract type across several of these projects. The strategy of reutilizing the same firms in several projects is still considered an emergent strategy, with no formal directives from the top management of MC.

Given the similarities in building type, location, governmental regulations, the same main contractor and architect, and several other firms fulfilling the same type of contract across several projects, these projects form a highly interesting foundation for research.

Goal and scope of thesis

The fundamental aspects of inter-organizational learning, performance and partnering in the construction industry have been well-debated and frequent topics of discussion in academic circles, the business press and within construction firm management. As in all policy areas, an important role for research is evaluation.

Partnering has been evaluated in a myriad of studies and the majority of these studies indicate positive outcomes by introducing the concept. However, several researchers have questioned the quality and objectivity of these studies (e.g. Green, 1999; Brensen and Marshall, 2000; Nyström, 2008).

This master thesis will first review and critique the current bulk of partnering evaluations. Subsequently, the thesis will present a refinement of Nyström's (2008) criteria for evaluating the performance effects of partnering to take into account the learning curve concept and contract specific evaluation.

Secondly, the goal of this thesis is to apply the refined approach to analyse data from three construction projects through a comparative case study. The projects are all consecutive partnering projects with a significant number of key firms fulfilling the same types of contracts across all three projects. The data foundation is documentation from the construction process; mainly site meeting minutes, contracts and formal written correspondence. All data is reviewed from the perspective of the main contractor. Based on this data, the following research question will be answered:

Has MC's partnering strategy yielded performance improvements and an increased competitive advantage?

To answer this question, the following academic concepts will be presented and discussed:

(1) Network effects and the learning curve concept
(2) Partnering in construction
(3) Performance measurements in construction
(4) The comparative case study research design

Network effects are used to explain the complex relations in and around construction projects. The learning curve effect is a broadly utilized theory that relate productivity and learning to repetition. Performance measurement theory explains how researches have approached the challenges of evaluating performance in construction. The comparative case study research design is a commonly used design for evaluating multi-case studies.

These theoretical concepts will then be applied to the data sets and discussed followed by a final conclusion.

Notice from the author: *This thesis relies on project and firm specific sensitive data. Firms and projects presented in this thesis are anonymized.*

Chapter II: Literature Analysis

Complexity, network effects and the learning curve concept

'The physical substance of a house is a pile of materials assembled from widely scattered sources. They undergo different kinds and degrees of processing in large number of places, require many types of handling over periods that vary greatly in length, and use the services of a multitude of people organized into many different sorts of business entities.'

Cox and Goodman wrote this description of construction projects in 1956. It is one of the earliest scientific papers describing the distribution of materials and manpower in housing construction projects. One of the conclusions Cox and Goodman made, was that there existed a large variety of permutations and combinations of processes, relations and states, even for a simple and standardized housing project (Cox and Goodman, 1956). The inherent complexity in larger construction projects and the related challenges are often described as formidable and daunting. However, these challenges are solved time after time as large and complex buildings are erected in the thousands every year.

Similar opinions have been shared by other researches. Shammas-Thoma *et al.* (1998) studied '*all those remarkable processes that enable the construction process to function at all*'. Gidao (1996) further discussed this theme by stating that there is a continuous increase in the complexity of construction projects due to external factors such as regulations, industry standards and environmental demands.

Fallrø (2012) discussed that the complexity of a construction project is a result of uncertainty and interdependencies. The inherent operational interdependencies dictate a high degree of coordination, and the nature of the dependencies mandate localized rather than centralized coordination.

Dubois and Gadde (2002) argued that the construction industry could be described as a loosely coupled system, and that a construction project can be viewed as a temporary network of firms within a more permanent industry network. The operational interdependencies and necessity for coordination of sequential activities at the construction site call for tight couplings between firms involved at the construction site. Akintoye *et al.* (2000) discussed that the supply chain firms are also tightly coupled to the rest of the construction firms, as delays of supplies to the construction site may halt all construction activities at the site. Fallrø (2012) argued that dependencies within each firm might result in tight couplings between projects. For instance, delays in one project may delay the transfer of operation critical manpower to another project, thus causing a '*domino effect*' of delays.

The mix of loose industry couplings and tight project couplings make it problematic to apply the coordination mechanisms for handling complexity that are used in other industry contexts (Dubbos and Gadde, 2002). Typically in other industries, uncertainties and interdependence are managed through tight long-term inter-firm couplings. Inter-firm adaptation and relational exchanges are usual ways of handling theses issues. A stellar example is 'just-in-time deliveries', a cornerstone process in the automotive industry.

However, the construction industry is characterized by few inter-firm adaptions beyond the individual project, and each firm mainly relies on short-term market based exchanges. Additionally, individuals in the project team are recombined in each project, which further complicates coordination.

Gidado (1996) stated that the learning curve concept could be used to describe how the varying nature of interdependencies, occurrences of inherent complexity and uncertainty factors may be linked to performance:

'It is human nature to learn from experience and improve in future similar processes; therefore, when roles are repeated over and over by the same team, it is quite possible that the effect … on standard time or cost may decrease.'

Wright was the first author to introduce the learning curve concept in academic literature (Yelle, 1979). The phenomenon, which Wright observed, was that as the quantity of manufactured units increase, the number of direct labor hours it took to produce one unit decreased at a uniform rate. The learning curve follows the mathematical function:

$$Y = KX^n$$

A basic introduction to learning curves is given by Carlson (1961). Carlson (1961) also described the most well known geometrical models for the learning curve, which are illustrated in figure 1.

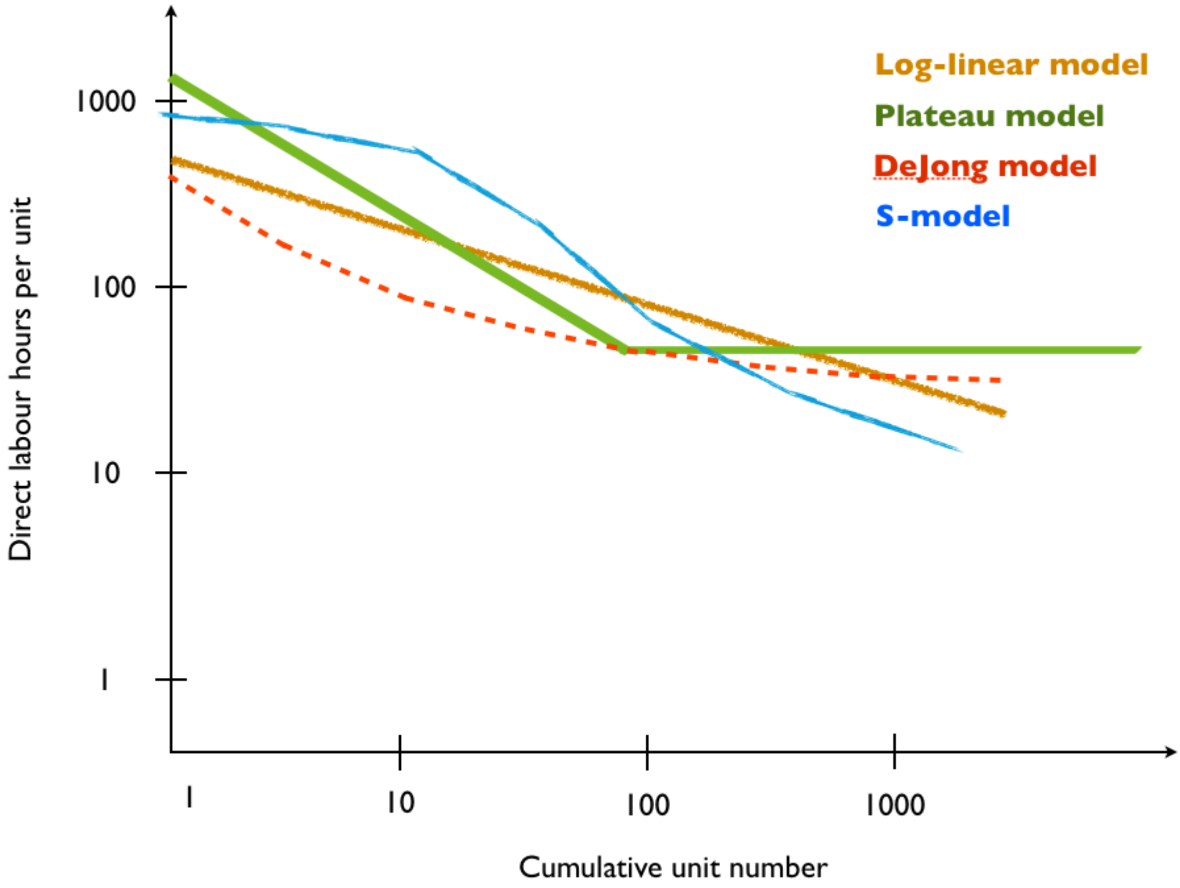

Figure 1: Various learning curve models with the same Y-value

Although the log-linear model has been, and still is by far the most widely used model, some industry manufacturers have found other models that better describe their experiences (Smunt, 1999).

At a macroscopic level, the learning curve includes two categories of learning: Labor learning and organizational learning. Yelle (1979) claimed that the two ways to improve learning lies '*in the inherent susceptibility of the labor in an operation to improve, and the degree to which this susceptibility is exploited by the organization*'.

Interruptions or discontinuities in the learning curve commonly occur when new model changes are initiated, the design of the product is altered or in the case of intermittent production of the same product. Gann (1996) argued that the inherent discontinuities between construction projects impact a firm's ability to learn and improve. He concluded that '*each building is treated as a prototype without a history or future*'. Hence, the fundamental necessities for organizational and labor learning seem to be lacking due to the current network arrangements in the construction industry. Figure 2 illustrates the learning curve of consecutive construction projects with discontinuities between each project.

