ROLES OF SUPPLY CHAIN MANAGEMENT IN CONSTRUCTION

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ABSTRACT

Supply chain management (SCM) is a concept that has flourished in manufacturing, originating from Just-In-Time (JIT) production and logistics. Today, SCM represents an autonomous managerial concept, although still largely dominated by logistics. SCM endeavors to observe the entire scope of the supply chain. All issues are viewed and resolved in a supply chain perspective, taking into account the interdependency in the supply chain. SCM offers a methodology to relieve the myopic control in the supply chain that has been reinforcing waste and problems.

Construction supply chains are still full of waste and problems caused by myopic control. Comparison of case studies with prior research justifies that waste and problems in construction supply chains are extensively present and persistent, and due to interdependency largely interrelated with causes in other stages of the supply chain. The characteristics of the construction supply chain reinforce the problems in the construction supply chain, and may well hinder the application of SCM to construction. Previous initiatives to advance the construction supply chain have been somewhat partial.

The generic methodology offered by SCM contributes to better understanding and resolution of basic problems in construction supply chains, and gives directions for construction supply chain development. The practical solutions offered by SCM, however, have to be developed in construction practice itself, taking into account the specific characteristics and local conditions of construction supply chains.

KEY WORDS

Supply chain management, construction supply chain, interdependency, myopic control.

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INTRODUCTION

Supply chain management (SCM) is a concept originating from the supply system by which Toyota was seen to coordinate its supplies, and manage its suppliers (Womack et al. 1990). In terms of lean production, SCM is closely related to lean supply (Lamming 1996). The basic concept of SCM includes tools like Just-In-Time delivery (JIT) and logistics management. The current concept of SCM is somewhat broader but still largely dominated by logistics.

Until now, in construction, initiatives belonging to the domain of SCM have been rather partial covering a subset of issues (e.g., transportation costs) in a limited part of the construction supply chain (e.g., the construction site). In most cases, the issues are regarded from a main contractor's point of view (e.g., Asplund and Danielson 1991, Wegelius-Lehtonen et al. 1996).

Statistical figures show that main contractors are purchasing more labor and material than previously. For instance, in 1994, in Dutch construction industry (i.e. residential, commercial and industrial building), the main contractors' share in the total national turnover had decreased to 24% (Scholman 1997). Thus, suppliers and subcontractors represented about 75% of turnover. Currently, this is expected to be more.

As a consequence, main contractors become more and more reliant on other actors in the construction supply chain (e.g., suppliers and subcontractors). Therefore, they need to revise their supply strategies and trading relations with subcontractors and suppliers.

Thus, the goal of this paper is to clarify the roles and possibilities of SCM in construction. Starting from the lessons learnt and methodological development of SCM in manufacturing, present supply chains in construction are observed, and recommendations for SCM in construction are presented.

The focus of this paper is on the supply chain of a main contractor. It has to be noted that in construction, real estate owners also may drive supply chain development.

SUPPLY CHAIN MANAGEMENT IN MANUFACTURING

ORIGIN OF SUPPLY CHAIN MANAGEMENT

SCM is a concept that has originated and flourished in the manufacturing industry. The first signs of SCM were perceptible in the JIT delivery system as part of the Toyota Production System (Shingo 1988). This system aimed to regulate supplies to the Toyota motor factory just in the right - small - amount, just on the right time. The main goal was to decrease inventory drastically, and to regulate the suppliers' interaction with the production line more effectively.

After its emergence in the Japanese automotive industry as part of a production system, the conceptual evolution of SCM has resulted in an autonomous status of the concept in industrial management theory, and a distinct subject of scientific research, as discussed in literature on SCM (e.g., Bechtel and Yayaram 1997, Cooper et al. 1997). Along with original SCM approaches, other management concepts (e.g., value chain, extended enterprise) have been influencing the conceptual evolution towards the present understanding of SCM.

In a way, the concept of SCM represents a logical continuation of previous management developments (Van der Veen and Robben 1997). Although largely dominated by logistics, the contemporary concept of SCM encompasses more than just logistics (Cooper et al. 1997). Actually, SCM is combining particular features from concepts including Total Quality Management (TQM), Business Process Redesign (BPR) and JIT (Van der Veen and Robben 1997).

