

Supply Chain Management in Construction: State of The Art

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Abstract

Supply Chain Management is a concept originally developed in the manufacturing industry and later implemented in the construction industry to reduce cost, on-time delivery, and better productivity. An extensive review of the literature published from 1982 to 2021 on the origin, types, and role of Supply Chain Management is discussed in this paper. Literature from the area of the supply chain in the construction industry was studied and a brief background on how Supply Chain Management can be diffused into the construction industry and the impact of Machine Learning in better decision making in Supply Chain Management are explained. This paper aims to review the existing literature and provide the synthesis and suggestions for future works. Further work on analyzing the compatibility of Supply Chain Management with the current strategies and its role in achieving sustainability in the construction sector can be carried out.

Keywords

Supply Chain Management, Construction Planning, Implementation, Project Management, Decision making

1. INTRODUCTION

The supply chain in construction is complex because of the high level of sub-contracting and projects of varying sizes and complexity. Since the 1990s supply chain management has emerged as an innovative concept and as a solution for the problems in the construction industry. Quality and profit can be increased in a systematic way using Supply Chain Management (SCM). The need to decrease cost and improve quality, productivity, and expansion in the economic weight of the supply chain calls for discussion about SCM (El Moussaoui et al, 2021). Along with the development of lean techniques in the construction industry, there has been development and research in SCM simultaneously. According to Vrijhoef and Koskela (2000), even in a normal situation, a large quantity of waste is generated in the construction supply chain and these wastes are mainly generated because of obsolete and myopic control of the construction supply chain. SCM in the construction sector can result in better integration among different parties and waste reduction. This paper includes a literature review about the trends of SCM in the construction industry. An extensive literature review has been done to understand the importance of SCM in improving companies' performance. Although the literature recommends that the generic supply chains must be simple and linear, the reality is different in the construction industry where a multitude of construction supply chains and markets are integrated to deliver the solution to the ultimate customer. Integration between vendors, designers, contractors, sub-contractors, and site team is essential to improve the project performance, reduce waste, and deliver the projects on or before the project completion time.

1.1 ORIGIN OF SUPPLY CHAIN MANAGEMENT

SCM is a concept that was originally developed in the manufacturing industry. The term Supply Chain appeared for the first time in literature in 1982 (Olivier and Webber, 1982). The initial steps of SCM can be seen as Just in Time delivery system in Toyota Production System. The generic configuration and understanding of the Supply Chain in Manufacturing are shown in Fig 1. The main aim of this concept was to decrease inventories drastically and to synchronize the supplier's interaction with the production line. After its appearance in the automotive industry, SCM has gained an independent status in industrial management theory and scientific research (Bechtel and Jayaram, 1997). Western contributors like Burbidge and Forrester played an important role in understanding the supply chain in manufacturing (Towill,1996). Though the development and application of SCM in the manufacturing industry have

been successful and achieved the expected outcome, its application in the construction industry has some problems because of the complex nature of the construction sector (Christopher, 1992). The expected outcomes include cost reduction, on-time delivery, improvement in productivity, value creation, and higher customer satisfaction. The major differences between supply chain in the manufacturing and construction industry are that most of the projects are unique, the equipment and methods of production vary from project to project.

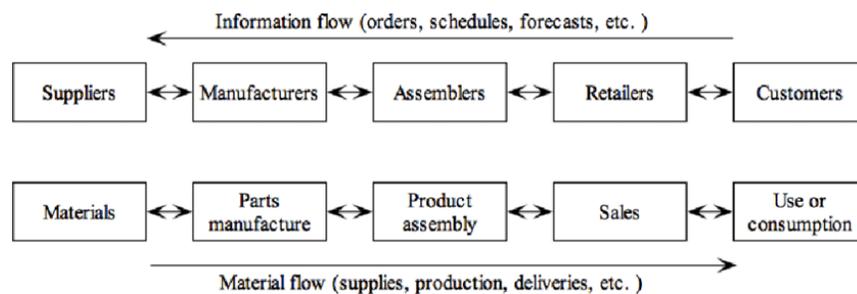


Fig 1: Generic configuration and understanding of Supply Chain in Manufacturing [Vrijhoef and Koskela (2000)]

This paper is divided into 4 sections. Section 2 describes the methodology of the paper; Section 3 describes the concept of Supply Chain Management and its subsection describes the types of Supply chain, differences between the traditional way of managing supply chain and SCM, Evolution of Supply chain in the construction industry, the role of SCM in construction and Machine learning in Supply chain management; and Section 4 presents the conclusion and direction for future research.