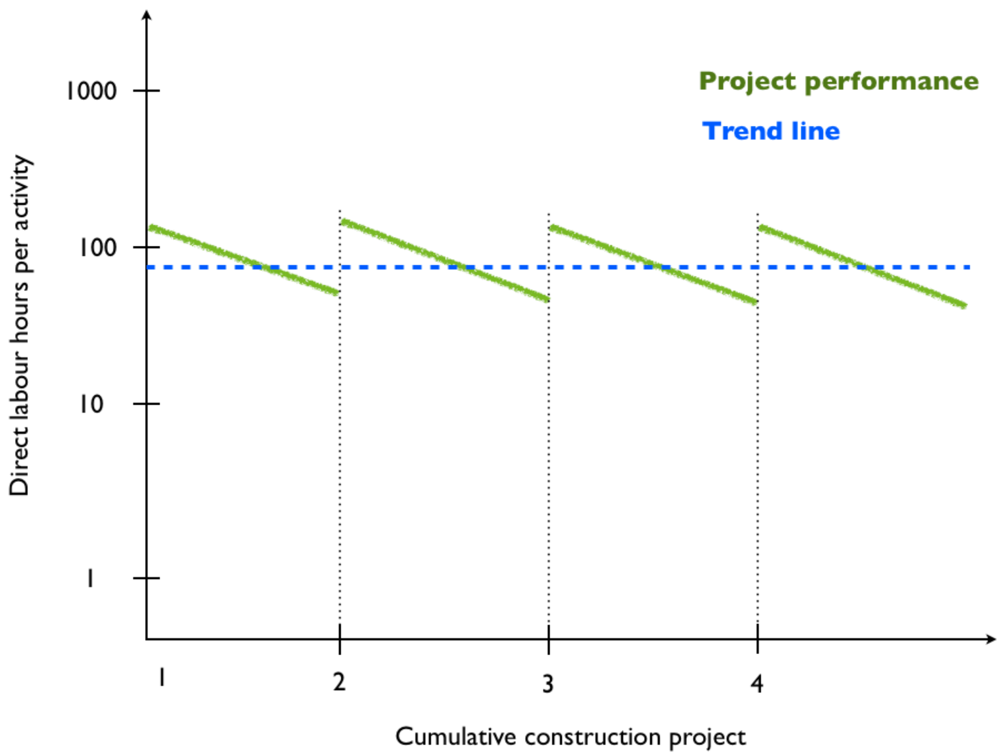

Figure 2: Construction project learning curve effect and discontinuities

Dubbois and Gadde (2000) concluded that the particular couplings in the construction industry favours short-term project productivity and negatively affect innovation, learning and long term performance. Short-term project oriented focus, market based transactions and loose couplings prevent the construction industry to catch up on other industries with respect to performance and efficiency (Fallrø, 2012). Closer couplings between main contractors, sub-contractors, suppliers and clients are expected to improve the general conditions in the industry. Transferring traditional construction site activities off-site through pre-fabrication is one example of measures that is expected to improve the industry performance. With these conclusions in mind, the most obvious experiment would be to redefine the pattern of loose and tight couplings and evaluate the new pattern performance.

Partnering in construction

"*Partnering and integration strategies attempt to address a fundamental characteristic of the industry … that is fragmented, as individuals from different organizations which are geographically and temporally dispersed are involved in the construction process.*"

With this sentence, Luck (1996) tried to summarize the difficulties partnering attempts to address in construction. As a relatively new concept within the construction industry in 1996, partnering and the related opportunities and challenges has seen a major interest from researchers during the last two decades.

According to Brensen and Marshall (2000), there exists a broad agreement amongst researchers about the overall philosophy of partnering, but there are varying views on a number of its features, including the role of contracts, duration, incentives and the need for formal team building and facilitation. Therefore, partnering is a rather inaccurate and inclusive concept spanning over a wide range of behaviours, attitudes, values, practices tools and techniques. Holti and Standing (1996) suggested *'rather than being a separate or definable initiative in its own right, partnering or increasing collaboration is best understood as the result of making progress with one or more of a number of inter-related technical and organizational change initiatives'.* With this notion in mind, partnering can be viewed as a technique to alter the loose couplings that exist in and around a construction project network.

Wilson *et al.* (1995) described partnering as *'an increasingly popular management tool aimed at reversing the negative effects of adversarial relationships in construction'*. Brensen and Marshal (2000) conducted a literature review and identified the following opportunities associated with partnering:

(1) The potential benefits that stem from increased productivity and reduced costs
(2) Reduced construction time due to early supplier involvement and team integration
(3) Increased quality as a result of more focus on learning and continuous improvement
(4) Improved client and end-user satisfaction and improved responsiveness to changing conditions
(5) Greater stability and predictability that enable better resource management

With these potential benefits, it comes as no surprise that the concept of partnering has received enormous attention amongst researchers and firms in the industry alike. It has even been referred to as '*the most significant development today as a means of improving performance*' (Wood and Ellis, 2005). A study of 280 construction projects concluded that 'partnered projects' achieved superior performance in terms of technical performance, costs control and customer satisfaction compared to projects managed in other ways (Larson, 1995).

However, several authors argue that there are issues with achieving the desired outcomes of partnering in the construction industry (e.g Green, 1999; Brensen and Marshall, 2000; Brown *et al.*, 2001; Nyström, 2008). The main bulk of critique stems from three aspects. (1) The research is based on subjective data, such as questionnaires aimed at key individuals in the project. (2) An evaluation is conducted without comparing the results to suitable reference projects. (3) The research does not control for other variables that might affect the performance of the project.

The long list of greatly contradictory opinions regarding partnering encourages a further investigation of this concept.

Chan *et al.* (2003) reviewed the benefits of partnering in general by providing a summary of 29 partnering papers. The paper presented a great overview of what researches and academics typically say about the benefits of partnering. However, a large number of the reviewed papers are purely theoretical with no empirical support, thus providing no factual basis for conclusions. Nyström (2006) structured the empirical papers in three categories (1) surveys, (2) case studies and (3) comparative studies with many observations. The findings are summarized in table 1.

(1) Surveys

Surveys are suited for gathering information about people's opinions concerning a specific issue (Balnaves and Caputi, 2001). This form of study is usually conducted with questionnaires. Many partnering assessments have been done in this manner. Nyström (2006) argue that the personal perception cannot be considered project facts and invalidate the results of these surveys. And even if the answers are objective, it is difficult for the subject to extract the unique effect of partnering and compare this to other projects. Hence, the conducted surveys lack controlled and factual data, an objective basis for comparative analysis and provide no way of controlling for other affecting variables.

(2) Case studies

Case studies are used to gather in-depth knowledge about a specific case. Many benefits of partnering have been pointed out with case study methods. All of these studies are conducted with interviews and questionnaires. Nyström (2006) argues that interviews combined with surveys strengthen the quality of the data. However, the condition to control for other affecting variables is not fulfilled in any of these case studies. Additionally, most of these studies do not include any comparative analysis with other construction projects.

(3) Comparative studies with many observations

Some scientific studies have been conducted with a large number of observations. The three identified studies are to a large extent based on questionnaires with 60, 280 and 400 observations. Despite the considerable number of observations, the studies suffer from the same issues as surveys (Nyström, 2006). As an example, theses studies can only say that partnering projects cut costs by 5% in relation to budget, but they cannot say that partnering in itself cut costs by 5% because these studies fail to address other variables that could cause this effect.

All studies presented have been found lacking in research quality. Even though most of them present partnering as a concept with considerable positive potential in improving communication and relationship between firms, shortcomings in the evaluations prevents these benefits from being settled (Nyström, 2008). With this conclusion in mind, new ways of measuring partnering effect must be explored.

Table I: Categorizing papers studying the effects of partnering (Nyström, 2008)

Author, year	**Based on project data**	**Comparative analysis**	**Control for other affecting variables**	**Improved outcome with partnering regarding**
Surveys				
Fortune and Setiwan (2005)	NO	NO	NO	Cost, delivery time and quality
Beach *et al.* (2005)	NO	NO	NO	Communication, mutual learning and understanding
Chan *et al.* (2003)	NO	NO	NO	Improved relationship, communication and flexibility
Haksever *et al.* (2001)	YES	NO	NO	Cooperation, team spirits, confidence of success, communication
Black *et al.* (2000)	NO	NO	NO	Fewer adversarial relationships, increased customer satisfaction
Case studies				
Emsley (2005)	NO	NO	NO	Time reduction, high quality good safety
Chan *et al.* (2005)	NO	NO	NO	Improved relationship, communication, better productivity, fewer disputes
Bayliss *et al.* (2004)	NO	NO	NO	Communication, commitment
Vassie and Fuller (2003)	YES	YES	NO	Improved relationships, improved communication, more responsive
Brensen and Marshall (2000)	YES	YES	NO	Time, cost, quality, design-construct integration
Ellison and Miller (1995)	YES	YES	NO	Saved the projects
Comparative studies with many observations				
Gransberg *et al.* (1999)	YES	YES	NO	Cost growth, time delays, improved project performance
Ruff *et al.* (1996)	YES	YES	NO	Budget and schedule
Larson (1995)	NO	YES	NO	Controlling costs, technical performance, satisfying customers

Measuring performance in construction

Research on performance measurements has been a subject of considerable attention during the past 20 years. Neely (1999) described an explosion of activity in the mid 90s, where some 3615 articles were published in the period from 1994 to 1996, and in 1996 a new book appeared on the subject every two weeks in the United States. The performance measurement revolution of the mid 90s has spread to many industries, including the construction industry.

