REVIEW OF CONSTRUCTION SUPPLY CHAIN OPTIMIZATION PAPERS FOR PERFORMANCE IMPROVEMENT

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ABSTRACT

For many countries, improving the construction sector's productivity is becoming more critical for achieving a sustainable long-term competitive advantage. Moreover, the construction industry is increasingly considering digitization, automation, and Information and Communications Technology (ICT) to achieve this objective. Advanced analytics application in supply chain optimization plays a critical role in supporting enterprise performance optimization in many sectors.

Therefore, this research aims to provide researchers with an overview of the recent developments of optimization techniques on the construction supply chain (CSC) for maximizing performance or minimizing cost and highlight the current research gaps in the field. The systematic desk methodology has been used in this research.

The findings of this study shows that there is need of a framework that integrate all CSC processes for its overall optimization as very few studies incorporated design phase processes with procurement and execution phase processes in their optimization model.

KEYWORDS

Off-site construction, supply chain management, modular construction, optimization, Integration.

INTRODUCTION

Construction supply chain management (CSCM) comes with challenges such as lack of collaboration among construction project stakeholders, lack of knowledge transferring and sharing capabilities, lack of standardization and lack of process integration(Saini, Arif, & Kulonda, 2019) and its optimization for maximizing productivity and minimizing project cost is even greater complex and challenging because CSC involves multiple players and such as owner, designer, contractor, sub-contractor, and   outsources labor and processes such as manufacturing ,warehousing , inventory ,transporation and execution at construction site.These stakeholders and processes are interdependent to each other at different levels of a project.

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In addition to this, the stakeholders' benefits and requirements are conflicting as well so it is intricate to achieve a win-win situation for every stakeholder in a construction project. Also, lack of engagement during project lifecycle results in over budget and longer duration for a construction project completion and due to these reasons small and medium-sized companies are way behind reaping optimized integration benefits involved in a construction project. (Bahadorestani, Naderpajouh, & Sadiq, 2020). Consequently, in order to optimize overall CSC of a project and avoiding any conflict , all the processes and their effects must be incorporated in a model developed for maximizing performance of a project.So there is need of a research that provide comprehensive overview of existing papers focused on application of optimization on CSC processes.

Therefore, in this study, an attempt has been made to review the CSCM optimization papers that incorporated major CSC processes in their model and identify research gaps for further improvement in this area.

LITERATURE REVIEW

There are few studies that reviewed CSCM papers but they were not related with optimization application. One review study was related to enablers in CSC (Q. Chen, Hall, Adey, & Haas, 2020) , one was related with decision making in CSC (Phuoc Luong Le, Elmughrabi, Dao, & Chaabane, 2020) and the other was done on the development of framework for SC planning consist of construction process critera(Thunberg, 2016).Furthermore ,one paper reviewed CSC papers in the context of industry 4.O (Dallasega, Rauch, & Linder, 2018) and one paper review is related with internet of things(Kumar & Shoghli, 2018) .Thus this study is going to be first of its kind that reviewed CSC optimization papers against SC processes.

To review the CSC optimization papers, a benchmark or refrence list of exhastuive SC processes was required to evaluate review papers against those processes.(Y. Liu, Dong, & Shen, 2020) and (Phuoc Luong Le et al., 2020) identified the CSC levels, phases and processes in a very comprehensive manner is presented in table 1. These processes is taken as benchmark and review of CSC optimization papers is carried out based on these processes in this study.

Table1: Phases and Processes in Construction Supply Chain Management

Collaboration Level								Execution level			
Design Phase			Procurement Phase					Construction Phase			
CSC Configuration	Modularity	Strategic Planning/ Risk Evaluation	Production/ Prefab components Planning	Supplier Selection	Purchasing Decision	Storage	Building Partnership	Transportation	Site Layout Planning	Controlling Information Flow and Other Delay Factors	Material Handling

- CSC Configuration (CC): To configure and allocate CSC factors, SC participants, material and information flows, strategies, and resources of the SC network.

- Modularity (M): To determine the modularity of a building under controlled conditions.

- Strategic Planning/ Risk Evaluation (SR): To identify, assess risks, raise mitigation and contingency strategies, and respond efficiently to recognized threats as they arise. Production/Prefab Components Planning (PP): To make and control the construction project's production plan and manufacturing processes.

- Supplier Selection (SS): To apply efficient methods for supplier evaluation & selection.

- Purchasing Decision (PD): To employ the efficient methods for material procurement.

- Storage(S): To figure out the most cost-effective warehousing of prefab components.

- Building Partnership (BP): To apply SCM in construction to achieve long-term and supportive partnerships among stakeholders to ensure project cost optimization

- Transportation (T): To establish and control the transportation system (Off & On-Site).

- Site Layout Planning (SLP): To improve the on-site construction performance by optimizing the arrangement of facilities.

- Controlling Information Flow and Other Delay Factors (CD): To control information and physical flows to avoid instability in construction execution.