2. METHODOLOGY

A narrative literature review involves a comprehensive and critical analysis of the existing knowledge on a particular topic. It forms an essential part of the research process and helps in identifying the trends in the studies to identify gaps and future research. The analysis of the literature was based on reviewing the published articles on Google Scholar between 1982 and 2022 and selecting those that included the studied objectives in the title or the abstract only (e.g. the concept, types, differences between traditional and SCM, and the evolution of SCM). The search included “construction supply chain management” as a keyword and only the articles written in English were included in the search.

Accordingly, 40 articles were selected to synthesize the concept, types, and role of SCM and to understand how to apply and integrate Supply Chain Management in the construction sector to address the issues of productivity and efficiency.

3. 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; Vrijhoef and Koskela 2000). In 1994, The International Centre for Competitive Excellence defined Supply Chain Management as the integration of business processes from end-user through original suppliers that provide products, services, and information that add value for clients (Cooper et al,1997). The general idea of SCM is to identify the interdependency in the supply chain and to enhance control and configuration based on the integration of business processes. It can also be defined as facilities involved in raw material procurement and transforming them into intermediate and final products (Lee et al, 1995). SCM aims to harmonize the requirements of the clients with material and information flow till a balance between client satisfaction and the cost is reached (Papadopoulos et al, 2016, El Moussaoui et al, 2021). Effective supplier management strategy is essential for end customers to maximize the business value of procured products and services (Cox and Ireland, 2001, Font and Grua, 2018). Another important factor is the type of firm selected to deliver solutions. A proper understanding of the relationship between clients, consultants, contractors, and subcontractors in terms of collaboration and integration is essential. The investigation of procurement approaches between 1960 and 2000 in the construction industry is summarized in Fig 2. In the early nineteenth century, the traditional single-stage approach to procurement dominated the construction clients (Saad et al, 2002; Butkovic et al, 2016). This approach is identified by short-term and adverse relationships. Alternative procurement routes such as ‘two-stage competitive tendering’, ‘Design and

Build', 'Management Contracting' and 'Construction Management' represent some differences in relationships, roles, and power between the consultants, contractors, and sub-contractors. These alternate approaches to procurement resulted in great potential for better collaboration and integration.

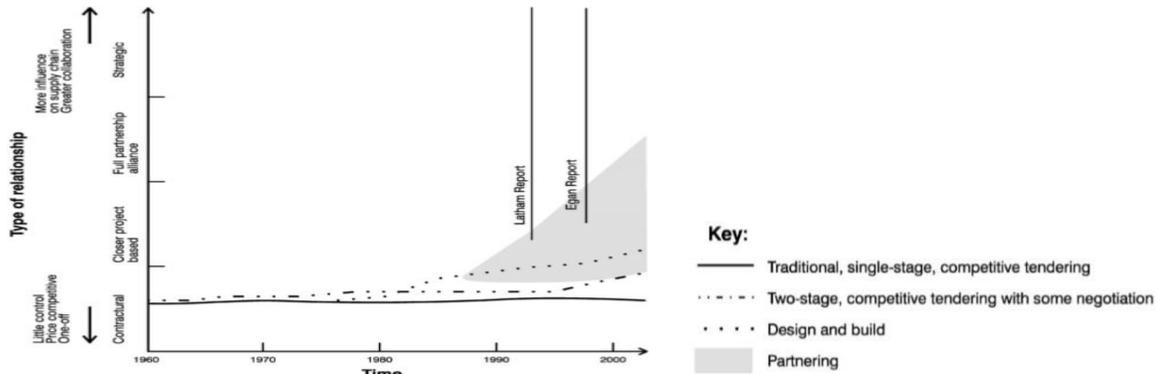


Fig 2: Relationships in the construction industry (Saad et al, 2002)

3.1 TYPES OF SUPPLY CHAIN

There are three types of the supply chain in construction (Butkovic et al, 2016).

