QUALITY IN CONSTRUCTION: A SUPPLY CHAIN PERSPECTIVE

Christian Koch[1] and Casper Schultz Larsen[2]

Department of Civil Engineering, Technical University of Denmark, DK- 2800 Lyngby, Denmark

Often the construction supply chain is perceived as consisting of two intertwined streams; a stream of materials and a stream of immaterial informational character. Moreover the supply delivery would be characterized by configuration by project. That this configuration is not always successful can be demonstrated by studying the emergence of failures occurring in the supply chain. The paper conceptualises the construction supply as a delivery network being partially stable, partially project specific and configured. It moreover develops a frame of understanding of the handling of quality issues in the delivery network, using operation management approaches. The paper presents case study work done in Danish construction. The method was observation of work at the construction site followed by interviews with actors backwards upstream the supply chain to the origin of the failure. The building project followed generated 160 failures over a three month observation period. The economic consequences are calculated to 8% of the production costs. The analysis of relations in the supply network showed that most of the failures were generated in the knowledge stream and then occasionally transformed into the material stream. The paper proposes initiatives to strengthen partnerships in supply chains, especially at mixed stable and project configured types. The contradiction between permanent enterprise organisations potentially capable of handling purchasing and the role of the project manager is discussed as a contradiction to overcome.

Keywords: failures, formal and informal quality management, supply chain types.

INTRODUCTION

The aim of this paper is to analyse the handling of failures in project configured supply chains. The paper proposes a theoretic conceptualization of the building process from an operational management approach as project configured supply networks of materials and knowledge considering quality in operations, site management activities and failures. Based on a study on failures in a Danish construction housing project (Apelgren *et al.* 2005) quality in the construction process is examined from a supply chain perspective.

In Denmark failures in construction is a topic of current interest, and The Danish Building Research Institute (SBI) estimates that the annual costs of failures in the Danish construction industry is almost 12 billion dkr. (1.7 billion euros) or almost ten percent of the total production value. As a result of the findings and the general focus on quality and failures in building processes the participants of the Danish building trade has initiated actions to reduce the expenses to 50 % before the end of 2008 (EBST 2005). An obligatory evaluation system in state contracts was enforced by July

[1] ck@byg.dtu.dk
[2] csl@byg.dtu.dk

Koch, C and Larsen, C S (2006) Quality in construction: a supply chain perspective. *In:* Boyd, D (Ed) *Procs 22nd Annual ARCOM Conference,* 4-6 September 2006, Birmingham, UK, Association of Researchers in Construction Management, 459-469.

2005, which can be a turning point in Danish Construction. The Benchmark Centre for the Danish Construction Sector will develop an important database of performance indicators that can be extremely instrumental in creating operational innovation and improved quality, where the data shows its needed (BEC 2005).

The paper is structured as follows. It opens with methodological remarks regarding the data sampling done. Then the theoretical frame is presented focusing on project configured supply networks and defining quality in operations management. A presentation of the findings of the case is presented, with two illustrative examples presented to illustrate that supply chain networks of materials and knowledge intertwine. Finally discussion, conclusions and implications deals with the role of supply networks in the handling of failures at the construction site.

METHOD

The applied approach was to observe construction work at the site, mapping the failures as they occur downstream during the production of the building. In a period of three month an observer followed the daily execution of work at the building site. From here, the analysis of each failure goes upstream to suppliers both in the knowledge and the material stream. Data was collected from one-on-one observations directly on the site, from observing conversations in the site-office and from attending the site-meetings. In total 38 observation days, sampling 160 failures in total and 1 to 10 failures per day and 4 in average. The project followed was a medium sized building project of 27 low building apartments. The budget was at 4.4 million Euros.

The upstream interviews covered 10 actors in the knowledge and materials chains. The aim was to follow the failures as far back as necessary. Moreover minutes from 9 project review meetings and a number of different project documents such as drawings, survey plans and contracts were used in the analysis.