- Material Handling (MH): To convey, elevate, position, transport, package, and store materials and facilities management.

RESEARCH METHOD

A systematic literature review has been carried out in this research. This approach is adopted from the papers (Seuring & Gold, 2012) and (Khan, Chaabane, & Dweiri, 2018), and it of papers (Mettler, Eurich, & Winter, 2014).
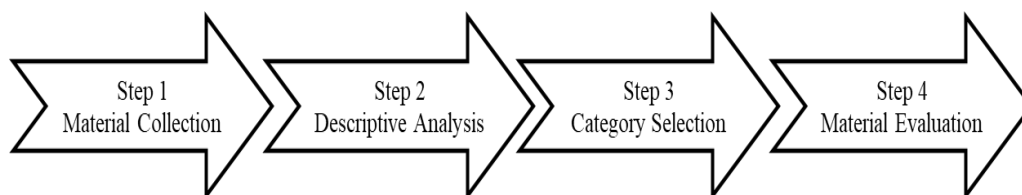

Figure1: Literature Review Method

- Step1: The Scopus database has been used in this research because it covers a superior number of journals and articles (Aghaei Chadegani et al., 2013). Unpublished work, non-reviewed papers, working papers, and book chapters are not considered in this study. The keyword search approach is used because it is the most common way of literature review in databases and library services (Seuring & Gold 2012). The different keywords and their combination results are shown in Table 2.

Table 2: Selected Keywords Combination Search Results

Keywords Combination	Search Results
Construction Supply Chain AND Optimization AND Logistics	99
Construction Supply Chain AND Optimization AND Material Planning	31
Construction Industry AND Optimization AND Supply Chain	146
Construction Industry OR Building AND Supply Chain	471
Building AND Optimization AND Supply Chain	536
Construction Supply Chain AND Modular AND Optimization	17
Building AND Optimization AND Logistics	291
Construction AND Supply Chain AND Optimization	516
Construction AND Supply Chain AND Improvement	522
Construction AND Logistics AND Optimization	726
Construction AND Logistics AND Improvement	506
Construction AND Material Planning AND Optimization	647
Construction AND Material Planning AND Improvement	591
Building AND Supply Chain AND Improvement	431

- Step2: After searching papers using different keywords combination, filtration of those papers was done through the criteria: If a paper studied or implement the application of optimization tools on construction supply chain processes as identified in this paper, that paper was selected. 41 papers were finalized after step 2, as shown in below graph 1.
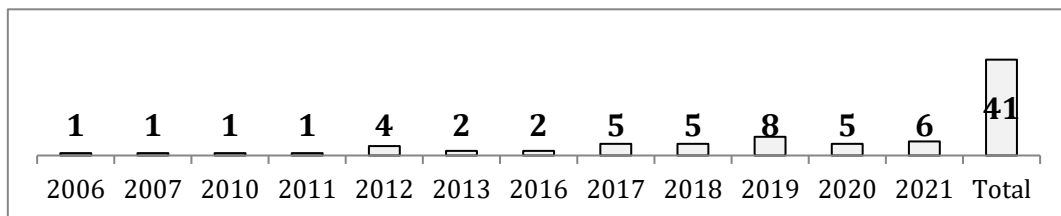
Graph 1: Year Wise break up of Selected Papers

- Step3: Categorized them on the basis of optimization tools and CSC processes.

- Step4: Evaluation of selected papers was done by reading the article's abstract, methodology, and conclusion. Then, identify what and how many supply chain process factors are incorporated in a paper's mathematical model. This material evaluation process was based on all authors' academic judgment, and cross-reading was performed to eliminate the discrepancy in understanding among authors for material evaluation.

- Step5: An additional step is also taken, which is not a part of this approach. The optimization tools identified in the papers mentioned in table 3 are verified with the literature definition of the tools to ensure correct understanding of the tools concept.

RESULTS

In line with the first research objective of this study , analysis was done on the filtered papers against CSC processes and optimization tools as mentioned in table 3. As mentioned in Table 3, the MCDM tool is found to be the most used optimization technique. In CSC, out of 41 papers, 25 and 24 articles have focused on CSC's transportation and purchasing decision processes, followed by the storage process, which has been studied 21 times. At the same time, CSC configuration and strategic planning received the least attention from the authors as only six studies have focused on them. The process such as material handling, site layout planning, and supplier selection has been studied moderately.Following is the analysis of table 3 findings:

DESIGN PHASE

Collaboration level processes received the least attention relatively with the rest of the processes. Only 19 papers from 44 have focused at least on one of the management-level processes. Very limited numbers of papers were found that used mathematical tools to develop construction supply chain configuration and strategic management, so the application of mathematical tools is still not very mature or underexploited.

PROCUREMENT PHASE

Most of the studies on CSC have focused on planning-level processes. Thirty-six papers from 44 have contributed to at least one of the CSC procurement phase processes as mentioned in Table3. Multi-criteria decision-making tools have been applied successfully in mostly supplier selection problems. Operation research modeling such as linear, integer, or even mixed-integer linear programming models along with stochastic models has been used to tackle manufacturing planning, material ordering, and storage issues of construction material and prefabricated components.