- Primary supply chain which delivers material for incorporation into the final construction product.
- Support chain which provides equipment and material to facilitate construction.
- The supply chain which involves the supply of labor.

Fig 3 illustrates that the supply chain is simple but the reality is quite different.

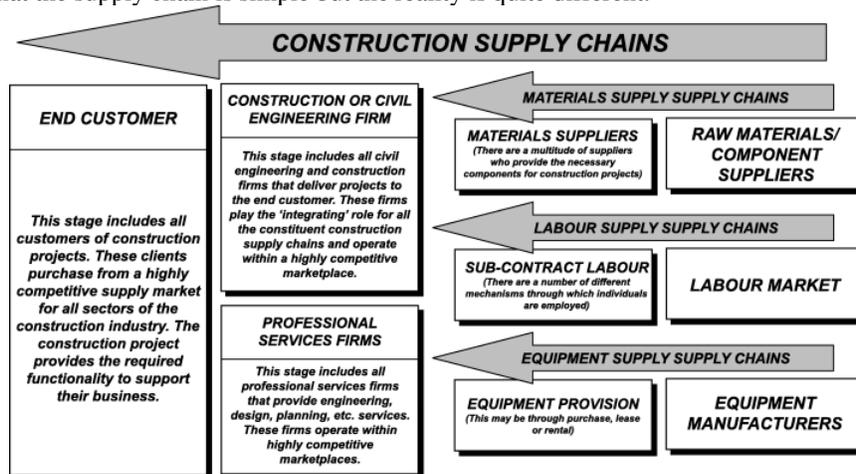


Fig 3: The myriad of the construction supply chain (Cox et al, 2001)

In a construction process, the end customer selects and appoints the construction firm or professional, and the construction firm plays the major integrating role within the generic supply chain. However, the construction industry involves a high degree of sub-contracting and main contractors engage third parties that can be integrated within the solution. Sub-contracting adds to the problem related to adversarial because of another party involved in the supply chain to earn margins to the detriment of other firms (Cox and Ireland, 2001).

3.2 TRADITIONAL SUPPLY CHAIN VS SCM

The traditional way of managing the supply chain was largely based on the transformation view of production while SCM is based on the flow view of production. Independent control of each production stage is suggested by the transformation view whereas SCM concentrates on control of the total flow of production (Koskela, 1992). The

differences between traditional management and supply chain management concerning different elements such as Inventory Management system, cost approach, etc. are explained in Fig 4 below.

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	On going
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

Fig 4: Differences between the traditional way of managing supply chain and SCM (Cooper and Ellram, 1993)

3.3 EVOLUTION OF SUPPLY CHAIN IN CONSTRUCTION INDUSTRY

The evolution of the supply chain in the construction industry is slower than in the general industry. The techniques like inventory management, production, and planning control were applied to improve the performance of construction projects (Fig 5). At present, the focus is shifted towards strategies and techniques such as Material Requirement Planning (MRP), Enterprise Resource Planning (ERP), Business Process Re-engineering (BPR), Computer-Aided Design (CAD), and optimization techniques (Xue et al, 2005; Vaidyanathan 2009).

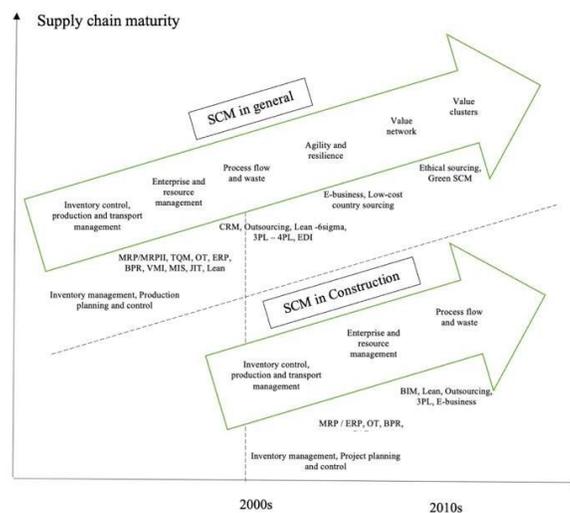


Fig 5: Evolution of supply chain in general and in the construction industry (Le Phuoc Luong et al, 2018)