The upstream analysis was carried out for each failure looking for proximal as well as distal causes either in organisation, technology or human resources. Moreover a calculation of the material and man-hour costs was carried out for each failure in collaboration with the project site management. The single failure analysis was followed by a thematic cross-failure analysis. In this paper two illustrative cases are chosen to illustrate how failures are produced and transformed in supply chains. The first case illustrates a failure in the knowledge chain transforming into the material stream, while the second case shows the dilemma of a contractor responsible for both design and assembly of an elevator. Subsequently a study on the supply chain initiatives at the main-contractor was conducted (Larsen and Schultz 2005).

The method adopted has its strength and weaknesses. Since the supply chain consists of several independent units the researcher has to gain access and built trust several times. The present analysis moreover does not study the chains in a “unit symmetrical” manner since the production unit is point of departure (See also Ellram 1996, Hyll 2005). Not all failures in the observation period were registered since it was not possible to follow all parallel activities on the building site (see also Josephsson *et al.* 1996). The paper is primarily based on (Larsen and Koch 2006).

PROJECT CONFIGURED SUPPLY CHAINS

The full implication of shifting customer demands is an engineer- and build-to-order strategy, which is organised by project. This implies supply chains, which in principle is project configured. According to client demands, smaller or larger part of the offered product will have to be sourced by sub-suppliers. Moreover location, staff and other factors will lead to project by project reconfiguration of the supply chains. This conceptualization is in contrast with most supply chain literature, which assumes that the structures of the supply chain are stable (Holweg and Pil 2004, New and Westbrook 2004, Mentzner 2004, London and Kenley 2001).

Although already Forrester (1958) in his seminal article on supply chain dynamics would demand a focus on five flows (information, materials , money, manpower and capital equipment) most SCM- writings adopt a more limited understanding of supply chains, more or less entirely devoted to the flow of materials (London and Kenley 2001). Construction value flows are distributed roughly as 60% of construction costs are materials (measured against a buildings total cost), whereas labour on the building site is around 20%, production equipment around 10% and design is around 10%. The importance of the knowledge stream related to its role as value-adder vis a vis the other streams. Behind these figures are considerable profits for material supply units (manufacturers, retailers, distributors), Hyll (2005) thus analyses an example of radiator procurement and finds a price augmentation of 272% from manufacturer to client. In the present work we focus on two flows; knowledge and materials.

In construction research these two flows are frequently described as independent (Hyll 2005 and many others). In a knowledge and service economy however, material manufacturers are design partners and design and production need to be relatively integrated. In other words the two streams are increasingly intertwined. Moreover the construction delivery processes can be described as multi-channeled, since there are often multiple suppliers in both the knowledge and materials flow.

The understanding of “project configuration” shouldn’t be overemphasised since considerable parts of the materials supply chain in construction exhibit rather traditional forecast based production and extensive stocks of materials at retailers as a main strategy of flexibility and responsiveness (Hyll 2005). Moreover retailers are successful in attaching contractors to them through price and discount agreements. All of this implies that to each project there will often be a certain degree of traditional deliveries and a certain degree of project-specific deliveries, suggesting that the supply chain can be described as partially stable, partially project specific.

As an important counter strategy to project specific supply chains a host of companies across sectors, but also within construction, have strived at using supply chain management (SCM) strategies in order to lever the stability. Bhote (1989) describe how SCM can improve results by reducing the number of supplier and by creating partnerships for long term relationships, escaping adversarial relations. Azambuja and Formosa (2003) investigate the design, procurement and installation of elevators in Brazil using supply chain management concepts and they emphasize that the establishment of partnerships between construction companies and their designers and elevator manufacturers plays an important role, bringing more interaction among the different agents in the early design stages.

Quality in processes

In a setting where the two flows of materials and knowledge are increasingly intertwined creating value and quality for both customers and enterprises becomes dependent of the ability to organise and coordinate in the supply chain. That the configuration is not always successful can be demonstrated by studying the emergence of failures occurring in the supply chain (Love and Li 2000). Quality measures are less fixed since important elements are continually changing. Meeting clients demands in an engineer to order setting quite often means rework as part of the process, which is a considerable problem in construction (Love and Li 1999).