In the contemporary literature, performance measurements have been traced back to the use of planning and control procedures by the U.S. railways in the 1860s (Chandler, 1977). By 1925, many of the financial performance techniques and methods used today had been developed (Chandler, 1977). The dissatisfaction with financially based performance measurement began in the early 1950s and gained momentum in the late 1970s. The shortcomings of financial measurements have been well documented by a range of researchers (e.g. Eccles, 1991; Letza, 1996; Neerly *et al.,* 2000). The main issue lies in the fact that financial information is a lagging indicator, as it describes the outcome of managerial decisions after they occur by at least one reporting period.

To address the issues with financial indicators, non-financial methods and frameworks were developed. Cross and Lynch (1989) proposed a set of underlying relationships among the basic performance dimensions through a concept named 'The Performance Pyramid' as illustrated in figure 3.

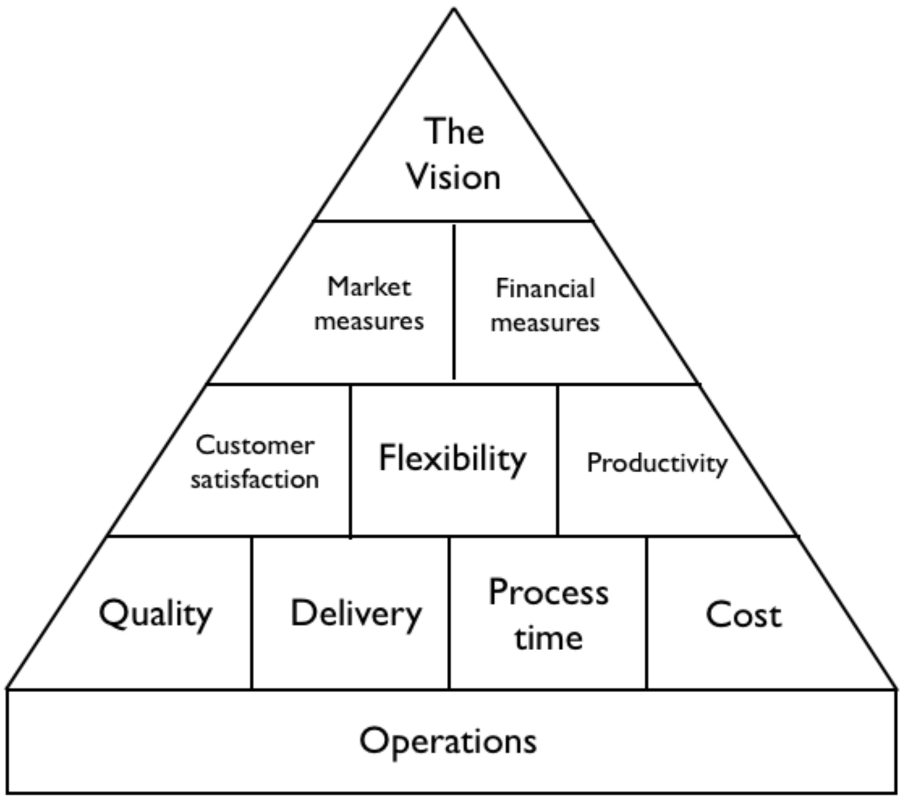

Figure 3: The Performance Pyramid by Cross and Lynch (1989)

Kaplan and Norton (1992) introduced the 'Balanced Scorecard', a new concept to performance measurement frameworks with four perspectives: (1) financial, (2) customer, (3) internal processes and (4) innovation. The scorecard was further presented as a strategic management system (Kaplan and Norton, 1996). Neerly and Adams (2001) introduced the 'Performance Prism'. With this concept, Neerly and Adams advocated that performance measurement focus should primarily focus on stakeholders' needs and contributions and secondarily focus on required strategies, processes and capabilities.

Parmenter (2010) divided performance measurements into four categories:

(1) Key Result Indicators
(2) Result Indicators
(3) Performance Indicators
(4) Key Performance Indicators

The common characteristics of key result indicators, is that they are a result of many actions over a longer period of time. For instance, customer satisfaction, net profit before tax and employee satisfaction are all key results indicators. Result indicators are financial short term measures, such as sales made yesterday or net profit on a specific production line per month. Performance indicators are non-financial performance measures with a short time horizon. Typical performance indicators can be number of employee suggestions implemented the last 30 days, late deliveries to key customers the last month and sales calls conducted during the last week.

Key performance indicators are current or future oriented. A key performance indicator can be the current amounts of late airplanes or number of visits to contacts that make up for the most profitable business (Parmenter, 2010).

Several methods for measuring performance and results have been presented, but the question remains: What is suitable for measuring the effects of partnering and the learning curve in construction projects?

Chan and Chan (2004) conducted a literature review to develop a set of key performance indicators and a benchmark for measuring the performance of a construction project. The result of the study was a set of objective and subjective result indicators. Although the indicators are interesting as tools to better understand construction projects, the great bulk of these indicators are either too impractical to measure or lack a direct relationship to partnering and the learning curve effect as variables in the construction process.

To measure the effects of partnering, the definition of project performance and its fundamental ties to partnering has to be identified.

The usual answer to project performance involves time, cost and quality (Gaddis, 1959). Basic economic theory describes value as benefits subtracted by costs. Hence, increasing benefits or decreasing costs creates value in a construction project. Cost is an easy and straightforward variable to interpret, however benefits are not always easy to interpret in a construction project.

Lancaster (1966) defined '*the package of goods*' in transactions by expressing them in characteristics. These characteristics consist of everything that influence the customer's benefits. For instance, in a hospital project, this could be the visual and functional experience of the operating room, how soundproof the doors are, the surrounding areas, public transportation to and from the hospital and so forth. A better operating room, a better surrounding areas and better connection to public transportation would then be directly connected to a higher benefit. Following Nyström's (2006) paper, this thesis assumes that quality consists of '*everything influencing the customers utility i.e. benefit*'. Hence, lowering costs or increasing a particular characteristic of quality creates value in a construction project.

When including time in the partnering evaluation, the question resides whether partnering entails a higher net present value than non-partnering projects. This can be achieved by lowering costs, increasing quality, postponing cost or making benefits come sooner. Nyström (2006) further argues that project performance should be defined by '*cost and quality, with time as a dimension of these two*'.

Other authors (e.g. Crane *et al.* 1999; Dainty, 2003) argue that cost, time and quality are not sufficient measurements for project performance, and that key performance indicators should be included in the definition. These key performance indicators typically include things such as participation satisfaction, personal development and information quality, construction team' satisfaction and so forth.

It can be questioned whether a project is successful if cost and quality are lacking, but the previously mentioned key performance indicators score high in a survey. However, these types of projects are not sustainable in the long run. Hence, key performance indicators are not interesting by themselves when evaluating project performance, but they might help improve the understanding of a construction project (Nyström, 2006).

Chapter III: Research Design and Methodology

The measurement problem of quality, cost and time performance

The definition of quality is hard to specify and formulate, as the concept is highly subjective. What one person could perceive as high quality might not be accepted by the next person. A potential solution is to agree on a certain objective level of quality. This is often the case in the construction industry, where the client and contractor formally agree on quality specifications in the contracting documents. Quality can then be defined as the level of fulfilling the contractual specifications.

This very definition is frequently used in the construction industry, and is generally known as conformance to requirements. However, this definition only solves the ex-ante problem of quality, and parties may still differ in their interpretation on whether an aspect of the contract is fulfilled or not. Issues regarding the interpretation of contractual agreements are complex, have seen a lot of academic debate, and can easily become a discussion worthy of another master thesis. Given the scope of this thesis, the definition of quality performance used throughout the thesis will be *'lack of conformance to contractual requirements'*.

Construction literature has often used growth measurement, where a percentage change of actual cost in respect to the contractual cost indicates the projects to define cost performance (Nyström, 2006). This measurement is inherently dependant on the initial contractual price, which causes several issues. First and foremost, with just a few observations, it is striking that the construction market is neither efficient nor that the contracted price always reflects the 'actual' cost of the project. The problem is even more evident in complex projects where cost estimation is considerably more difficult. Additionally, the growth measurement is affected by macroeconomic trends. For instance, fluctuations in material cost from the time of signing a design-build contract to actual procurement from a supplier may greatly affect the main contractor's profitability in a project.

The initial price of the contract cannot be used as a sufficient baseline to evaluate a project's cost performance. Hence, in this master thesis, cost performance will be defined as *'additional cost related to individual, organizational or inter-organizational dysfunctions affecting the construction project'*.

Similar to growth measurement, the definition of time performance in academic literature is typically a percentage change of actual progress in respect to the initial schedule (Chan and Chan, 2004). This measurement is inherently dependent on the validity of the initial schedule estimation, and as growth measurement, this causes issues. External factors, such as local weather and bedrock hardness are next to impossible to take into account during pre-contractual scheduling. The initial schedule cannot be used as a sufficient baseline to evaluate a project's time performance. As a result, time performance will be defined as *'additional time spent related to individual, organizational or inter-organizational dysfunctions affecting the construction project'*.

How should partnering performance be assessed in light of the learning curve effect?

Nystrøm (2008) argued that in order to say something well founded about the effects of partnering in general, the following three basic criteria must be fulfilled:

(1) *It must be based on project facts.* The project specific facts should be as objective as possible. Indicators of cost and quality may be used if more direct data are difficult to obtain. Subjective declarations by participants about the performance effects of partnering cannot be considered facts and are thus unfounded for a performance evaluation.

(2) *It must be a comparative analysis.* The outcomes of partnering projects have to be compared with non-partnering projects if anything is to be said regarding the effects of partnering. A comparison with the general perception of the construction industry is insufficient and explicit non-partnering reference cases are needed for a valid comparison.

(3) *It must control for other variables affecting the outcome of the project.* Construction projects are incredibly complex with many variables that affect the outcome of a project. It is difficult to extract the unique effect of partnering and separate this effect from other variables. It is therefore necessary to control explicitly for other variables and '*as far as possible make a ceteris paribus analysis*'.