CONCEPT OF SUPPLY CHAIN MANAGEMENT

The supply chain has been defined as 'the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer' (Christopher 1992).

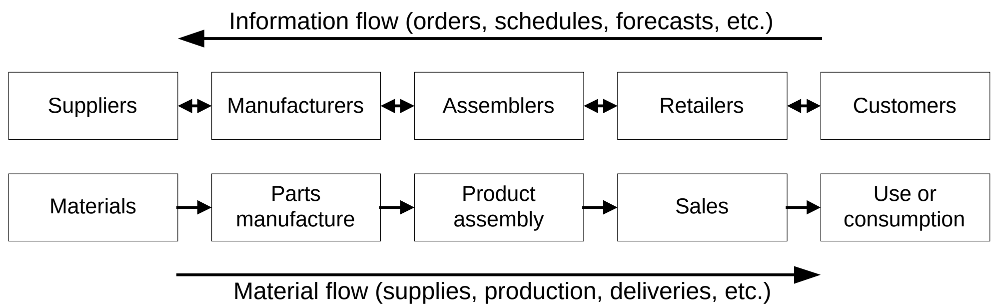

Figure 1: Generic configuration of a supply chain in manufacturing

SCM looks across the entire supply chain (Figure 1), rather than just at the next entity or level, and aims to increase transparency and alignment of the supply chain's coordination and configuration, regardless of functional or corporate boundaries (Cooper and Ellram 1993). According to some authors (e.g., Cooper and Ellram 1993), the shift from traditional ways of managing the supply chain towards SCM includes various elements (Table 1).

The traditional way of managing (Table 1) is essentially based on a conversion (or transformation) view on production, whereas SCM is based on a flow view of production. The conversion view suggests that each stage of production is controlled independently, whereas the flow view focuses on the control of the total flow of production (Koskela 1992).

METHODOLOGY OF SUPPLY CHAIN MANAGEMENT

In the literature on SCM, many supply chain methods have been proposed. Most methods address logistical issues of the supply chain, e.g., quality rates, inventory, lead-time and production cost.

The methods of **pipeline mapping** (Scott and Westbrook 1991), **supply chain modeling** (Davis 1993) and **logistics performance measurement** (Lehtonen 1995) analyze stock levels across the supply chain. The **LOGI method** (Luhtala et al. 1994, Jahnukainen et al. 1995) studies time buffers and controllability problems of the delivery process. **Supply chain costing** (La Londe and Pohlen 1996) focuses on cost buildup along the supply chain. Integral methods like **value stream mapping** (Hines and Rich 1997, Jones et al. 1997) and **process**

performance measurement (De Toni and Tonchia 1996) offer a “toolbox” to analyze various issues including lead time and quality defects.

Table 1: Characteristic differences between traditional ways of managing the supply chain and SCM (Cooper and Ellram 1993)

Element	Traditional management	Supply chain management
Inventory management approach	Independent efforts	Joint reduction of channel inventories
Total cost approach	Minimize firm costs	Channel-wide cost efficiencies
Time horizon	Short term	Long term
Amount of information sharing and monitoring	Limited to needs of current transaction	As required for planning and monitoring processes
Amount of coordination of multiple levels in the channel	Single contact for the transaction between channel pairs	Multiple contacts between levels in firms and levels of channel
Joint planning	Transaction-based	Ongoing
Compatibility of corporate philosophies	Not relevant	Compatibility at least for key relationships
Breadth of supplier base	Large to increase competition and spread risks	Small to increase coordination
Channel leadership	Not needed	Needed for coordination focus
Amount of sharing risks and rewards	Each on its own	Risks and rewards shared over the long term
Speed of operations, information and inventory levels	“Warehouse” orientation (storage, safety stock) interrupted by barriers to flows; localized to channel pairs	“Distribution center” orientation (inventory velocity) interconnecting flows; JIT, quick response across the channel

Besides assessing and improving the supply chain, other elements are essential to the methodology of SCM. A generic methodology of SCM can be deduced combining and generalizing the commonalities of different SCM methods. In a way, the SCM methodology bears resemblance to the Deming Cycle (Figure 2). Generically, the methodology of SCM consists of four main elements: (1) Supply chain assessment, (2) Supply chain redesign, (3) Supply chain control, and (4) Continuous supply chain improvement.