Quality is a central performance parameter for operations and (Galloway 1998: 164) proposes a distinction between three quality parameters; design, conformance and operational quality. Design quality is concerned with the degree to which the product and/or service achieve the costumers' demand (Dale 2003), both as fitness for purpose and value for the money. Conformance quality means producing a product or providing services to its design specifications (Slack *et al.* 2004). Operational quality is meeting the specifications the first time without failures (Galloway 1998).

In construction, quality can be difficult to define, since the product is often one-of-a-kind and may not be described to an extent that provides a meaningful reference to measure the quality. Nicolini *et al.* (2000) emphasizes the difficulties of keeping the focus on improving quality and reducing underlying costs in the construction sector, where actors tend to organize their procedures project by project in traditional inefficient ways. The design often prescribes certain measurable demands, but in the construction processes the interaction between trades, companies and professions imply that interpretations of process and product quality are multiple and continually negotiated and contested. A direct implication of this understanding is moreover that what constitute a failure is equally difficult to define since different actors comprehend situations differently (Apelgren *et al.* 2005). In a construction setting operation processes, input and output are rarely fully described in a way which makes is meaningful to understand failures as merely deviations from defined quality.

In terms of quality assurance there are a number of critical junctions, who are usually assumed will assure the production of design, conformance and operational quality. The following activities are part of the critical junctions: Design review, project review, auditing plans, begin and end controls (relating to operation processes), 1 year audit and 5 year audit (post construction).

Quality in Supply Chain Processes

Quality control in operations in supply chain can be understood as consisting of three types of control for each supplier; 1) entrance quality control, 2) operational quality control and 3) exit quality control, referring to quality control of input, transformation process and output, respectively. In this manner it is strived to optimize quality in each part of the supply network to optimize the total quality of the end product (Deming 1986; Dale 2003).This means that each part of the supply network ensure quality of the input, ensure quality in the transformation process and finally ensure the quality of the output which is to be delivered to the next part of the supply network. Oakland and Marosszeky (2006) emphasize that quality must be integrated in the processes, instead of quality checks of the final product, so it is necessary to define, monitor and control the inputs to the process. Procurement through closer relationships e.g. through supply chain efforts and/or partnering is usually assumed to hold the potential of ensuring the focus on quality in the transformation processes and increasing the knowledge of input quality demands and expectations between the actors in the processes. Supply Chain Management would reduce the number of suppliers enable a closer relationship and stability in quality. SCM however tends to focus on dealing contracts on, say, one year delivery. The agreements specify delivery conditions and state a gross delivery. Quality is moreover specified in general terms. Such contracts of delivery create stability, and act as an overall governance creating trust and cooperation. They might also be accompanied with stronger communication tools such as web based IT-interfaces between the partners. But they rarely assure the project specific delivery is of the right quality however.

Moreover in a multi-channel setting, like construction, quality concerns multiple material supplies as well as multiple knowledge deliveries. As discussed by Sousa and Voss (2003) integration between channels become crucial. Apart from integration issues between channels, tensions are created in the delivery, when clients describe their demands not only through the design brief, but as a continual process in parallel with design. Similarly the delivery of the design is often done piecemeal vis a vis the contractor as a parallel process to construction (Pietroforte 1997).

SUPPLY CHAIN EFFORT

Over the last 5-6 years the main-contractor in the case-study has made a strategic supply chain effort to reduce costs, heighten quality and strengthen relationships with suppliers. This main-contractor has minimized the number of suppliers from approximately 7.000 to 1.700 including delivery of materials, sub-contractors and knowledge based deliveries from architects and engineers. The company operates with records on past performance of all suppliers. Longer relationships are often sought through contracts where e.g. materials suppliers are guaranteed a certain sale based on forecasts of quantities (Larsen and Schultz 2005). The number of current suppliers indicates that no suppliers are single-source within a category. The main-contractor has not got the intention to go as far as single-source suppliers and total co-operation as suggested by Bhote (1989). However the reduction in suppliers and the establishing of long term relationship suggest that the supply network is now that of co-opetition. The stability from the long-term relationships with the suppliers combined with project specific elements, such as e.g. demand for specific solutions or materials, stress that the supply network can be characterized as partly stable and partly project configured. The suppliers is rated on basis of performance in prior co-operations, but the subsequent study on the supply chain initiatives (Larsen and Schultz 2005) shows, that although a supplier has a good ratings, it does not guarantee that he will perform on quality in subsequent projects.