These three conditions are useful for evaluating partnering versus non-partnering projects. However, condition (2) does not take into account the potential learning curve effects and it cannot be applied to studies where key firms fulfil similar contracts across several similar construction projects. As a result, in this particular partnering evaluation, a further refinement of condition (2) is needed:

(2) *It must be a comparative analysis.* The outcome of a particular partnering project have to be compared with another consecutive partnering project if anything is to be said regarding the learning curve effect as a variable in the partnering process. A comparison between individual firms involved in the project is required. A general comparison with the perception of firm performance in the construction industry is insufficient and explicit reference cases that fulfil condition (3) to a high degree are needed for a valid comparison.

By fulfilling the three given conditions, it is now possible to say something well founded about the learning curve effect in partnering projects.

Design and methodology: comparative case study and document analysis

The selected study design is a comparative case study tailored to evaluate partnering construction projects. A case study is an empirical study that investigates a contemporary phenomenon within its real-life context (Yin, 2008). It is particularly well suited for studies where the boundaries between the phenomenon in study and the context are not clearly defined.

The case study inquiry copes with the technically distinct situation in which there will be significantly more variables than data points. The study design relies on multiple sources of evidence, needing data to converge in a triangulating fashion. It also utilizes benefits from prior development of theoretical propositions to guide data collection and analysis (Yin, 2008).

Lijphart (1971) argues that a *'scientific approach is unavoidably comparative'*. Thus, a comparative approach is a broad, general method, rather than a specialized, narrow technique. There is no clear dividing line between the statistical and comparative method, the difference depends on the number of cases (Lijphart, 1971). The selection of comparative cases should not be random, but information oriented. Additionally, the variables defining the study should be identified early in the process prior to selecting a strategy for comparison.

Generally, two approaches are used in comparative research: The most similar system design (Smelser, 2003) and most different design (Teune and Przeworski, 1970). The foremost attempt to select cases where as many variables as possible are similar with the exception of the variable to be examined. The latter is designed to maximize the number of different variables in order to investigate the phenomenon.

The data presented by MC for this is highly unique in the aspect that many variables in each project are similar. Thus, the data is highly suitable for a most similar system design. In this study, clients, sub-contractors, suppliers and engineers are compared in terms of negative impact on project performance with in relation to previous experience in MC's projects. The methodology for doing the comparison is document analysis, which is further explained below.

Data sources: project documentation

Initially, this thesis aimed to evaluate six school projects conducted by MC in the same county. A pre-screening of documents stored in MC's database from all six projects was conducted prior to the analysis. This screening was conducted to identify comparable data across all projects, and revealed that three projects had sufficient documentation. The data provided by MC for analysis in this master thesis consists of the following documents and reports.

Table II: Data Sources

Project name	Contract documents	Site meeting minutes	Formal correspondence
Project X	N/A	N/A	N/A
Project Y	N/A	N/A	N/A
Project A	17	37	47
Project B	28	84	37
Project C	52	116	132
Project Æ	N/A	N/A	N/A

Contract documents include all contractual agreements between MC, clients, architects, engineers, subcontractors and suppliers. Site meetings include weekly site meetings between the same parties. Formal correspondence includes all written correspondence that stems from the contractual agreement such as formal warnings regarding delays, delay penalties and interventions.

The variation in project documentation quantity between projects A, B and C is mainly related to the size and construction speed of the project. Additionally, the most recent projects provide more detailed documentation, as new IT-tools and documentation routines have been introduced. Project documentation from project X and Y were either incomplete or could not be found at all in MC's internal databases and were thus disqualified from the analysis. Project Æ has yet to be completed and could therefore not be analysed.

The three presented projects marked in green in Table II are consecutive projects, where project A is the oldest and project C is the most recent. Each project was finished before the next was initiated.

Measuring quality, cost and time performance with the available project documentation

Nyström (2006) suggests that contract flexibility, additional work and disputes have an effect on cost and quality performance. Additionally, it is suggested by the author of this thesis that disputes and unsatisfactory quality have an effect on time in addition to cost performance. The following areas will be explored when analysing project data:

(1) *Contract flexibility.* Construction contracts are limited by the knowledge of the parties at the time of signing. Due to the inherent complexity of construction projects, it is likely that new information will arise during a project that would give rise to renegotiations or changes to the project design or execution. A flexible relationship between the main contractor and other firms in the project is likely to facilitate identifying the most efficient solution regarding both quality and cost for the project as a whole. In order to assess this flexibility, site meetings and contractual agreements will be studied.

(2) *Additional work* is often initiated by the main contractor due to shortcomings in the contracting documents (Nyström, 2008). This type of work is unexpected and thus adds an additional expense to either the client or the main contractor depending on the contractual agreement. This extra work is often caused by insufficient collaboration between the client, main contractor, architect and engineers or lack of experience with the construction type. In order to assess additional work, site meetings will be analysed.

(3) *Disputes*. Larson (1995) argued that partnering was a tool to avoid expensive litigations. However, many disputes arising in the construction project does not end up in court (Pinnel, 1999). Identifying how disputes are handled between firms in the project provide further information about the collaboration climate in the project, for instance, disputes can be handled smoothly or they could hold up the project. Site meetings and formal correspondence will be used to assess how disputes are handled.

(4) *Unsatisfactory quality.* Due to the subjective nature of quality, it may often be problematic to interpret the intended level of quality requirements in contractual documentation. Lack of experience with the specific project type or poor collaboration between firms may cause an asymmetry regarding the intended and executed level of quality. Unsatisfactory quality may lead to disputes, potentially followed by rework. Site meeting minutes and formal correspondence will be used to evaluate how unsatisfactory quality affects the project.

Judging the quality of research

Yin (2008) argues that four tests are commonly used to establish the quality of empirical social research:

(1) *Construct validity*. Includes identifying the correct operational measures for the concepts that are being studies.
(2) *Internal validity.* Concerns seeking to establish a casual relationship between conditions, whereby certain conditions are believed to lead to other conditions.
(3) *External validity.* Regards defining the domain to which the findings of a study can be generalized.
(4) *Reliability.* Demonstrates that the operations of the study can be repeated with the same results.

Construct validity and internal validity has been discussed in detail in the first two parts of Chapter III. The measurement problems of time, cost and quality performance have been discussed, and the conceptual link between performance and the learning curve effect has been examined and established. Key informants in MC have reviewed this report, evaluated the analysis, discussion and conclusion. In addition, rival explanations to the study findings are discussed in Chapter V.

An important factor to address regarding internal validity is the relationship between project variables and the performance measurements in question. This relationship is discussed and analysed in chapter IV.

External validity covers the question of generalization. Although this study is limited to a particular type of construction project with one specific main contractor, neither the construction type and process nor the main contractor and other firms involve are particularly unique. In addition, the theory applied in this case study is developed from a range of different construction project types, contractor types and geographical locations.

In terms of reliability, the data sources utilized and the link between data and operational measures in question have been documented and discussed in Chapter III. Each data point is described in detail in chapter IV. The data types are not unique for the specific research cases, and are commonly available in construction projects.

A practical summary of design and methodology

The following step-by-step description of the study design and methodology concludes this chapter. It is presented for researchers and other interested individuals to repeat this study:

(1) Identify several similar consecutive construction projects where the main contractor has utilized a significant amount of the same engineering firms, sub-contractors and suppliers
(2) Conduct an initial screening of project documentation to identify if the necessary data is comparable across the selected projects
(3) Evaluate the initial screening to identify if the data is able to fulfil the three criteria presented earlier in chapter III.
(4) Define a threshold for which events should be included in the study, and which should be disregarded in terms of importance. For this particular study, the requirement of formal correspondence was chosen
(5) Identify events that negatively affected the presented performance variables by analysing site meeting minutes, formal correspondence and/or similar documentation
(6) Validate these events by presenting them to key project individuals such as the main contractor's Project Managers
(7) Map similar contracts across all projects into specific contract types and map all firms to each type of contract
(8) Map the identified events to each firm and contract type in each project
(9) Analyse the findings and identify the firm experience ratio and issue experience ratio
(10) Validate the findings with key project individuals

Chapter IV: Data Analysis

Project variables

It is imperative to control for other variables when analysing the effects of partnering and learning. This chapter summarizes key variables in the three construction projects and discuss how they may affect project performance.

Ideally, a solid theoretical foundation to identify which key variables to control for should have been utilized. However, the author has not been able to identify any theoretical frameworks or previous works that outlines important construction project variables affecting time, cost or quality in relation to the learning curve effect and partnering. Therefore, a simple framework has been developed. The following four variables will be controlled for in this thesis:

(1) Client procurement method and key standards
(2) Size of project
(3) Involved firms
(4) Geographical location and other external factors

Client procurement method and key standards define the level of quality requirements for the building. As a result, different procurement methods and standards require different levels of quality. For instance, the quality requirement of a wall in a hospital operating room is significantly higher than the requirements of a wall in a storage facility. Therefore, constructing the wall in the hospital operating room is significantly more difficult, requires more skilled labour, and is more costly than a wall in a storage building and more sensitive to quality deviations.

The size of a construction project affects time, cost and quality performance. Additionally, the size of the project affects the information distribution, coordination and communication requirements for the project. As complexity rises due to increased project size, it is expected that more issues arise due to difficulties in coordination and communication.

Controlling for involved firms is particularly important as this variable is expected to affect the learning curve effect. The premise of this thesis is that learning affects project cost, time and quality performance, making it obvious to control for this variable.

Geographical location and other external factors are expected to affect both time and cost performance. Factors such as weather, climate, bedrock hardness and seasonal variations can all cause delays, hold-ups or even damage the unfinished construction.

The four previously mentioned variables will be analysed for all three construction projects in the next section.

