Literature Review of Areas of Application of Supply Chain Management in Construction Industry

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***Abstract*— Construction projects are becoming increasingly complex and the conventional methods of managing them have plateaued over the years. The complexity could be traced to the complexity of designs, which requires inputs from different suppliers/contractors. This has led to fragmentation where suppliers/ contractors specialize in a given project and are contracted to deliver only on their area of expertise. The aim of this paper is to produce evidence of the areas of application of supply chain management (SCM) in the construction industry. The aim was achieved by a thorough literature review of works done in the area. The results showed that all the selected research on the SCM falls within eight major areas. They are procurement, logistics, models application, information, performance evaluation, customer relationship, environmental management and sustainability. Other subfields can be derived from the areas.**

***Keywords*—** *Supply chain, lean construction, green supply chain, construction, procurement, recycling, logistics, sustainability.*

1. Introduction

Supply chain management (SCM) is the planning, execution and coordination of the moving of goods and services from the point of origin to where they are to be further processed into finished goods or consumption. SCM involves the management of

Interconnected, interlinked and interrelated networks of human resources, software, projects, activities, tasks, capital, machinery and information that are deployed in the movement of a product or service from a supplier to customers. Goods are transformed in the process and delivered as a finished or semi-finished products or services to the end-users. Supply chain management is intrinsically linked to value chain management [1]. The latter is concerned with the delivering of valuable products and services to the market while the former considers all categories of products and services. SCM also includes planning, management, and coordination of suppliers, service providers and customers in procurement and logistics activities [2].

The origin of SCM can be traced to the manufacturing industry [3] but the concepts have been applied to different fields thereafter. Logistics and inventory management are areas that depend on SCM [4-6]. Different industries use SCM to improve responsiveness to customers, reduced time of goods delivery to the customers and to achieve competitive advantage. Some examples of industries where SCM has helped to improve production and minimize losses are aviation [7-8], fashion [9] and food [10-11]. Specifically, the concept of SCM is very important in the marketing of manufactured goods and services, hence effective use of SCM have proved decisive in investment and portfolio management [12-15]. Other areas can be found in [16-19].

The construction industry is one of the key economic sectors. Construction activities are often one of the measures of economic advancement and quality of life. Construction projects are becoming increasingly complex and the conventional methods of managing them have plateaued over the years. The complexity could be traced to the complexity of designs, which requires inputs from different suppliers/contractors. This has led to fragmentation where suppliers/ contractors specialize in a given project and are contracted to deliver only on their area of expertise. What is obtainable now is that suppliers handle fragments of projects because of the disintegration of the project design. This has where SCM comes in to effectively manage the fragments to achieve the whole project. Although, this has made SCM a very volatile in the construction industry for the following reasons. 1). Decentralization reduces the time required to achieve effective control. 2). Managing contractual agreements can be very tedious as many firms are involved. 3). An overlap of projects can lead to conflicts of interest and mistrust among the suppliers/contractors. 4). Advances in technology have reduced the project time and hence, there is little time to build complex relationships with the clients.

Despite the challenges, SCM continues to be useful in the construction industry around the world because buildings are outcomes of SCM. Construction projects come in different sizes, types and complexities. The construction industry has utilized supply chain management to improve its performance and competitiveness, thereby minimizing the cost of buildings and building collapse [20-21]. In addition, Supply chain management relies heavily on sound transportation systems and any form of disruptions for example road expansion; reconstruction can distort the flowchart of activities [22].

The aim of this paper is to produce evidence of the areas of application of SCM in the construction industry. The aim was achieved by a thorough literature review of works done in the area. The review precipitated some areas of further research prospects.

2. Procurement

Procurement is a key element in construction project management. SCM is the network of interconnected people (suppliers, building material manufacturers, suppliers, logistics) needed to ensure that the process of procurement is successful. There seems to be a shift from traditional or conventional procurement practices to a modern one driven by information technology**.** The adoption of modern technology guarantees uninterrupted SCM in construction procurement systems [23] which increases profitability and reduction in the instances of time overrun. One of much widely used technology is the electronic procurement, although, the construction industry seems to be lagging behind in its adoption when compared with other sectors of the economy [24].