Of the 17 sub-contractors working at the case-site, 6 were in-house personnel employed by the main-contractor. The remaining 11 sub-contractors was invited to submit tender, and the project manager hired them in on basis of different parameters where performance data from the suppliers' database was one and price another of several parameters. There were six main suppliers of knowledge to the project, which was three in-house suppliers; electrical engineering, HVAC-engineering and the building physics design. The three hired deliverers of knowledge was the architect, the elevator-company and partly the pre-cast concrete elements company.

More than 50 suppliers participated in the material chain of raw materials, components and systems, related to one main contractor and 17 subcontractors. However, only a few failures could be traced back to material and component suppliers exclusively. As indicated the knowledge and material chain were intertwined in a way that make them only partly distinguishable. The forms of integrations between the project specific suppliers and the main-contractor can in this case be described from the main-contractors point of view; 1) delivery of knowledge from architect, 2) delivery of knowledge, materials and workforce from the elevator-company and the pre-cast concrete elements company, 3) subcontractors delivering workforce and materials, and 4) material-suppliers only for in-house production.

160 failures in the delivery network

The analysis of the 160 failures showed that the vast majority had multiple causes which related to more than one unit in the supply chain. 14% of the failures however were entirely related to production, whereas the rest originated from elsewhere in the supply chains and subsequently led to further problems.

Organisational problems like communication and coordination were the most prevalent. Out of the 160 failures problems with communication and cooperation occurred in 61% of the processes behind, problems related to design in 45%, production planning and control in 42%, project review meetings in 36%, production work 34%, process and product control 29%, weather and theft 20% and access to skilled workforce 15%. Further causes scored less. The expenses were calculated to be 8% of the production costs. It is less interesting to measure quality in parts per million or the like since the product is of the “one of a kind” type.

Regarding the suppliers initiating the failures, most failures was initiated by the pre-cast concrete element company, who was both in charge of the production and the assembly of the elements (19 % of the failures in all) followed by designers (11 %) and the contractor in charge of the building site installations (7,5 %).

First example of a delivery process

This particular failure show how a failure generated in the knowledge stream transform into the material stream. In the knowledge stream the first unit, the architect, specified where to place radiators in a staircase area. He had aesthetic concerns about the placing of a mailbox together with the radiator. As a solution he used a used a standard radiator of the dimension 80 cm. The architect material was handled over to the next unit in the chain, the building physics design engineers, who used the architects design as basis for the design of the main structure and transferred it to the first element in the material chain, the contractor responsible for producing and assembling pre-cast concrete elements. In parallel to this the architect also handled the project over to the HVAC design engineer, who calculated the necessary heating for the staircase and prescribed a 100 cm radiator. This design discrepancy was revealed at a review meeting between architect and HVAC engineer after which the building physics design engineer was informed. The 80 cm radiator was thus maintained and modelled into the pre-cast concrete elements. The HVAC engineer however forgot to change his own project, so the 100 cm prescription was channelled to the HVAC contractor, who ordered a 100 cm radiator from the supplier. Upon assembly of the radiator on the building site, the plumbers discovered that the holes in the pre-cast concrete element did not fit the radiator. To make up for this failure, project management decided to fill up the original holes and drill new holes fitting the 100 cm radiator - without notifying the architect. Later, the architect however insisted on the aesthetic dimension the original design, and managed to re-change the radiator, which again involved both the sub-contractor and the supplier. Several quality checks did not function properly in the two streams. Quality auditing at the end of design, and a major and detailed check of all project material by the main contractor should have revealed the failures in the two streams. The end result of the described process is therefore conformance with the project of the architect. Hence we evaluate the quality for the end-user to be untouched by the process. For the involved actors however, the losses were calculated to 2826 Euro. It is in other words the loss of efficiency of the supply chain units, which carry the most important implications, and not the customer.