3.4 THE ROLE OF SCM IN CONSTRUCTION

In the manufacturing system, multiple products pass through the factory whereas a construction factory revolves around a single product. The construction supply chain is represented by uncertainty, fragmentation (Studer et al, 2021), instability, unpredictability, and separation between the design and construction phases. Construction projects involve creating a new prototype or product every time with little or minor repetition. Therefore, it involves making to order supply chain where each project requires a new product or prototype. According to Vrijhoef and Koskela

(2000), SCM has four major roles in the construction industry which is represented in Fig 6. Firstly, the emphasis should be on the effect of the supply chain on the site activities. The aim is to reduce the cost and time duration of site activities. The primary concern should be to ensure labor and material flow to the site to prevent workflow disruption which can be achieved by focusing on the relationship between contractors and direct suppliers. Secondly, the focus must be on the supply chain itself, with the aim of cost reduction specifically those related to logistics, inventory, and lead time. Thirdly the focus is on transferring activities to earlier stages of the supply chain from the site to reduce total cost and duration. Fourthly the emphasis should be on integrated management, supply chain improvement, and site production. All four roles of SCM are applied simultaneously to increase the efficiency of the supply chain.

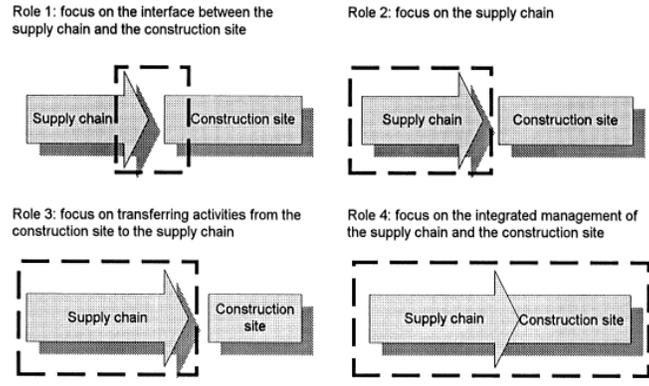


Fig 6: The roles of supply chain management in construction (Vrijhoef and Koskela, 2000)

Decision-making plays a significant role in the construction supply chain. During the first phase, the general contractor provides feedback to the designer. The owner plays a vital role in managing the general contractor's plan in terms of cost, time, and quality. The separation of design and construction, lack of communication between different disciplines, and lack of strategies to share risk results in inefficient construction planning and design (Xue et al, 2005; Vaidyanathan 2009). Advanced technologies such as cloud-enabled BIM help in better and transparent communication among clients, designers, and contractors (Papadonikolaki et al. 2015; Dave et al, 2016, Dakhli and Lafhaj, 2017). During the second phase, the general contractor concentrates on decisions of partnership building, selecting suppliers, production planning, and material purchase as shown in fig 7. In the third phase general contractor is responsible for decisions related to onsite operations. IT-based planning and logistics-based planning are recommended to reduce the uncertainty in on-site construction operations (Dakhli and Lafhaj, 2022).

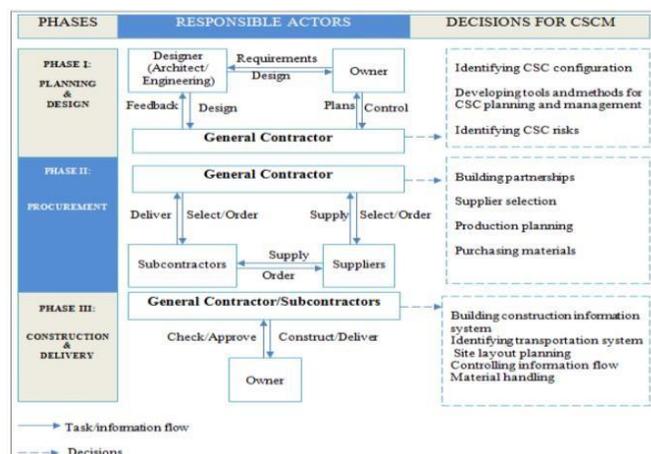


Fig 7: Focused decision on each phase of a construction project (Le Phuoc Luong et al, 2018)

3.5 MACHINE LEARNING IN SUPPLY CHAIN MANAGEMENT

The main aim of the supply chain is to satisfy customer demand and minimize the cost. But uncertainty in demand and supply risk results in the bullwhip effect. To overcome these obstacles Machine Learning algorithms can be used for better decision making and predictions (Bousqaoui et al, 2018).