Client procurement method and key standards

Project A

MC delivered a standard design-build contract NS3431. The tender was divided into three elements:

A) The school
B) A multipurpose gymnasium
C) Public road

Tolerance class was set according to NS3420-0, and surface finish was set according to tolerance class B (2) table 2 in NS3220-0. The concrete elements were designed according to NS3473 and build according to NS3465. Steelworks was designed according to NS3472 and built according to NS3464. Woodworks were designed according to NS3470 (part 1 and 2). Reliability requirements were set according to NS3490. All ductworks are conducted according to NS3560 and NS3561.

Project B

MC delivered a standard design-build contract NS3431. The tender was divided into four elements:

A) The school
B) A gymnasium
C) Public road, sewage and waterworks
D) Contaminated soil

Tolerance class was set according to NS3420-0, and surface finish was set according to tolerance class B (2) table 2 in NS3420-0. Concrete elements were designed according to NS3473 and built according to NS3465. Steel constructions were designed according to NS3472 and built according to NS3464. Woodworks were designed according to NS 3470 (part 1 and 2). Reliability requirements were set according to NS3490. Ductworks are conducted according to NS3560 and NS3561. The project was conducted according to TEK07 regulations.

Project C

MC delivered a standard design-build contract NS3431. The tender was structured as one element:

A) School with an integrated gymnasium, a separate parking lot and large outdoor works

Tolerance class was set according to NS3420-0, and surface finish was set according to tolerance class B (2) table 2 in NS3420-0. Concrete elements were designed according to NS3473 and built according to NS3465. Steel constructions were designed according to NS3472 and built according to NS3464. Woodworks were designed according to NS 3470 (part 1 and 2). Reliability requirements were set according to NS3490. All ductworks are conducted according to NS3560 and NS3561. The project was conducted according to TEK07 regulations.

Summary

All three projects share similar client procurement methods. Key standards are similar across all projects. Project B and C was both conducted according to TEK07, which entails stricter environmental requirements. Overall, some differences exists between each project, but nothing that is expected to affect cost, time or quality performance significantly.

Size of Projects

Project A

This project was designed to accommodate around 540 pupils and 60 employees. The gross contract size of each element was:

A) The School: MNOK 66
B) A multipurpose gymnasium: MNOK 12
C) Public road: MNOK 1

The school building and gymnasium is 5760 and 2020 net square meters respectively.

Project B

The project was designed to accommodate around 540 pupils and 50 employees. The gross contract size of each element is:

A) The school: MNOK 102
B) A gymnasium: MNOK 43
C) Public road, sewage and waterworks: MNOK 10
D) Contaminated soil: MNOK 2

The school building and gymnasium is 6696 and 2709 net square meters respectively.

Project C

The project was designed to accommodate around 1300 pupils and 300 employees. The gross contract size of each element is:

A) The complete contract: MNOK 298

The school building is 21351 net square meters.

Summary

Project A and B are quite similar in size, however project C is considerably grander in size and contractual cost. In general, project C is expected to exhibit significantly more issues and challenges related information distribution, communication and coordination due to the scope of the project. These differences have to be accounted for when comparing each project and the involved firms with respect to the learning curve effect.

Involved firms

Table 3 includes key firms contractually involved in design and construction of the three projects. A light green cell indicates that the firm is involved in several school projects. A dark green cell indicates that the firm has previous experience at the specific contract in a previous MC school project. The number in parenthesis behind a selection of the firms indicates the total number of school projects it has collaborated with MC[1]. The blank cells are either a result of lacking data or that the specific contract not fulfilled in the particular project. Either option cannot be determined by the provided data.

Notice: All firm names are anonymized.

Table III: Key contracted firms

Type of contract	Project A	Project B	Project C
Client	Hengsha county (3)	Hengsha county (4)	Diagong District
Project management	Belltower Properties / Sarif management (3)	Belltower Properties / Sarif management (4)	Diagong District
Building architect	Grayson Architecture (3)	Grayson Architecture (4)	Grayson Architecture (5)
Landscape architect	Milwaukee Architecture	Milwaukee Architecture	Chiron Arch*
Civil engineering		MC	MC
HVAC engineering	Typhoon Engineering	Typhoon Engineering	Typhoon Engineering
Energy engineering			Typhoon Engineering
Electrical engineering	Typhoon Engineering	Typhoon Engineering	Typhoon Engineering
Acoustics engineering	Van Breen Engineering	Van Breen Engineering	Van Breen Engineering
Fire engineering	MC	MC	Praxis
Geotechnical engineering	Tai Yong Engineering	Bliderberg Group	XNG
Environmental engineering		Bliderberg Group	XNG
Road and infrastructure engineering	MC	MC	

[1] Notice from author: This number is only applied to firms confirmed through project documentation provided by MC. Some firms may have been involved in previous projects, but has not been mentioned in the given documentation and has not been accounted for.
* Milwaukee Architecture was restructured and rebranded to Chiron arch

Demolitions	Steiner-Bisley Demolitions	Steiner-Bisley Demolitions	Steiner-Bisley Demolitions
Outer wall elements	Sasiuk Elements	Versa Walls	
Facades			Page Industries
Site ground works			X-51
Rebar works	Silouette steel	Silhouette Steel	United Rebars
Prefabricated concrete elements	Zyme Elements	DX3 Zenith	DX3 Zenith
Concrete works	MC	MC	MC
Steel, stairs and handrails	Hengsha Steelworks		Hengsha Steelworks
Roof works	Kubrick United	Pritchard	Ter Horst Roof Service
Window supplier	Mantega Timber Supplies	BriSun	Mantega Timber Supplies
Tinner	Kubrick United	Thomas Shea	Denton Tin
Glass and aluminium works	Reyes	Ford Glass Edge	Saman Industry
System ceilings and walls	Ubair Systems	Ubair Systems	Soundscape
Elevator	Patton Elevators / TRAC	TRAC	Patton Elevators
Paint works and floor covering	JC Denton	Maxwell and Nassif	Highland Paint
Parquet			GJ Floor Systems
Plumbing	A Jensen (3)	A Jensen (4)	A Jensen (5)
Electrical works	Jiu (3)	Tong Si Electrical	Tong Si Electrical
HVAC	Malik HVAC (3)	Sanders Technology	Ban-K
Building automation	DE	Siemens	Ban-K
Laboratory equipment and furnishing	Mei Suen		Mei Suen
Gymnasium floor	M.B. Taggart		United Sportsystems
Gymnasium equipment	Mueller Industries	O'Mally Sport	- no contract -
Gates	- no contract -	- no contract -	Chet Technologies
Doors, locks and lock cases	Colvin Systems	Colvin Systems	Darrow Projects
Inner walls			Saman Industry
Kitchen / furniture	Bale Interiors	Panchaea Woodworks	NTE
Blacksmith		Hengsha Steelworks	Hengsha Steelworks
Tiles, walls and plastering	Reng Z. Tsai	Page Industries	Reng Z. Tsai / Page Industries
Heavy Machinery		Deus Crest	Deus Crest

In general, MC has contracted a significant number of the same firms for design and engineering across all three projects. MC has to a lesser extent contracted the same sub-contractors and suppliers across several projects. Several firms have been involved in all three projects, either fulfilling the same type of contract or different contracts in each project.

Across all three projects, 41 contracts are fulfilled by firms with previous experience at the same type of contract in an similar MC project. 66 contracts are fulfilled by firms with no previous experience in a similar MC project.

Geographical location and other external factors

Project A

The project is built in Hengsha County. No documented extraordinary external factors such as weather affected the construction project in significance. The HVAC system is designed for temperature interval between -19 degrees centigrade and +23 degrees at 60% relative humidity. All aspects of Belltower Properties' requirement specification KS00001 are fulfilled.

Project B

The HVAC system is designed for temperature interval of -19 degrees centigrade and +23 degrees at 60% relative humidity. All aspects of Belltower Properties' requirement specifications KS00001 are fulfilled. The project is built in Hengsha County. No documented extraordinary external factors such as weather affected the construction project in significance.

Project C

The HVAC system is designed for temperature interval of -19 degrees centigrade and +23 degrees at 60% relative humidity. The project is built in Hengsha County. No documented extraordinary external factors such as weather affected the construction project in significance.

Summary

All projects are situated in the same region, located within 10 miles of each other, are subject to similar regulations and neither experienced any extraordinary external factors that affected cost, time or quality performance.

Project evaluation

The following presented events are issues and/or disputes that negatively affect time, quality or cost performance in the project, where formal letter exchange between MC and one or several other parties occurred. Formal correspondence is reviewed alongside site meeting minutes and presented project by project followed by a summary. Each event heading is colour coded to illustrate the experience level of the firm in question. A green bold heading indicates an experienced firm, and a black normal-weighted heading indicates an inexperienced firm. The analysed events cover the construction period only. Events that were identified after handover has not been included.

Project A

Event #1: Zyme Elements

Before initial contract signing, Zyme Elements informed MC that it would not be able to provide prefabricated concrete elements according to the project schedule due to lack of production capacity. MC adjusted the general project schedule to take into account the limited production capacity. Several issues occurred due to poor coordination and communication, lack of production capacity, and a key employee at Zyme Elements had en eye surgery and was absent without a replacement. The schedule slipped by six weeks. The prefabricated concrete element schedule is vital to the overarching project schedule, thus delaying the entire project by 6 weeks.

After handover, several holes were drilled in the prefabricated elements in order to assemble electrical articles. During drilling, several pockets of water trapped in the prefabricated elements were punctured. The water leaked through the holes onto an art installation, damaging the installation.

In addition to the six weeks of delay and a damaged art installation, 68 meetings and correspondence exchanges between the parties has been accounted for. This significant communication overhead is not only costly for both parties, but tie up man-hours that could be used elsewhere in the project. This event greatly affected the project's cost and time performance.