Some strategic decisions have shown to be helpful in improving the procurement process via the SCM. Early sourcing decisions will help in the SCM planning which involves the selection of suppliers, planning for logistics and budgeting which ultimately leads to proper management of procurement method [25]. Investigation of the resilience of the supplier [26] and effective supplier quality practices at different stages of the projects will help reduce the instances of rework, delays and wastage of scarce resources [27-28]. This also helps to ensure the ethical codes involved in procurement are not violated, for example, the determination ownership and conflict resolution in the procurement process [29]. An effective subcontracting strategy has been cited to be helpful in effective process improvement in the construction industry supported by SCM [30]. Materials management is also a strategy that ensures that quality building materials are procured through the supply chain [31].

In spite of the strategies, many challenges persist. The complexity of the supply chain makes an assessment of quality very difficult [32]. The fragmented nature of projects accompanied by many tasks to be accomplished within a limited time makes it very to map the supplies with the quality specifications. The effect is more evident at the preconstruction phase [33], which can cause a delay in order, and delivery of construction materials and equipotent and waste of human and capital resources. Available studies have recommended sustainable procurement initiatives. Sadly, lack of awareness and funding have limited the adoption of sustainable procurement in construction industry [34-35].

3. Logistics

Logistics is believed to have a military origin and is linked with deployment of military personnel and their associated supplies to areas of conflicts, wars and civil disturbances. Logistics has been used interchangeably with SCM but a clear difference exists between them. Supply chain is a network of people and organizations that interact, relate and cooperate to aid the process of logistics in order to achieve procurement. Logistic management is a subset of SCM. In addition, SCM is the coordination of different logistic operations of firms involved in the supply chain of construction projects. Technically logistics simply deals with the flow of construction materials and services, which are integrated to achieve competitive advantage [36].

Optimization of transportation to the construction site is one way of improving the supply chain process in general and logistic in particular [37]. Optimization is crucial in dealing with the complexity and temporary nature of the supply chain. The numerous interactions between suppliers are to be managed to obtain the feasible way of allocation of scarce resources and increasing efficiency to avoid rework. Third-party logistics providers have also be advocated but its adoption is still in infancy [38].

The advances in construction technology have yielded semi-finished construction materials, which have changed the logistic nature of SCM, used in construction industries. Semi-finished construction materials (prefabrication) are now conveyed to construction sites against the previous practice of supply of raw materials [39]. Interestingly, the status quo is still maintained in low-income countries. The attitudinal changes such as commitment, effective communication, trust and unalloyed cooperation are needed for logistics management to be successful within the supply chain of construction industries [40].

Another aspect of logistic is reverse logistics (RL). Reverse logistics in this context refers to the movement of building materials and products from salvaged buildings to a new construction site [41]. The concept is relatively new and it is yet to be fully incorporated in SCM of construction industry. Two general aspects of RL are deconstruction management and recycling [42] and the purpose ranges from capturing values to ensuring proper disposal [43]. The process is economic as the waste can be used for construction, thereby reducing the cost of procurement and logistics. Some barriers to the full implementation of RL have been unearthed. These include legal and regulatory issues, long time expended and high costs incurred during the process, environmental concerns and poor planning [44].

Tracking of construction materials is required in the logistics and reverse logistics within the SCM framework. Tracking helps to ensure proper accountability, transparency and reduction of operational costs within the supply chain. Radio frequency identification (RFID) [45-46] and geographical information system (GIS) [47] have been applied in case studies.

4. Application of Models in SCM

Models are developed and applied where they are gaps within the supply chain. This cuts across all the aspects of SCM. The complexity, size, quantity and the relatively short life span of the projects in construction industry necessitated the development of models that can aid the management of complex relationships inherent within a supply chain. The models help reduces the cost implications of rework and aid logistics, procurement and flow of information [48]. Logistics can be improved using models that assess the proximity of the suppliers to construction sites [49]. Supply chain cost models have been recommended for reducing the total cost of the project. This is achieved by assessing the impacts of all the fragments as it relates to the total construction cost [50]. The uniqueness of the goals and missions of the different firms/suppliers means that it is difficult to manage their decisions to achieve the common goals, which creates lapses and conflicts of interest within the suppliers/subcontractors. In [51], a model known as a value optimization strategy was proposed to tackle the problem.

Models that are created for supplier partnerships and product life cycle management have helped improve the efficiency of SCM in the construction industry [52]. Moreover, the cumulative risks evaluated from all the suppliers can be used to determine the overall risk models that can help to reduce the risks inherent in the construction projects [53]. When the risks are neglected or unattended to, the construction project is vulnerable to supply chain disruptions [54].