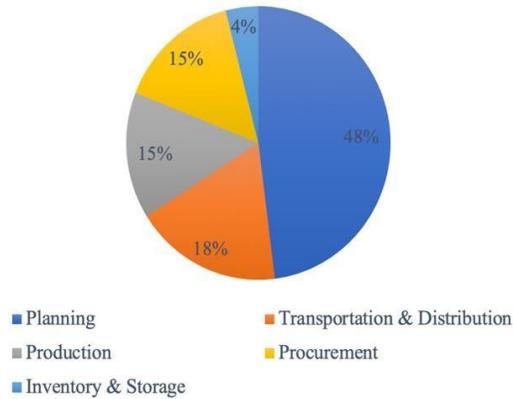


Fig 8: Machine Learning Algorithms applied in each area of the supply chain (source: Bousqaoui et al, 2018)

According to Fig 8, most of the Machine Learning application is during the planning stage, in which the most important is selection of suppliers and Just in Time (Wild, 2018; Hoppe, 2019). The next important area of application in the supply chain is the transportation and distribution area, which mainly includes the vehicle routing problem. The goal is to find the best possible vehicle route to deliver the products to the respective production facility or customer. According to the study conducted by Becker et al, 2016, it has been revealed that the performance of neural network models is 48% more than that of standard optimization heuristics. The third most important field is the production process. Better calculation and prediction of lead time and manufacturing time before the production stage can avoid delays in customer delivery. The model created on the influence of the algorithm indicated a good performance when employed to predict the manufacturing time of new batches. The industries which used Machine Learning to organize their supply chain activities had shown better results in logistics and demand forecasting (Hoppe, 2019).

4. CONCLUSION

This paper focuses on providing an overview of the context of supply chain studies within the construction sector. The interface between site activities and the supply chain has to be developed and improved. Logistics is the main focus of SCM in construction (Wegelius-Lehtonen and Pakkala, 1998). To improve the total flow of material, the focus has to be on suppliers' and contractors' cooperation. An extensive cost and time analysis are vital for supply chain development and improvement. For overall improvement, the trade-off between inventory, transportation, and production costs should be considered. Uncertainty in the supply chain and varying site conditions have an impact on productivity and supply chain performance (O'Brien, 1995). On-site, activities can be transferred into offsite activities by remodeling the supply chain. For instance, prefabrication can be regarded as means of eliminating on-site activities from the total production chain. For the integration of supply chain and construction site, alternatives like open building and sequential procedure have been recommended. (Bobroff and Campagnac, 1987). Efforts from the professionals, contractors, subcontractors, and other parties involved are necessary for the effective adoption of SCM in construction projects. Proper application of SCM in the construction sector helps the project managers in strategic planning to achieve a partnership with different parties and to improve efficiency in operational construction.

The current study covers the trends of the supply chain management and concludes that the use of digitization and the practices of industry 4.0 might present many solutions to improve the SCM in construction projects as they are helpful to trace and improve the flow of the materials, achieve better visibility for the chain, improve the collaborative work between the partners, and support the delivery processes and site works.

4.1 CONTRIBUTION OF THE STUDY AND FUTURE DIRECTIONS

The current study aims to contribute to the existing efforts made regarding the support of improving practices of construction supply chain management. This summary is useful for researchers and academics to present new

directions for future research. It also serves as a reference for practitioners who are working to improve the practices of supply chain management in their projects.

Detailed studies on strategies and methods to improve construction supply chain management have to be done. Further research can be carried out to analyze the compatibility of Supply Chain Management strategies with existing strategies and the role of Supply Chain Management in achieving sustainability in the construction sector and research has to be conducted to fill the knowledge gap.

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