Event #2: Mueller Industries

During handover, the building owner informed MC that several elements of Mueller Industries' contract were not fulfilled. This included several articles of sport equipment and a sound dampening movable wall divider. MC was forced by the building owner to contract Van Breen Engineering for testing and documentation of the wall divider, as Mueller Industries did not provide the necessary O&M documentation. The testing concluded that the sound dampening was 30% lower than the requirement specifications.

Mueller Industries' lack of conformance to quality requirements negatively affected the project's cost performance.

Event #3: M.B. Taggart

The gymnasium floor passed all tests upon handover to the building owner. However, the floorboards began to separate from each other at various locations less than six months after installation.

M.B. Taggart's lack of conformance to quality requirements negatively affected the projects cost performance. In addition, the gymnasium was unusable for a period of time, thus significantly affecting the project's time performance.

Project B

Event #1: Steiner-Bisley Demolitions

In a letter dated 20th of August 2008, MC issues a formal warning of potential delay penalties to Steiner-Bisley Demolitions. Steiner-Bisley Demolitions' offer, dated the 12th of December 2007, detailed that an activity schedule would be established after the contract was won. MC accepted a verbal agreement prior to the summer holidays that Steiner-Bisley Demolitions could conduct decommissioning works throughout week 32 on the premise that the firm would provide an activity schedule. This schedule was not provided as of the 14th of August, and MC representatives met on-site with Steiner-Bisley Demolitions' representatives to discuss the issues at hand. MC later gave Steiner-Bisley Demolitions a deadline to the 1st of September to finish the decommissioning works.

No further formal correspondence has been recorded, nor any evidence of delay penalties. Thus, this incident did not affect the time performance of the project. The unnecessary correspondence and meetings had a minor effect on the project's cost performance.

Event #2: Ubair systems

In a letter dated 30th of November 2009, MC formally warned Ubair systems of potential intervention due to delays. MC required Ubair systems to provide an overtime schedule to make up for the lost progress. This letter was filed after the protocol for contractual handover with the sub-contractor was signed. During a meeting the 8th of December, the remaining issues was discussed and solved.

This incident did not affect the overall time performance of the project, but had a minor impact on the cost performance of the project due to unnecessary meetings and coordination.

Event #3: Panchaea Woodworks

The 30th of October 2009, MC formally warned Panchaea Woodworks of potential intervention due to delays. MC required Panchaea Woodworks to provide an overtime schedule to make up for the lost progress. The 20th of November, MC signed the protocol of contractual handover according to schedule. Thus, Panchaea Woodworks did not negatively affect the project's time performance, and barely affected it's cost performance.

Event #4: Page Industries

The 30th of October 2009, MC formally warned Page Industries of potential intervention due to delays. MC required Page Industries to provide an overtime schedule to make up for the lost progress. According to schedule MC signed the protocol of contractual handover the 20th of November. Thus, Page Industries did not negatively affect the project's time performance, and barely affected it's cost performance.

Event #5: Colvin Systems

The 30th of October 2009, MC formally warned Colvin Systems of potential intervention due to delays. MC required Colvin Systems to provide an overtime schedule to make up for the lost progress. According to schedule, MC signed the protocol of contractual handover the 20th of November. Thus, Colvin Systems did not negatively affect the project's time performance, and barely affected it's cost performance.

Event #6: O'Mally Sport

During an equipment inspection the 26th of November 2009, cracks in several articles of sports equipment and a faulty electric engine for the wall divider was identified. An investigation into the faulty deliveries revealed that the articles were damaged by weather during outdoor storage. O'Mally Sport later claimed that MC was responsible for proper storage; however this was not a part of the contractual agreement with the parties, and the claim was disregarded. The event negatively affected the project cost performance.

Project C

Event #1: Deus Crest

The 15th of May 2012, MC filed a formal letter to Deus Crest, rejecting a warning of debt collection. Multiple meetings had been conducted regarding this specific warning of debt collection and two other unresolved similar warnings. MC argued that the invoices in question had been disputed as MC had filed formal complains regarding Deus Crest's work. The issue was later resolved through meetings and formal correspondence. The unnecessary time spent in this dispute negatively affected the project's cost performance.

Event #2: Highland Paint

During final account negotiations, Highland Paint and MC exchanged 19 letters and conducted several meetings to agree upon the cost several change orders. The case was eventually resolved after a significant amount of negotiations, affecting the projects cost performance negatively.

Event #3: Saman Industry

An inspection by MC at Saman Industry's factory the 7th of September revealed several pressing issues. Prior to inspection, Saman Industry was 8 and 5 weeks behind schedule with respect to Part 1 and Part 2 of their contractual delivery. Saman Industry revised their schedule to make up for lost progress, however the following findings were expressed after the inspection:

(1) Production was not set up according to Saman Industry's revised plan
(2) Deliveries to the construction site was not conducted according to the revised plan
(3) Saman Industry had insufficient control of what was produced in the factory
(4) Saman Industry's production was not in accordance to assurances given in a meeting September 6th

MC further demanded a day-to-day schedule for production and a formal confirmation that the factory management had committed to the schedule. In a letter dated 5th of October, MC expresses that site coordination had been hampered due to additional delays by Saman Industry and formally warned of potential delay penalties. The 10th of October, a Saman Industry truck transporting supplies from the factory broke down, causing further delays. Additionally, Saman Industry's on-site project manager stopped showing up for work.

The 4th of November, MC formally requested documentation of fire resistance for several wall partitions after delays. MC notified Saman Industry that an invoice due November the 15th would be retained if Saman Industry did not comply. This deadline was not met, and despite several letters from MC, Saman Industry did not reply regarding this issue until the 8th of February 2012. The 13th of February 2012, MC reserved rights to claim compensation regarding the documentation issue and other issues occurring on-site.

After many letters and conversations, Saman Industry conducted the required tests to document the wall partitions in a Swedish laboratory. A law firm confirmed the documentation July 5th 2012.

During on-site quality inspection in July, MC identified 64 doors that did not comply with sound and fire quality regulations. Saman Industry claimed that 18 doors did not comply. After a period of dialogue, all 64 doors were repaired in early August. In December, additional claims were made from the building owner. Several doors, including those previously repaired, had malfunctions. In total, 74 doors did not comply with contracted specifications and had to be repaired less than one year after handover to the client.

These series of events drastically affected the projects time, cost and quality performance.

Event #4: X-51

In a final account negotiations meeting dated the 7th of February 2013, several issues regarding X-51's work was discussed. MC withheld a significant amount of the contract payment as multiple aspects of X-51' contract delayed or not accounted for. In total 11 issues regarding warranty or lack of conformance to contracts was unsolved and deadlines had to be postponed. This issue negatively affected the project's cost and time performance.

Event #5: Ter Horst Roof Service

MC filed a formal letter to Ter Horst Roof Service, rejecting a warning of debt collection 10th of May 2012. Phone conversations and formal correspondence had been conducted regarding this specific warning of debt collection and other unresolved similar warnings. MC argued that the invoices in question had been disputed as MC had filed formal complains regarding Ter Horst Roof Service's work. The issue was later resolved through meetings and formal correspondence. The unnecessary time spent in this dispute negatively affected the project's cost performance.

Summary

14 events that negatively affected time, cost or quality performance has been identified. Some are more severe than others. All events are significant, as they required formal letter correspondence between the prime contractor and the other party.

The most noticeable finding is that only three of fourteen events involve an external firm with experience from the same contract in a previous MC school project. Furthermore, two of these three events have a minor performance impact compared to the average finding. The following table sums up the key findings from the analysis.

Table IV: Key analysis findings

Key variables	***Project A***	***Project B***	***Project C***
Client procurement method	NS3431	NS3431	*NS3431*
Key standards	NS3420-0 NS3220-0 NS3473 NS3465 NS3472 NS3464 NS3470 (part 1 and 2) NS3490 NS3560 NS3561	NS3420-0 NS3220-0 NS3473 NS3465 NS3472 NS3464 NS3470 (part 1 and 2) NS3490 NS3560 NS3561	NS3420-0 NS3220-0 NS3473 NS3465 NS3472 NS3464 NS3470 (part 1 and 2) NS3490 NS3560 NS3561
Contract Value	MNOK 79	*MNOK 157*	MNOK 298
Building size	5760 + 2020 m^2	6696 + 2709 m^2	21351 m^2
Contracts fulfilled by experienced firms	7	*16*	*18*
Contracts fulfilled by inexperienced firms	26	*18*	22
Firm experience ratio	***7 : 26 = 0.26***	***16 : 18 = 0.88***	**18 : 22 = 0.81**
Events related to experienced firms	*0*	2	*1*
Events related to inexperienced firms	*3*	*4*	*4*
Event experience ratio	***0 : 3 = 0***	***2 : 4 = 0.5***	**1 : 4 = 0.25**

Chapter V: Discussion

The most noticeable finding in this study is that only three of fourteen events negatively affecting performance involve an external firm with specific related experience from a previous MC project. In all evaluated projects, the firm experience ratio is higher than the event experience ratio. On the basis of these findings, it can be advocated that experienced firms contribute to fewer negative events than inexperienced firms.

The following chapter discusses how these findings may be related to the previously presented theories and the validity of the analysis.

The learning curve effect

Gidado (1996) argued that the learning curve effect could be used to explain the lack of productivity improvements in the construction industry. On the same note, the author believes the learning curve effect can be used to explain the results of this study.

The learning curve concept is generally used to explain organizational or individual learning in environments with a high degree of repetition and high amount of repetition, such as manufacturing plants with a standardized product series. In this study, the theory is applied to three construction projects in a total series of six similar construction projects.