5. Information

Although the global knowledge of the flow of information in construction is low **[55]**, information flow remains vital to the material management during construction SCM. The complexity and fragment nature of the processes warrants an efficient information integration. The fallout of such complex relationships is information gaps, which can occur through the life span of the construction projects. Information flow is key to the success of procurement, logistics and reverse logistics. Apart from direct data generated or needed in construction, topographical and weather data can be considered especially in environmental challenges prone areas [56].

Building Information Modelling based construction has been widely used to bridge any observed gaps in the flow of information [57]. BIM is usually implemented using software or application packages. Operational flexibility, proper coordination, faster decision making, transparency and accountability are most likely areas that are improved with the adoption of BIM.

Ontology can be a powerful framework to be utilized in data integration in the construction SCM thereby alleviating the problems of data sharing and heterogeneity [58]. As stated before, the complexity of the operations in the supply chain generates individual data that has to be cleansed and harmonized in other to facilitate easy decision-making. Harmonization is inevitable if effective supply SCM is anticipated.

Context-Aware Cloud Computing Building Information Modelling (CACCBIM) has been proposed to aid data integration, provides current information within the precast supply chain [59]. Proper management information within the precast supply chain will help improve integration, reduce conflicts and mistrust among the suppliers, enhance the planning process and coordination and reduces the probabilities of poor communication and wrong deliveries. The occurrence or wrong or inadequate deliveries can be reduced drastically since the timely information generated from CACCBIM alerts the authorized users or project managers to take important decisions within a short period [60].

Another aspect of information management in SCM presented in [61] is the use of a decision support system (DSS) where relevant experiences of past projects are stored and called upon when needed. This helps greatly in decision making, planning and project execution.

Large quantities of data are generated in the construction industries and this leads to big data. Enterprise integrated data platform (EIDP) was proposed by [62] in managing big data emanating from construction SCM which is expected to optimize construction processes and support quick and swift decision making.

The construction industry is drifting towards lean oriented SCM but lack of adequate competencies and know-how in information technology is frustrating the speedy adoption of construction lean processes [63] and smart construction sites [64].

6. Performance Measurement

Supply chain performance measure can be referred to as an approach to evaluate or appraise the performance of the supply chain system. It is the auditing of construction SCM. Supply chain performance in the construction industry can be qualitative (ranking of areas of strengths and weaknesses suppliers/contractors/vendors, quality of construction materials and customers' satisfaction) or quantitative [65].

Quantitative measures are the assessment that quantifies the performance of the process that constitutes the supply chain. It appears that quantitative measures are often used in construction industry. They include a). cycle or lead time b). Customer service level: order fill rate, stock out rate, backorder level and the probability of on-time delivery. c). Inventory levels that can be used to measure raw materials, work in progress, finished products and recycled or waste products d). Resource utilization deals with how resources are utilized for optimum performance such as human resources, logistics resources [66], financial resources and procurement [67], marketing resources [68], information systems, building materials and construction machines. Financial resources include the cost of construction/building materials, procurement and logistics costs, cost of reverse logistics, cost of recycled or construction waste [69].

Construction performance measures help to detect gaps in the construction process and hence build resilience into the system [70].

7. Customer Relationship

Human factors are the controlling force in factors of production. Coordination of construction SCM will require a smooth relationship devoid of rancor and distrust. In this aspect, the relationship among the players in the construction industry will guarantee the timely completion of projects and reduction of overrun [71]. Social and demographic attributes of all members play a prominent role in the management of the complexity of interrelationship among the suppliers especially in the areas of negotiation and procurement [72]. At times, there is a need for the customers to be oriented towards acting within the boundaries of defined terms and conditions, thereby improving the value chain and competitive advantage [73].

8. Environmental Management in Construction

Environmental management in the construction supply chain entails targeted actions to control the effects of construction process on the environment. The impact of construction supply chain on the environment is revealed from the scientific process of quality checks and impact assessment. It appears that there is no consensus on the ways of addressing the negative environmental impact of construction and all the suggested solutions are disjointed [74] and fragmented [75] and hence, cannot be applied in some instances. Process-based life cycle assessment (PBLCA) has been cited as the most widely used methodology in predicting and assessing the impacts of construction on the environment. PBLCA requires detailed and predetermined process information to function effectively but the uncertainty nature of construction supply chain limits its adoption and application [76].