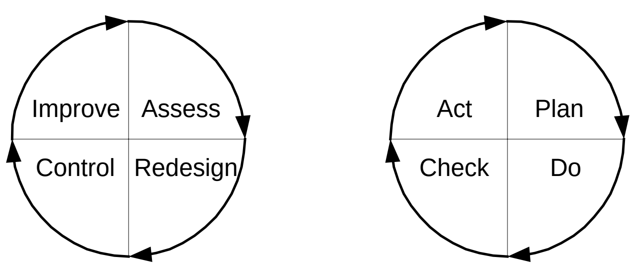

Figure 2: Generic SCM methodology compared to the Deming Cycle

The first step is to assess the current process across the supply chain in order to detect actual waste and problems. The issue here is to find the causality between the waste and problems, and locate their root causes. Once the causality is understood, and having found out about the root causes, the next step is to redesign the supply chain in order to introduce structural resolution of the problems. This includes redistribution of roles, tasks and responsibilities among the actors in the supply chain, and a review of procedures.

The next step is to control the supply chain according to its new configuration. An important part of the control is the installation of a monitoring mechanism to continuously assess how the supply chain operates. This includes systems to measure and estimate waste across the supply chain process, and feedback systems to discuss and evaluate underlying problems. The objective is to continuously identify new opportunities, and find new initiatives to develop the supply chain. In fact, this continuous improvement implies the ongoing evaluation of the supply chain process, and the recurring deployment of the previous three steps: assessment, redesign and control (Figure 2).

SUPPLY CHAIN MANAGEMENT IN CONSTRUCTION

ASSESSING CONSTRUCTION SUPPLY CHAINS THROUGH CASE STUDIES

In this section, three case studies that were executed in the Netherlands and Finland are being described, representing three exercises of supply chain assessment. The case studies represent three separate analyses of different supply chains. The case studies give some insight in the waste, problems and causes, and their interdependence presently existing in construction supply chains (Table 2).

Table 2: Case study methodology

Method		**Case study 1**	**Case study 2**	**Case study 3**
Quantitative analysis	*Measurement*	Waste: time buffers		
Qualitative analysis	*Observations, interviews etc.*		Problems: controllability problems	
Implicit analysis	*Impressions etc.*			Causes: traditional trading

The case studies merely applied to the part of the supply chain coordinated by the main contractor (Figure 3). The first case study represented a measurement (i.e. quantitative analysis) of time buffers along a part of a chain process of concrete wall elements in residential building (Vrijhoef 1998). The second case study represented a problem analysis (i.e. qualitative analysis) to identify and locate controllability problems in a chain process of composite façade elements in residential building (Vrijhoef 1998). The third case study represented a quick scan of the cost impact of trading methods used by a main contractor to purchase materials. The scan was an undercurrent part (i.e. implicit analysis) of a larger research program to investigate new ways of materials management by a main contractor.

The case studies represent some good examples of the effects of interdependency in the construction supply chain (Table 3). Time buffers, as observed in the first case study, were mainly located in between the sub-processes, separating the sub-processes in order to cope