Second example of a delivery process
The elevator contractor is both in charge of the elevator project engineering and the delivery of six elevators going from the ground floor to the second floor at a cost of approximately 285.000 Euros. The elevator engineer erroneously calculated the size of a ventilation hole on basis of the area of the elevator cage instead of the shaft as prescribed in the legal requirement. Therefore the ventilation hole diameter measured 150 mm, instead of the required 200 mm, in the project material delivered to the architect who implemented the 150 mm ventilation hole into the building physics engineer project drawings.

At a project review meeting, where the architect was not invited, the HVAC-engineer and the plumbing and heating contractor discovered the error and the meeting minute emphasized that the ventilation hole should be changed to a diameter of 200 mm. Unfortunately no-one reacted to this, and three days later the project managers handed the pre-cast concrete project over to the pre-cast concrete elements contractor with a reference to the architects drawing with the 150 mm ventilation hole. The elements were cast on the factory and after that assembled at the building site and only when the carpenter commenced shuttering at the top of the shaft the site manager discovered the error. The site manager immediately summoned the involved craftsmen, which in this case were the elevator installation team, the carpenter and the diamond drill team to discuss the situation. If the hole had to be widened the carpenter would have to tear down the shuttering risking that water from the diamond drill could damage installations in the shaft including a frequency converter. Facing the large consequences the site manager approached the building inspector and asked for an exemption with the authorities in this specific elevator shaft. The exemption was granted so that there was no rework. The expenses as a result of the waiting time were estimated to approximately 185 euros.

Since the case-study finished, the main-contractor has actually extended the database and performance records even further and strengthened the relationship with suppliers. Additionally the permanent enterprise organisation handles all greater purchasing tasks which are typically negotiating quantities, quality, terms and contacts with the suppliers. Only the purchase initiation is done by the project manager which implies a major reorganisation of procedures especially the role of the project manager.

DISCUSSION

In the following we will discuss quality in the supply chain network, how the materials and knowledge streams intertwine, construction supply as partly stable and partly project configured, partnerships in the supply network and varying boundaries between contractors and suppliers.

Regarding the quality in the supply network, the study shows that only 7-8 % of the failures affected the final quality, which is either design quality or conformance quality, and therefore most failures affected operational quality. The radiator-example exhibits all three types of quality. The designer defines the design quality, when making esthetical assumptions on behalf of the customers, and conformance quality is maintained in the end when the radiator is replaced with the prescribed model and therefore meets the design specification. Already when the HVAC-engineer forgot to change his project material the operational quality was affected. When the assembly of the radiator commenced, the many additional operations affected the operational quality of many actors in the supply network. Design quality is impaired, since the design does not meet the legal requirements. In this case conformance quality is actually met since the product actually meets the prescribed -albeit erroneous- design. Operational quality is affected and a lot of actors are involved in the process. Azambuja and Formosa (2003) similarly finds that the installation process of an elevator has a high level of interference with other ongoing processes in the building site. In the elevator case the design quality is apparently affected by the lack of professional competencies by the designer. The exit control of the elevator designer did not find the deviation and only at the exit control of the HVAC engineer project the failure was discovered. The mistake was actually caught in the project review process of the HVAC-project (exit control), but no-one reacted. The end result is not conformance to requirements since the ventilation hole was less that 1 % of the area of the elevator shaft, affecting design quality and conformance quality although in a hidden manner. Operational quality is affected since the product is not meeting the specifications the first time without failures. The project review meeting and the other types of quality checking seems to decay into symbolic actions, were the meeting are held on a basis of poor preparation and follow up is poor as well.