Recently, it appears that research activities on green SCM in construction industries [77]. Going green will ensure that the environment is protected against the harmful effects of pollution generated via the different construction supply chain processes. However, a lack of a definite and working framework for the assessment of green SCM has frustrated the full adoption [78]. The cost of implementation of green SCM is small compared with the disasters obtainable when the environment is not shielded from the effects of construction wastes generated from construction SCM processes [79]. Moreover, the efficient use of construction resources leads to the reduction of the impact on the environment, thereby creating lesser wastes to be managed.

Waste management is one of the aspects of mostly encountered terms in construction SCM. Waste disposal and waste recycling are used interchangeably but both are part of waste management. The priority of strategic waste management is waste prevention, re-use preparation, recycling, other forms of recovery and waste disposal.

Prefabrication has been adjudged as one of the most important strategies in minimizing waste generated in the construction industry. The prefabrication process is robust and ensures the minimization of the negative impacts of construction on the environment [80].

Causes of wastes in a typical construction supply chain can be categorized into four:

1). Structural design: These are wastes arising from poor building design, changes in design and failure to incorporate waste management in the design process.

2). Procurement: These include: multiple orders, change in orders [81], errors in ordering, suppliers error.

3). Logistics: Errors in packaging and careless delivery, damage during transportation, poor transportation network and mishandling of construction materials.

4). Others such as political instability, crime, vandalism, environmental disaster, poor installation, climatic factors, break down in information, corruption, lack of effective communications, conflicts of interests and legal or regulatory bottlenecks, offcuts and rework.

Robust waste management practice helps to reduce the cost of material cost and the cost of labor associated with the waste. Reduction of cost implications of carbon (IV) oxide emissions from construction materials such as cement leads improves the entire value chain [82]. The aggregate of all the cost reductions is an economic benefit of the firms handling construction projects.

Researchers believe that the incorporation of waste management in the life cycle of construction SCM is the best strategy in the reduction of the adverse environmental impact of construction wastes. However, the absence of a unified and standardized methodology limits the incorporation of environmental management in general and waste management in particular [83]. Recycling, landfilling and incineration remain the three most adopted strategies of waste management in construction supply chain [84]. Although due process is mandatory for the implementation [85]. Life cycle assessment is expected to reveal grey areas and critical activities that needed adequate waste management intervention [86]. Logistics is one of the most critical supply chains to considered in this aspect [87].

9. Sustainability in Construction SCM

Sustainability in the construction supply chain is a fast becoming a major area of research interest. The triad of environment, social and economic factors are the drivers for the demand for sustainability in the construction industry. Details of the three factors can be found in [88]. In practice, sustainable supply chain management (SSCM) stipulates that all issues (environment, social and economic) regarding sustainability throughout the whole organization have to be assessed and addressed and strategies crafted to mitigate the risks associated with them [89]. The complexity and fragmented nature of construction supply chain remain an issue with the implementation and management of SSCM. However, the success of SSCM depends largely on SCM. Sustainability in construction requires input from all the stakeholders, players in the construction supply chain, and hence they cannot be achieved in isolation [90].

It appears that the environmental aspect of sustainability in construction industry gets all the attention of researchers and stakeholders. For example, prefabrication is seemed to be more sustainable than on-site construction methods [91]. Although the combination of environmental and economic (financial) factors yield the green SCM in the construction industry. The reduction of greenhouse gas emissions (GHG) from construction supply chains features prominently in this context [92]. Reduction of energy and water consumption are also benefits of adopting sustainable construction especially in concrete production [93] where understanding the cement production standards enhances the adoption of SSCM [94].

Sustainability in construction supply chain is complex and the knowledge of the complex flow of construction materials is required for smooth adoption [95].

Lack of integration is the major sustainability issues within the construction supply chain. Other barriers of the adoption and implementation of sustainability includes: social-demographic variables, legal restrictions [96], procurement and logistics policies [97], financial risks, lack of awareness, lack of integration with information technology, poor organizational structure, poor supply commitment, corruption [98], competition and uncertain business environment.

10. Conclusion

The review has revealed eight different areas of application of supply chain management (SCM) in the construction industry. SCM in construction supply chain falls within eight major areas. They are procurement, logistics, models application, information, performance evaluation, customer relationship, environmental management and sustainability. Other subfields can be derived from the areas. The review will help to raise awareness of the importance of adopting SCM in the construction industry. Several research areas can be explored.

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