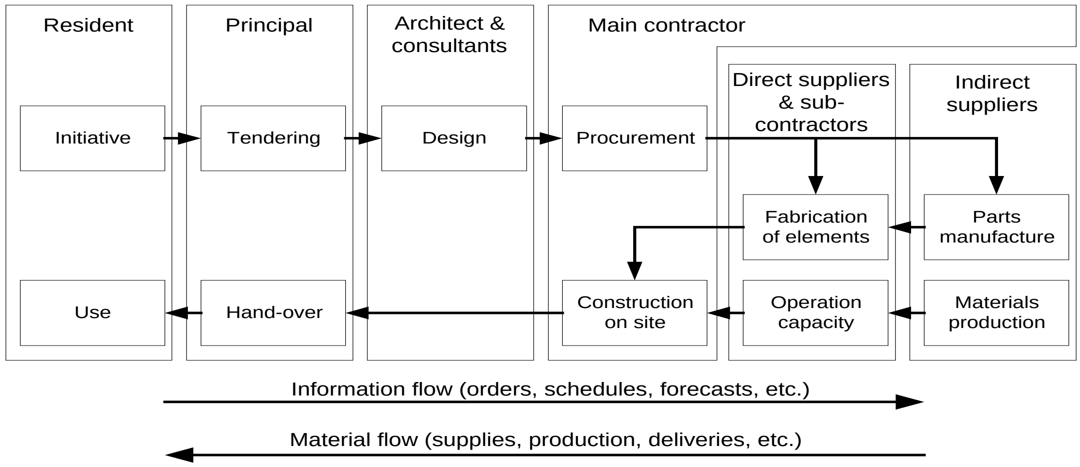

Figure 3: Generic configuration of a traditional supply chain in residential building

Table 3: Overview of the First Two Case Studies

	Case study 1	**Case study 2**
Description	This case study refers to time measurement to detect and analyze time buffers in a part of a supply chain process of concrete wall elements including the excavation and delivery of sand, the fabrication and delivery of elements, and the site installation of elements.	Involves problem analysis to identify and locate controllability problems in a part of a chain process of composite façade elements. The observed part included the job preparation, price bargaining, engineering, assembly, and site installation of the elements.
Objective	Analysis of the time use along the process in order to get insight in the time buildup, and the magnitude and location of time buffers.	Analysis of the controllability problems along the process in order to get insight in the occurrence and causality among the problems and their causes.
Method	Decomposition of the process in sub-processes and activities Time measurement of the activities Categorizing time use per activity: wasted, non-value-adding, value-adding Locating and quantifying time buffers Composing the process time buildup	Decomposing the process in sub-processes Uncovering the controllability problems per sub-process Identifying and locating the causes Finding connections between the problems and causes
Results	It appeared that at the beginning and the end of the sub-processes remarkable time buffers occurred. The time buffers were particularly due to inventory and delays. The share of the time buffers compared to the total lead-time was quite large (70-80%). Underlying problems of the time buffers included separate planning. The problems referred to various root causes including inter-organizational barriers.	The controllability problems were numerous. Root causes included non-collaborative working relations between parties, and adversarial bargaining. Most problems that were encountered on an operational and managerial level were caused by strategic and cultural issues. These included lacking common targets, reluctance and opportunism.

with variability and non-synchronicity. The time buffers were having a large impact on time buildup in the total process (Figure 4). Controllability problems, as observed in the second case study, mostly stemmed from earlier activities in the chain, performed by prior actors (Figure 5). The controllability problems caused much waste, including time buffers.

From the case studies three main conclusions can be drawn. **First**, even in normal situations much waste and problems exist in the construction supply chain. However, this is not seen or often ignored. In the chain, most actors (separate companies and divisions of the same company) appear to be managing just their own parts, securing their own businesses. **Second**, most of the waste and problems are caused in another (i.e. earlier) stage of the construction supply chain other than where they are found. The root causes of the waste and problems were rarely found in the activity where they were encountered, but rather in a previous activity executed by a prior actor, often operating on a higher organizational level. **Third**, waste and problems are largely caused by myopic control of the construction supply chain. Many actors in the chain seem to be not able or interested to see the impact of their behavior on other (i.e. later) activities in the chain. In most cases, actors are not prompted to consider the effects of their activities. Instead, they are encouraged to optimize their own part of the chain, not taking into account other activities and actors in the supply chain.

The conclusions are based on three case studies. In order to underpin the conclusions, the case study results are being compared to findings in existing research.