In light of the learning curve concept, each construction project can be interpreted as a production series. Each series consists of a myriad of small and repeated tasks, such as installing a door, assembling a ceiling tile or pouring concrete into a prefabrication mold. For every repetition, each involved individual's performance is slightly improved. Similarly, each meeting, phone call and letter should gradually improve each firm's communication and coordination with the other firms.

The transition from one project to another can be viewed as an interruption or model change. As such, the fewer variables that has changed, the more experience from the previous model can be applied in the production of the new model. Traditionally in construction, few variables remain similar between projects. As a result, the level of learning that could be transferred to another project was low.

As a majority of the variables in the presented construction projects are similar, the discontinuities normally seen between projects are reduced. Hence, the potential of reusing experience and solutions from previous projects can to a much greater extent be realized.

The study findings uncovered that a firm with previous experience from a MC school project performs better than a firm without experience. With this result in mind and the presented theory, it can be argued that these firms have learned how to better handle this specific situation of construction through previous learning.

It is expected that the best conditions for transferring learning between projects exist when the inherent variables of the construction projects, such as size, legislations, building type, standards of quality and execution along with other external factors are as similar as possible. This fundament of similar conditions is best exploited by a group of firms that has worked together in these similar types of construction projects.

Whereas Gann (1996) studied projects where '*each building is treated as a prototype without a history or feature*', this study has identified a series of construction projects where firms and processes are reused to a significant extent. It can therefore be argued that the fundamental necessities for organizational and labor learning are present in the evaluated series of projects.

Given the broad utilization of the learning curve concept in other industries (Yelle, 1979), the author believes it represents the most viable theory for explaining the findings of this study. A conceptual link between the learning curve concept and the evaluated construction projects is illustrated in figure 4.

Figure 4 illustrates such a case with four construction projects, and how a firm such as a sub-contractor, supplier or engineer will gradually decrease direct labour hours per activity as the firm's experience increase. Despite a noticeable discontinuity between each project, the amount of similar variables enables more experience to be applied into the next project. Over time, this approach should result in improved project performance for the prime contractor and the experienced supporting firms through the learning curve effect.

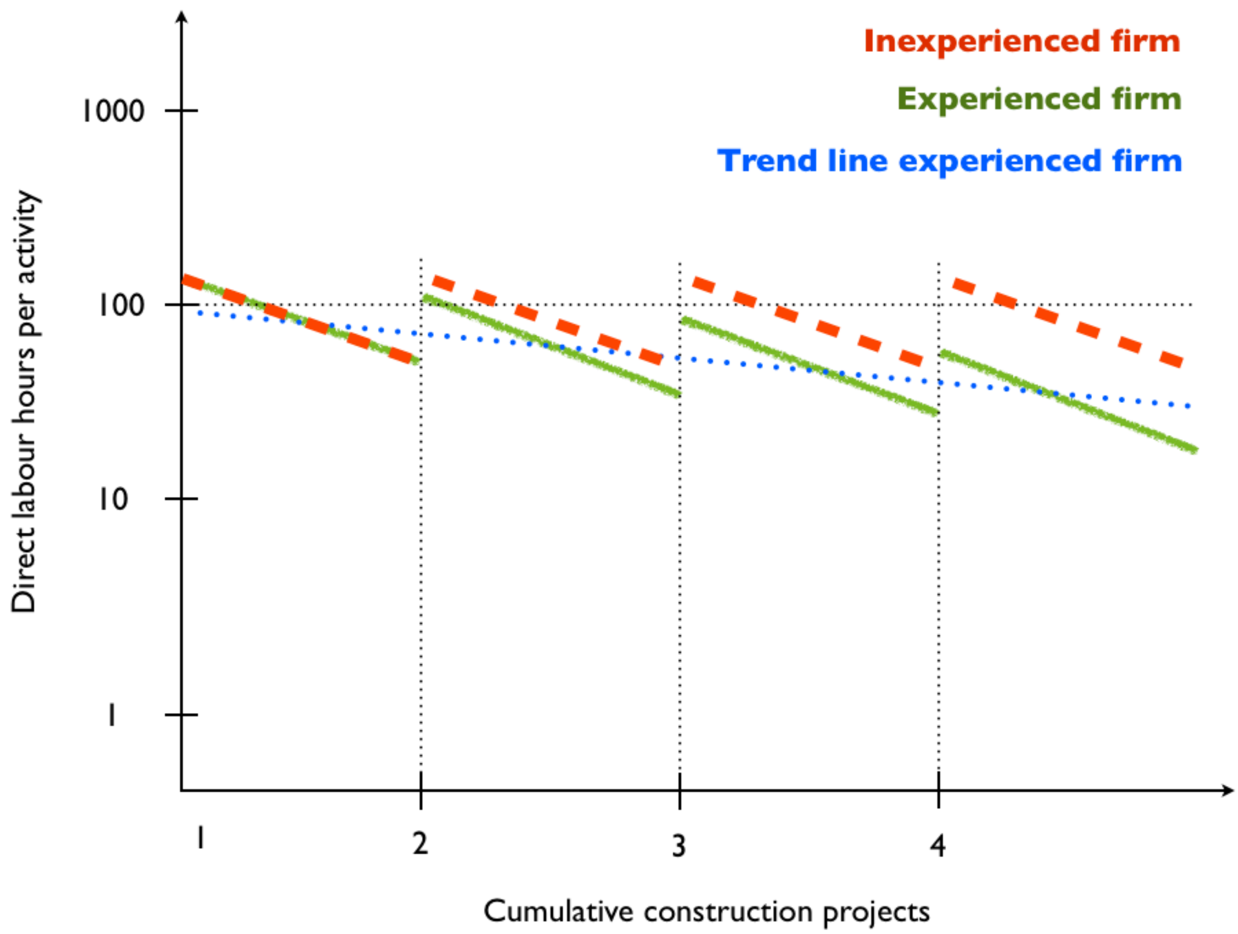

Figure 4: Conceptual illustration of the learning curve effect in multiple construction projects with a high degree of similar variables.

Trust-based relationship and less formalized communication

Although the learning curve concept is assessed to be a strong explanation for the study findings, other theories should be assessed to evaluate the validity of this research (Yin, 2008).

The study analysed formal project documentation to evaluate the performance of each involved firm. Potentially, a more trust-based relationship could develop between MC and other firms, which in turn could result in less formalized communication (Wood et al. 2002). Less formalized communication could in turn affect the study findings, as events with a negative performance impact would not be documented through formal correspondence.

The analysed communication is an outcome of contractual obligations. Furthermore, the contractual agreement commands formalized communication between each party when disputes and issues regarding a contractually bound action is handled. It seems unlikely that MC would put itself at risk of litigation by breaching the contractually bound method of communication.

If MC had breached the contractually agreed form of communication, such as not sending a formal letter regarding a warning of intervention or delay penalties to suppliers or sub-contractors, all formal responsibility would be placed on MC. If a delay caused by a sub-contractor did affect the final handover date with the client, MC would then be contractually responsible to pay for the delays.

After conferring with key involved employees in each project with the study findings, several comments were made. First and foremost, the events described in Chapter IV were evaluated as the most severe events with a negative impact on project performance by key project individuals. Secondly, the contractual obligations and agreements are revered highly, and from a main contractors perspective, breaching the contractually agreed method of communication with sub-contractors, is not common practice. However, key individuals noted the threshold for sending a formal letter to a firm with a previous relation might be higher than a firm without a previous relation. Based on this feedback, the author finds it unlikely that a *'friendlier'* tone and a less formalized form of communication would significantly affect the result of the analysis.

The statistical significance of the study and generalization

To address the statistical significance of the findings, the following null hypothesis should be tested:

H_0: The probability that an inexperienced firm is related to an event that negatively affects performance is similar to that of an experienced firm.

Given that this study only uncovered 14 events, the author assessed that not enough data points are available to disregard the null hypothesis at a significance level of 0.1. Therefore, a broader set of data is needed to form a statistical foundation for a generalization.

Although the findings in this study do not qualify for statistical generalization, the theoretical foundation of this thesis is broadly applicable, and the external conditions are not particularly unique. The study findings clearly indicate a significant positive impact of partnering in construction projects from a MC point of view.

Chapter VI: Conclusion and Recommendations

Conclusion

This thesis aimed to answer the following research question:

Has MC's partnering strategy yielded performance improvements and an increased competitive advantage?

Theory from four relevant areas of research has been presented and a comparative qualitative case study was conducted. The study analysed 107 contracts across three construction projects and identified 14 events where formal communication was necessary to resolve issues and disputes that negatively affected time, cost of quality performance of the projects.

The analysis shows that firms fulfilling the same type of contract across several similar projects with MC performs better than firms without previous experience in a similar project type. In this respect, it is likely that MC's partnering strategy has yielded performance improvements in the evaluated projects. A definitive answer is not attainable without a true '*ceteris paribus analysis*'.

Given that MC has established a portfolio of experienced suppliers, sub-contractors and engineers in school construction projects, it also seems likely that MC has an increased competitive advantage over other prime contractors in it's operating region.

The learning curve concept is the leading hypothesis for explaining the study findings. By reducing the discontinuities between each project, project performance is improved. The results of this study is expected to be broadly generalizable, as neither the construction type and process nor the main contractor and other firms involved in the study are particularly unique.

Recommendations

For academics

The study has revealed compelling evidence that MC's partnering strategy has yielded performance improvements. The most obvious next step would be to analyse other series of construction projects with a high degree of similar variables with the same evaluation principles. Particularly other types of projects with other main contractors are highly interesting subjects of study to address the question of generalization.

Other interesting questions have arisen from this study such as; *to which extent must variables between two construction projects be similar for a noticeable learning effect to occur? How does building type and regulations affect the transformation of learning between a series of projects? How do the organization and the reorganization of individuals between projects affect performance?*

Further research should be conducted to review how actual working experience between parties affects the project performance over time. The conceptual link between the learning curve effect and partnering should be further evaluated, and links other theories, such as inter-firm social adaptation should be explored.