The elevator-example also reveal that integration of material and knowledge aspects does not prevent all failures, which echoes Sousa and Voss' (2004) emphasis on integration between channels as crucial for quality. Although the elevator producer is also the designer the failure still occurs. Having material suppliers involved as early as the design-phase is often accentuated as a way of improving quality in the projects, which does not seem to be the case in this example. This highlights the need for continuous focus on quality control procedures, both as entrance and exit control, also when designer and sub-contactor is the same company.

The analysis of relations in the supply network both shows relations to materials and knowledge chains and their interaction. Most of the failures were generated in the knowledge stream and then occasionally transform into the material stream. The illustrative cases shows that the knowledge and material were intertwined, since a failure generated in the knowledge network could transform into the material network and vice versa. In the case-study by Azambuja and Formosa (2003) most of the problems are in the interfaces between the actors in the supply chain, which is also our main causes (Apelgren *et al.* 2005) and the case in both of our examples in this paper. The interfaces and contact surfaces between the actors in the knowledge network becomes critical junctions in the process - in-between the exit and entrance controls.

In the building project studied, the delivery network can be characterised as partially stable, partially project specific and configured. In the knowledge delivery network only the architect and the elevator designer is not in-house personnel from the main-contractor so the remaining design is done by in-house personnel where the relation must be characterised as stable. Regarding the architect, the relations must be characterised as project specific and configured. The project configuration of the sub-contractor and materials delivery also must be characterised as partially stable, partially project specific and configured on basis of the supply chain strategy applied by the main contractor. Although the conditions of the supply network is characterised as partly stable, the interfaces and contact surfaces between the actors in the supply networks still becomes critical junctions in the building processes.

The reorganisation of the building procedures especially the role of the project manager has a lot of implications. Traditionally the project management handled most of the purchasing obtaining lucrative prizes on parts of the supply through the personal relationship with the supplier. The reorganisation of processes removes these tasks from project management – the tasks which often were hallmarks of project managers. This contradiction has to be overcome, since there is a need for strengthening relationships and the large profit margins on material and equipment is clearly an area where the contractors see a possibility to gain surpluses. By centralizing purchasing in the permanent enterprise organisation, the contractor has greater “purchasing-power” through greater quantities to enforce cheaper prizes and quality improvements.

The pre-cast concrete element company, in charge of both the production and the assembly of the elements, were involved in almost a fifth of the failures in spite of the company’s good past performance recognized by the main-contractor. This indicates strong variations in deliveries from project to project from the same suppliers, also emphasizing the problems of implementing supply chain initiatives in construction, where there can be large quality variations within each supplier from project to project - also within the main-contractor. This implies that boundary surfaces between main-contractor and suppliers are continuously varying causing insecurities to the projects.

CONCLUSIONS AND IMPLICATIONS

The analyses and cases illustrated, that the vast majority of the failures occurred in the knowledge chain (in a broad sense) and some transferred into the material chain. However the end result was compliance with customer requirement since only 7-8 impacted the end quality. It seems a prevalent result that quality auditing at interfaces between units in the supply chain, becomes critical junctions in the process. Project review meeting and other types of quality checking decays into symbolic actions, were the meeting are held on a basis of poor preparation and follow up is poor as well.

The results also indicated the necessity of initiatives to strengthen partnerships in supply chains, improve integration between channels; especially at mixed stable and project configured types, to fulfill the complexity of the building projects. Moreover the reorganisation of site processes, removing responsibility of supply network management from project management, is clearly a large contradiction; but a contradiction to overcome. Initiatives to strengthen partnerships in supply chains; especially at engineer to order production, could be, and are indeed, taken in the Danish construction industry. These encompass alliances with fewer suppliers and continual performance evaluations. Multi skilled teams are another way to integrate further knowledge types in delivery and reduce the number of sub-contractors. The efforts show the contradiction between the permanent enterprise organisation potentially capable of handling strategic and operational purchasing and the traditional strong role of the project manager as local purchaser and contract negotiator.

Supply chain fragmentation and the limited success of quality management governed by enterprise and project alliance interests, have set the sector associations and the state in motion. A quality improvement plan has been elaborated as a first step of a common effort of bringing down failures. An obligatory evaluation system for state contracts based on self reporting is active by July 2005 with other initiatives to follow.