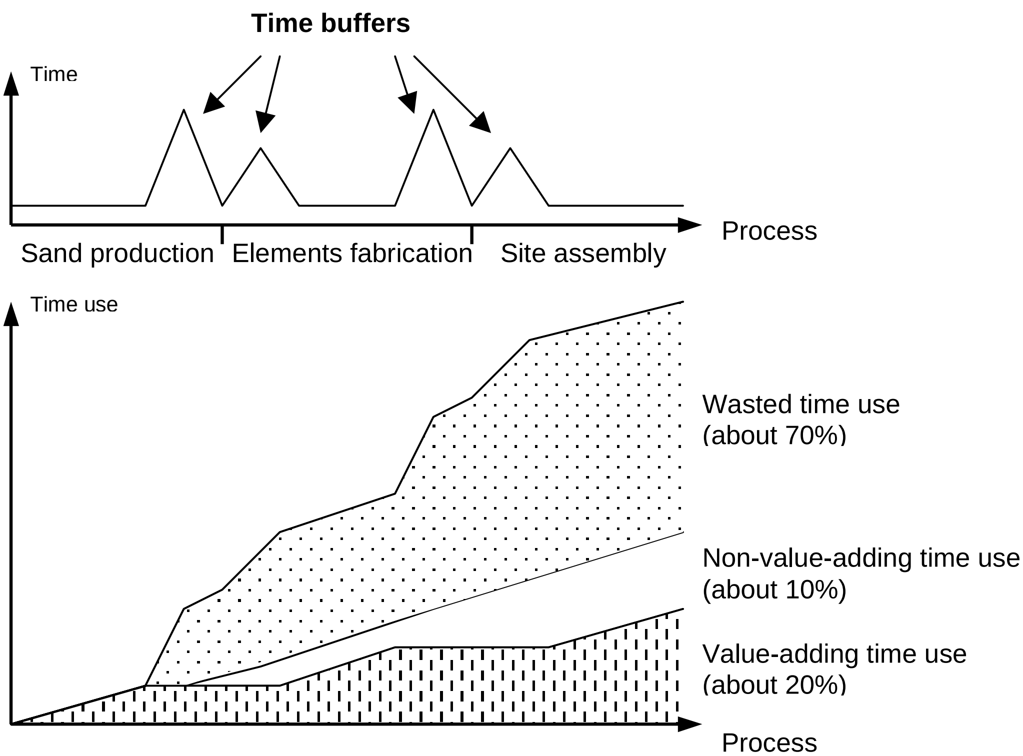

Figure 4: Case 1 - Time measurement of concrete wall elements

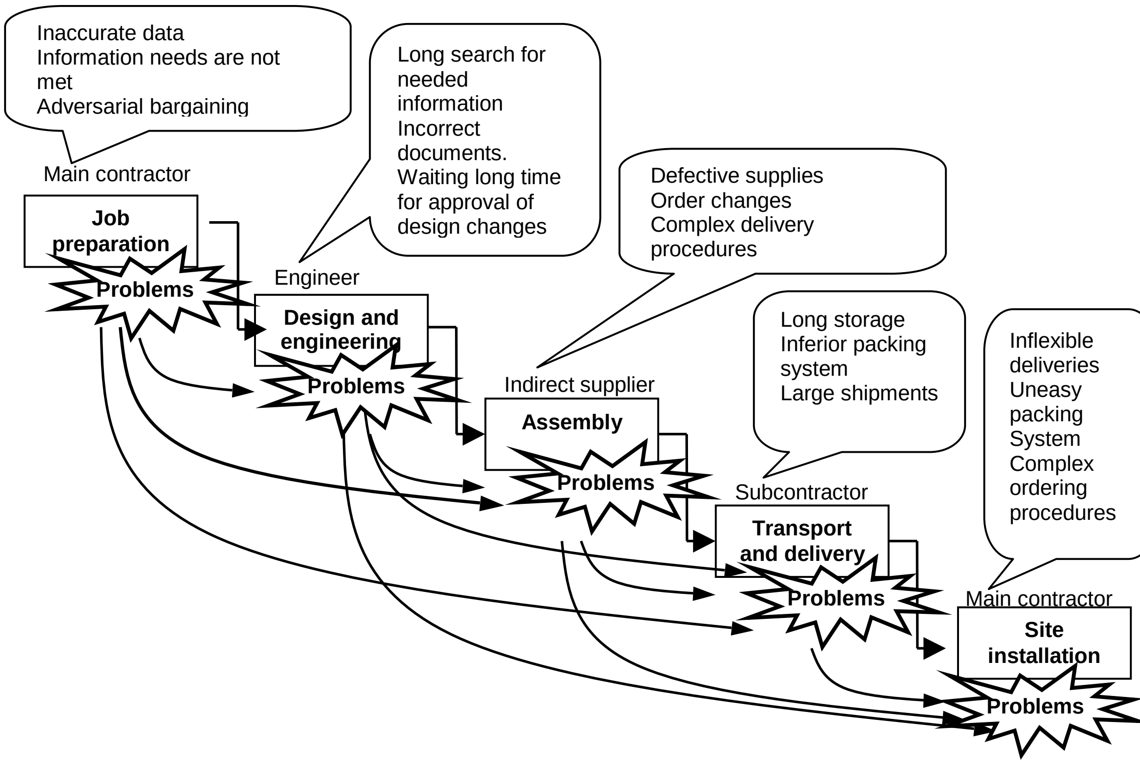

Figure 5: Case 2 - Problem analysis of composite façade elements

COMPARISON OF CASE STUDY RESULTS WITH FINDINGS IN EXISTING RESEARCH

Jarnbring (1994) found in his study on material flows in Swedish construction that the value-added time of those flows is only 0,3% to 0,6% of the total flow time. Various studies show a cost reduction potential varying from 10% to 17% of the material costs (i.e. purchasing price) by means of improved logistics (e.g., Asplund and Danielson 1991, Jarnbring 1994, Wegelius-Lehtonen 1995). Most researchers argue that chances for these cost savings would increase if contractors and suppliers would co-operate to identify joint opportunities to improve logistics. However, in a study into construction logistics, Wegelius et al. (1996) found that the purchasing price is still the dominating criterion for supplier selection, which is confirmed by Jarnbring (1994). Särkilahti (1993) found that, in general, subcontractors are also selected on the basis of price.

The tenor of these findings support the conclusion from the case studies as for the existence of considerable waste in construction supply chains (i.e. the part of the chain involving contractors and suppliers). Also, the argument that joint improvement of logistics would be more efficient (i.e. less costly) when actors in the supply chain would cooperate demonstrates the fact that adversarial bargaining is wasteful. When taking the whole supply chain into consideration, and all possibilities for improvement, the amount of avoidable waste and problems must be considerably higher.

Laitinen (1993) found that each actor of the supply chain adds a time buffer for himself in the schedule, and often produces in a different sequence or speed than the next or previous actor, optimizing just his own activities. It is also customary to use material inventories as buffers against variations and uncertainties in the