In addition, a more extensive link between project variables and their effect on time, cost and quality performance may lead to further insight into the inner workings of construction projects and better ways of evaluating different attempts to improve the industry performance.

For MC and other firms in the industry

Given the findings in this study, it may be recommended that MC should continue the practice of reutilizing the same key firms in future school construction projects. It is also recommended that the potential of replicating this strategy for other types of construction projects should be investigated.

Other main contractors in similar positions should investigate the possibilities of following in MC's tracks.

If more compelling evidence is found to support the findings of this thesis and the question of generalization is answered, the author suggests that main contactors should start building 'portfolios' of experienced sub-contractors, suppliers and providers engineering services for specific types of construction projects to improve project performance.

On a more strategic note, the findings seem to indicate an untapped potential of differentiation and specialization for firms in the industry. In an industry with low profit margins, fierce competition and a relatively large amount of homogenization, this should lead to improvements in the construction industry in terms of value for money, profitability and reliability.

Chapter VII: References

Akintoye, A., McIntosh, G. and Fitzgerald, E. (2000) A survey of supply chain collaboration and management in the UK construction industry. European Journal of Purchasing & Supply Management, 6, 159–68

Balnaves, M. and Caputi, P. (2001) Introduction to quantitative research methods: an investigative approach. London: Sage

Bayliss, R., Cheung, S-O., Suen, H. C. H. and Wong, S-P. (2004) Effective partnering tools in construction: a case study on MTRC TKE contract 604 in Hong Kong. International Journal of Project Management, 22(3), 253-263

Beach, R., Webster, M. and Campbell, K. M. (2005) An evaluation of partnership development in the construction industry. International Journal of Project Management, 23(8), 611-621

Beach, R., Webster, M., Campbell, K., (2005) An evaluation of partnership development in the construction industry. International Journal of Project Management 23, 611–621

Black, C., Akintoye, A. and Fitzgerald, E. (2000) An analysis of success factors and benefits of partnering in construction. International Journal of Project Management, 18(6), 423- 434

Bresnen, M., Marshall, N. (2000) Partnering in construction: a critical review of issues, problems and dilemmas. Construction Management and Economics 18, 229–237

Brown, D., Ashleigh, J., Riley, M., Shaw, R. (2001) New project procurement process. Journal of Management in Engineering 17 (4), 192–201

Carlson, J. G. (1961) How Management Can Use the Improvement Phenomenon. California Management Review, Vol. 3, No. 2, 83-94

Chan, A, Chan, D and Ho, K (2003) An empirical study of the benefits of construction partnering in Hong Kong. Construction Management and Economics, 21(5), 523-533

Chan, A. P. C., Chan, A. P. L. (2004) Key performance indicators for measuring construction success, Benchmarking; ProQuest 11(2) 203-221

Chan, A., Chan, D., Fan, L., Lam, P. and Yeung, J. (2005) Partnering for construction excellence - A reality or myth? Building and environment, *41*(12), 1924-1933

Chan, A., Chan, D., Ho, S. (2003) Partnering in construction: critical study of problems for implementation. Journal of Management in Engineering 19 (3), 126–135

Chandler, A. D. (1977) The visible hand: The managerial revolution in American business, Harvard University Press, Cambridge, Mass.

CII (1991) In Search of Partnering Excellence. CII Special Publications, Construction Industry Institute, Austin

Cox, R. and Goodman, C. (1956) Marketing of house building materials. Journal of Marketing, 21, 36–61

Crane, T. G., Felder, P. J., Thompson, M. G. and Thompson, P. J. (1999) Partnering Measures. Journal of Management in Engineering, 15(2), 37-42

Cross, K. F., and Lynch, R. L. (1988–1989) The SMART way to define and sustain success Nat. Product. Rev., 9(1), 23–33

Dainty, A. R. J., Cheng, M. and Moore, D. R. (2003). Redefining performance measures for construction project managers: an empirical evaluation. Construction Management and Economics, 21(2), 209-218.

Dubois, A. and Gadde, L.-E. (2000) Supply strategy and network effects: purchasing behavior in the construction industry. European Journal of Purchasing and Supply Management, 6, 207–15

Eccles, R. (1991) The performance measurement manifesto, Harvard Bus. Rev., 69(1), 131–137

Egan, J. (1998) The Report of the Construction Task Force: Rethinking Construction. Department of the Environment, Transports and the Regions, London

Ellison, S. D. and Miller, D. W. (1995) Beyond ADR: Working Toward Synergistic Strategic Partnership. Journal of Management in Engineering, 11(6), 44-54

Emsley, M W (2005) A benefits analysis of partnering: a case study of a community primary school in the UK. Journal of Financial Management of Property and Construction, 10(1), 69-79.

Fallrø K. (2012) Prestasjonsmåling og kontunerlig forbedring i byggenæringen: analyse av kontekst og konsekvenser for implementasjon. Prosjektoppgave høstsemesteret 2012. Institutt for industriell økonomi og teknologiledelse. Trondheim, NTNU

Fortune, C. and Setiawan, S. (2005) Partnering practice and the delivery of construction projects for Housing Associations in the UK Engineering. Construction and Architectural Management, 12(2), 181-193

Gaddis, P. (1959) The project manager. Harvard business review, 37(3), 89-97

Gann, D. M. (1996) Construction as a manufacturing process? Similarities and differences between industrialized housing and car production in Japan. Construction Management & Economics, 14(5), 437-450

Gidado, K. I. (1996) Project complexity: the focal point of construction production planning. Construction Management and Economics, 14, 213–225

Gransberg, D., Dillon, W. D., Reynolds, L. and Boyd, J. (1999) Quantitative analysis of partnered project performance. Journal of construction engineering and management, 125(3), 161-166

Green, S.D. (1999) Partnering the propaganda of corporatism. Journal of Construction Procurement, 5(2), 177–86

Haksever, M., Demir, I. and Giran, O. (2001) Assessing the benefits of long-term relationships between contractors and subcontractors in the UK. International Journal for Construction Marketing, 3(1)

Holti, R., & Standing, H. (1996). "Partnering" as Inter-related Technical and Organisational Change: Background Paper Prepared for the Workshop Current Research on Partnering and Supply Chain Management, Salford University, 13 May 1996. Tavistock Institute

Kaplan, R. S., and Norton, D. P. (1992) The balanced scorecard— Measures that drive performance, Harvard Bus. Rev., 70(1), 71–79

Kaplan, R. S., and Norton, D. P. (1996) Using the balanced scorecard as a strategic management system, Harvard Bus. Rev., 74(1), 75–85

Lancaster, K. (1966) A New Approach to Consumer Theory. Journal of Political economy, 74, 132-157

Larson, E. (1995) Project partnering: results from a study of 280 construction projects. Journal of Management in Engineering 11 (2), 30–35

Latham, M. (1994) Constructing the Team. HMSO, London

Letza, S. R. (1996) The design and implementation of the balanced scorecard. Bus. Process Reengineering Manage. J., 2(3), 54–76

Lijphart, A. (1971) Comparative politics and the comparative method. The American Political Science Review, 65(3), 682-693

Luck, R. (1996) Construction Project Integration Strategies. Department of Construction Management and Engineering, University of Reading

Neely, A. (1999) The performance revolution: Why now and what next? Int. J. Operat. Product. Manage.19(2), 205–228

Neely, A., and Adams, C. (2001) The performance prism perspective, Journal of Cost Management, 15(1), 7–15

Neely, A., et al. (2000) Performance measurement system design: Developing and testing a process-based approach Int. J. Operat. Product. Manage., 20(10), 1119–1145

Nyström, J. (2006) The naivety of partnering assessments. Construction in the XXI Century: Local and Global Challenges

Nyström, J. (2008) A quasi-experimental evaluation of partnering, Construction Management and Economics, 26:5, 531-541

Parmenter, D. (2010) Key performance indicators (KPI): developing, implementing, and using winning KPIs. Wiley

Pinnel, S. (1999) Partnering and the management of construction disputes. Dispute Resolution Journal, 54(1), 16-22

Ruff, C. M., Dzombak, D. A. and Hendrickson, C. T. (1996) Owner-contractor relationships on contaminated site remediation projects. Journal of Construction Engineering and Management, 122(4), 348-353

Shammas-Toma, M., Seymour, D. and Clark, L. (1998) Obstacles to implementing total quality management in the UK construction industry. Construction Management and Economics, 17, 177-192

Smelser, N. J. (2003) On comparative analysis, interdisciplinary and internationalization in sociology, International sociology 18(4), 643-657.

Smunt, T.L. (1999) Log-linear and non-log-linear learning curve models for production research and cost estimation. Int. Prod. Res., 37(17), 3901-3911

Stortingsmelding 28 (2012) Gode bygg for et bedre samfunn. Det kongelige kommunal- og regionaldepartementet. Godkjent 15. Juni 2012. Oslo: Regjering Stoltenberg II

Teune, H. and Adam P. (1970) The logic of comparative social inquiry, New York, John Wiley & Sons

Vassie, L. H. and Fuller, C. W. (2003) Assessing the inputs and outputs of partnership arrangements for health and safety management. Employee Relations, 25(5), 490-501

Wilson Jr., R.A., Songer, A.D., Diekmann, J. (1995) Partnering: more than a workshop, a catalyst for change. Journal of Management in Engineering 11 (5), 40–45

Wood, G., Ellis, R. (2005) Main contractor experiences of partnering relationships in UK construction projects. Construction Management and Economics 23, 317–325

Yelle, Louis E. (1979) The learning curve: Historical review and comprehensive survey. Decision Sciences 10.2, 302-328

Yin, R. (2008) Case study research: design and methods, fourth edition. Thousand Oaks: Sage.