The major result of the research is however that the single enterprise can obtain considerable productivity improvements if project partnerships could be improved. Better handling of especially the knowledge chain has a considerable business potential, which in turn would improve even the product offered to the clients.

REFERENCES

Apelgren, S, Richter, A and Koch, C (2005) *Snublesten i byggeriet.* Lyngby: BYG·DTU, Technical University of Denmark. (Stumbling Stones in Construction).

Azambuja, M M B and Formosa, C T (2003) Guidelines for the Improvement of Design, Procurement and Installation of Elevators Using Supply Chain Management Concepts. *In*: *International Group of Lean Construction 11th Annual Conference*, 22-24 July 2003. Virginia Tech, Blacksburg, Virginia, USA

Bhote, K R (1989) *Strategic Supply Chain Management – A Blueprint for revitalising the manufacturing/Supplier partnership.* New York: American Management Association.

BEC (2005). www.byggeevaluering.dk Website accessed 31. January 2006.

Dale B G (2003) *Managing Quality.* Malden: Blackwell Publishing.

Deming W C (1986) *Out of the crisis.* Cambridge. Massachusetts: MIT centre for advanced Engineer study.

EBST (2005) *Byggeriets handlingsplan mod fejl og mangler.* Erhvervs- og Byggestyrelsen, København, June 2005. www.ebst.dk

Ellram, L M (1996) The Use of Case Study Method in Logistics Research. *Journal of Business Logistics*, **7** (2), 93-138.

Forrester, J (1958) Industrial Dynamics. *Harvard Business Review,* July- August, 37-66.

Galloway, L (1998) *Principles of Operations Management*. 2ed. London: Thomson.

Hyll, H (2005) *Logistical Principles in Construction Supply Chains*, Thesis for the degree of Licentiate in Engineering, Lund University.

Holweg, M and Pil, F K (2004) *The Second Century: Reconnecting Customer and Value Chain through Build-to-Order.* London: MIT Press.

Josephson, P-E and Hammarlund, Y (1996) *Kvalitetsfelkostnader på 90 talet – en studie av sju byggprojekt.* Göteborg: Institutionen for Byggnadsekonomi, Chalmers.

Larsen, C S and Koch C (2006) Quality issues in project configured supply chains - Can a fragmented network learn from its failures? *Paper prepared for the 3rd European Forum on Market-Driven Supply Chains, 7-8 March 2006*, EIASM, Brussels.

Larsen, C S and Schultz M (2005) Interaktion på tværs af niveauer i en større dansk *entreprenørvirksomhed*,. Master thesis, BYG·DTU, Technical University of Denmark.

London, K A and Kenley, R (2001) An industrial organization economic supply chain approach for the construction industry: a review. *Construction Management and Economics*, **19** (8), 777 - 788.

Love, P E D, Li, H and Mandal, P (1999) Rework: A Symptom of a Dysfunctional Supply-Chain. *European Journal of Purchasing and Supply Management*, **5**, 1-11.

Love, P E D and Li, H (2000) Quantifying the causes and costs of rework in construction. *Construction Management and Economics*, **18** (4), 479-490.

Mentzer, J T (2004*) Essentials of Supply Chain Management*. Sage publications.

New, S and Westbrook, R (2004) *Understanding Supply Chains. Concepts, Critiques and Futures.* Oxford: Oxford University Press.

Nicolini, D, Holti, R, and Smalley, M (2000) *The Handbook of Supply Chain Management.* London: CIRIA Publications.

Oakland, J and Marosszeky, M (2006) *Total Quality in the Construction Supply Chain.* Oxford: Butterworth-Heinemann.

Pietroforte R (1997) Communication and Governance in the building process. *Construction Management and Economics*, **15**, 71-82.

Slack, N, Chambers, S and Johnston R (2004) *Operations Management.* 4ed. London: Pearson.

Sousa, R and Voss, C (2004) Service Quality in Multi Channel Services, employing virtual channels. *Operations and Technology Management papers,* OTM 04-023. London: London Business School.