supply chain (O'Brien 1995). In a study on deliveries of concrete façade components, Laitinen (1993) found several problems causing variation and uncertainty in the delivery process. For instance, design information was often deficient, and difficult design issues were often not detailed. In addition, design changes were caused by non-available, late, wrong or incomplete information, and they were often not being communicated to the factory.

The case studies showed that most of the waste and problems found were caused by another actor in another stage in the supply chain. The case studies as well as the findings in existing research indicate the causal relationship between problems in one stage of the supply chain causing waste in another (i.e., the next) stage.

Jarnbring (1994) found that deficient planning and deficient information on the needed amount of material are characteristic for materials purchasing in construction. In a study on the implementation of lean production in construction component manufacturing, Koskela and Leikas (1997) found that there is a tendency to place construction component orders with missing information due to incomplete design. According to Jarnbring (1994), decision making on logistical solutions is often constrained to those solutions one has experience of or insight in.

Thus, the causes of waste and problems in construction supply chains, as mentioned earlier, include decisions that are made with a lack of information or understanding. This appears to be valid for operating the supply chain itself, but also for finding solutions (e.g., for logistics).

Comparison of the results of the case studies with prior research justifies that waste and problems in construction supply chains appear to be extensively present and persistent. Due to interdependency in the supply chain, the occurrence of waste and problems is interrelated with causes in other stages and levels of the supply chain. Myopic control of the construction supply chain reinforces waste and problems, and complicates their resolution.

ROLES OF SUPPLY CHAIN MANAGEMENT IN CONSTRUCTION

The generic concepts, methods and lessons learnt, which have been developed in the framework of SCM, can be used in different ways for the improvement of construction supply chains. In the following, we illustrate how the methodology of SCM can contribute to the understanding of construction supply chain problems, and in giving direction to improvement efforts. The bottom-line is the effective resolution of interdependency-caused issues in the construction supply chain, including basic problems and myopic control.

SUPPLY CHAIN MANAGEMENT'S CONTRIBUTION TO RESOLVE BASIC PROBLEMS IN CONSTRUCTION: UNDERSTANDING CONSTRUCTION SUPPLY CHAIN PROBLEMS

The case studies and existing research show that problems in construction supply chains are largely characterized by interdependency. Myopic control of the construction supply chain, combined with traditional trading and non-cooperative relationships, reinforces the problems, and complicates their resolution.

Above, SCM has been introduced including an appropriate methodology to resolve the basic problems in the construction supply chain. The first step of the methodology suggests a chain assessment to uncover the nature and causality of the problems, which has been demonstrated earlier in the case studies. Understanding existing problems is an absolute necessity to be able to resolve them effectively. The goal is to become totally aware of the real basics of the problems (i.e. seeing the “big picture”), and approaching the issue properly (i.e. holistically) in order to unlock possibilities for effective improvement of the supply chain. In fact, it’s a matter of making waste and problems visible and tangible, and identifying and detecting the root causes to make it possible to resolve them all.

Argument for Supply Chain Management in Construction: Fulfilling the Supply Chain Methodology

Based on the insight gained by means of supply chain assessment, the SCM methodology needs to be fully applied to resolve the problems that were found in the construction supply chain. Because most problems spread across (a considerable part of) the supply chain, solutions are needed that equally cover multiple stages of the supply chain, including the actors involved. The range of the solutions and the part of the supply chain involved depend on the scale of the problems.

After having assessed the supply chain, the SCM methodology suggests redesign (reconfiguring the supply chain’s structure), control (coordinating the supply chain according to the new configuration) and continuous improvement. For instance, towards suppliers, the methodology could include reengineering the procurement process, installing joint coordination of logistics and recurring product development programs. Typically, such activities include joint activities between separate actors in the supply chain.

Supply chain arrangements counteracting adversarial relations with other actors (e.g., partnership) are needed to enlarge the magnitude of the SCM methodology, and clear the way for resolution of interdependency-based problems and myopic control. In fact, actors are dependent on each other for implementing the supply chain methodology successfully. Supply chain development should take place in co-operation with a growing number of actors tackling a growing number of issues (Figure 6). The actors involved should have a common development goal, share the same view on the development, and adopt the same approach to issues such as grasping concrete and objective performance information, and searching for improvement opportunities cooperatively (Wegelius-Lehtonen and Pahkala 1998).

It is interesting to compare the development issues of SCM, as defined by Lin and Shaw (1998), to the actual practice of construction (Table 4).

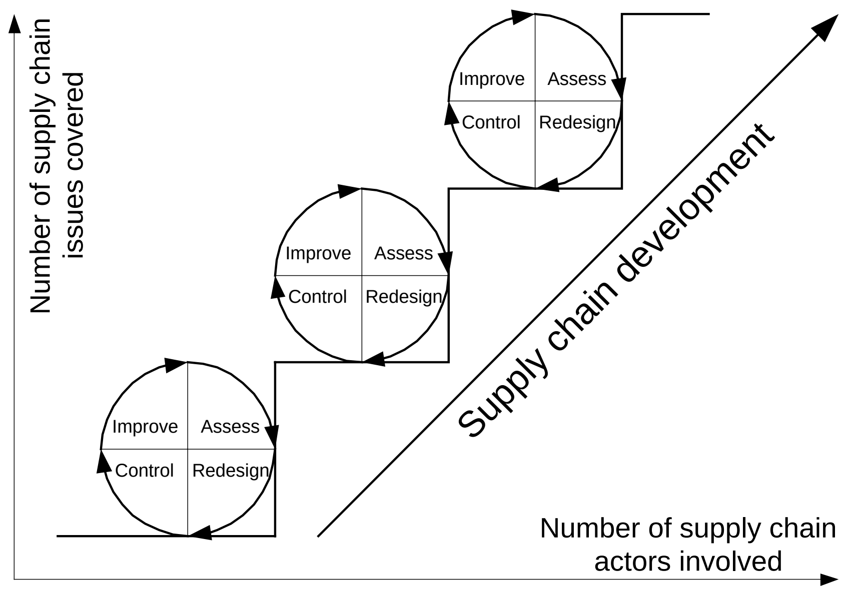

Figure 6: General Approach to Supply Chain Development

Table 4: Development Issues of SCM According to Lin and Shaw (1998)

Development issues	Description of the development	Actual construction practice
Order information transparency	The issue is how to manage the order information propagation to improve the supply chain.	It is not rare to find that the placing of a subcontract or material order is delayed due to price negotiations. As a result, the order information propagation is effectively halted.
Reduction of variability	The issue is how to reduce variability and how to make the supply chain robust when facing uncertainty.	Changes to orders, originating from the sphere of the client, the design team or the main contractor, are quite usual.
Synchronization of material flows	The issue is how to synchronize the availability of materials for assembly.	It is not uncommon to see that materials are produced in an order suitable for the supplying factory, and delivered to the site in a mode minimizing the transportation costs. Thus, other considerations than the needs of assembly dominate.
Management of critical resources	The issue is how to identify critical resources, lay out a critical path network and put the effort on reducing the workload of critical resources.	In the traditional design-bid-build procurement in construction, where the parties are selected based on price, it often is impossible or difficult to objectively identify critical resources of the supply chain in advance.
Configuration of the supply chain	The issue is how to evaluate and then change the chain.	This kind of continuous and long-term improvement of the supply chain is out of question, because for each project, a new supply chain is configured.

SUMMARY

Actual practice in construction not only fails to address issues of supply chain, but rather follows principles that make supply chain performance worse.

SCM can play major roles in construction. The principle roles of SCM are covered by the generic SCM methodology. The SCM offers general guidelines that can be used to analyze, reengineer, properly coordinate, and constantly improve virtually the complete construction supply chain, resolving basic problems and the myopic control that have been plaguing the supply chain. This would be practically impossible to realize in the short term. Therefore, initially, the SCM methodology is properly deployed on a lower scale, addressing partial supply chain problems, involving a limited number of supply chain actors. Due to its recurring character, the SCM methodology implies a continuous improvement process of which the scope can be enlarged over time, involving an increasing number of areas of application.

Some areas of application, which may be, and to a certain extent have been subjected to SCM, include the reduction of costs (especially logistical costs), lead-time and inventory in the supply chain. In view of the large share of these costs in construction, this focus is often fully appropriate. Secondly, the focus may be on the impact of the supply chain on site activities. Here, the goal is to reduce site costs and duration. In this case, the primary consideration is to ensure material (and labor) flows to the site for the sake of avoiding disturbances in the workflow. Thirdly, the focus may be on transferring activities from the site to upstream stages of the supply chain. The rationale may simply be to avoid the inferior conditions of site, or to achieve wider concurrency between activities, which is not possible in site construction with its many technical dependencies. Here, the goal is again to reduce the total costs and duration.

In practice, these areas are intimately interrelated. It is often difficult to improve the dependability of the deliveries of a supply chain without addressing the total supply chain. If activities are transferred from site upstream the supply chain, it is requisite that the resultant, more complex supply chain is orderly managed and improved in order to have the benefits intended.

In view of these roles, gaps in prior initiatives to advance the supply chain can be identified. For instance, the logistics initiatives, stressing (average) costs, have often failed to address the impact of supply chain variability on site assembly. In addition, industrialized construction, with its long and complex supply chain, has often been lacking even basic principles of SCM.

The generic body of knowledge accrued in the framework of SCM leads to improved understanding of the characteristics of construction supply chain problems, and gives direction for action. However, the practical roles for SCM have to be developed in construction practice itself, taking into account the characteristics of construction and the specific situation. Cooperation between research and practice may be instrumental in this endeavor, as argued by Wegelius and Pahkala (1998).

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