CONSTRUCTION PHASE

32 papers have focused on at least any one of the processes of this phase. Hybrid models, simulation techniques, and multi-criteria decision-making have been applied to predict delays on construction sites and supply material transportation. Using mathematical models for optimizing transportation processes is very mature in other sectors and looks promising in other processes as well.

Authors	Optimization Tool	CC	ML	SR	PP	SS	PD	S	BP	T	SL	CD	MH
(Elimam & Dodin, 2013)	MILP				√	√	√	√		√			
(Alayet, Lehoux, & Lebel, 2018)	LP				√			√		√			
(Cengiz, Aytekin, Ozdemir, Kusan, & Cabuk, 2017)	MCDM					√				√			
(Q. Chen, García de Soto, & Adey, 2021)	NLP						√	√		√			
(W. W. Chen, Lei, Wang, Teng, & Liu, 2018)	MILP					√	√	√		√			√
(Costa, Granja, Fregola, Picchi, & Staudacher, 2019)	MCDM	√		√					√			√	
(Deng, Gan, Das, Cheng, & Anumba, 2019)	NLP					√	√	√	√	√	√		√
(Hemanth et al., 2017)	MCDM			√					√			√	
(Hsieh, 2016)	Hybrid Methods									√	√	√	
(P. Y. Hsu, Angeloudis, & Aurisicchio, 2018)	Two-stage Stochastic		√		√	√	√	√		√			
(P. Y. Hsu, Aurisicchio, & Angeloudis, 2017)	MILP		√		√	√	√	√	√	√			
(P.-Y. Hsu, Aurisicchio, & Angeloudis, 2019)	Hybrid Methods		√		√	√	√	√		√	√	√	
(Jaśkowski, Sobotka, & Czarnigowska, 2018)	MILP					√	√	√					
(Karabayir, Botsali, Kose, & Cevikcan, 2020)	MCDM					√							
(Kayhan, Cebi, & Kahraman, 2019)	MCDM			√		√	√						
(S. Kim, Chang, & Castro-Lacouture, 2020)	Simulation methods											√	
(T. Kim, Kim, & Cho, 2020)	Simulation methods			√	√					√	√	√	√
(Y. W. Kim, Han, Yi, & Chang, 2016)	Simulation methods	√			√		√	√		√			
(Komsiyah, Wongso, & Pratiwi, 2019)	MCDM					√			√				
(Kristy & Zagloel, 2020)	MCDM					√			√				
(Leontaris, Morales-Nápoles, Dewan, & Wolfert, 2019)	Simulation methods			√			√			√	√	√	√
(van der Beek, van Essen, Pruyn, Aardal, & Hopman, 2019)	MILP		√		√		√	√					
(J. Liu & Lu, 2017)	LP		√				√			√		√	√
(Yazdi, Fini, & Forsythe, 2020)	LP		√		√						√		
(Jing Liu & Lu, 2018)	Hybrid Methods		√	√	√		√			√		√	√
(Tserng, Yin, & Li, 2006)	Constraint Programming				√		√	√	√	√			
(Castro-Lacouture, Medaglia, & Skibniewski, 2007)	LP							√					
(Taghaddos, Hermann, AbouRizk, & Mohamed, 2010)	Simulation		√		√		√	√		√	√	√	√
(Pan, Lee, & Chen, 2011)	LP	√				√	√	√		√			
(Cadena, Ramos, Gómez, & Munoz, 2012)	MILP										√	√	√
(D. Liu, 2012)	Genetic Algorithm	√											
(Said & El-Rayes, 2012)	Genetic Algorithm						√	√		√	√		
(Xanthopoulos, Aidonis, Vlachos, & Iakovou, 2012)	LP										√	√	√
(Said & El-Rayes, 2013)	Hybrid Methods	√					√	√		√	√	√	
(J. H. Chen, Yan, Tai, & Chang, 2017)	Linear Programming				√					√			
(Golkhoo & Moselhi, 2019)	Hybrid Methods						√	√		√		√	√
(Jaafar, Elbarkouky, & Kennedy, 2021)	MILP										√	√	√
(P. L. Le, Jarroudi, Dao, & Chaabane, 2021)	LP					√	√	√	√	√			
(Mirghaderi & Modiri, 2021)	Hybrid Methods	√			√		√	√		√			√
(Son, Duy, & Dat, 2021)	Hybrid Methods				√		√	√		√			
(Zhu, Dai, Liu, Xu, & Alwisy, 2021)	LP		√		√		√			√		√	√
Total papers / CSC Process		6	9	6	15	14	24	21	11	25	12	16	14

DISCUSSION

RESEARCH OPPORTUNITY (RO) 1

"Best Decision-Making Tool for Each Construction Supply Chain Process"

There are papers where operations research is applied to the construction supply chain process, and some papers even try to cover the whole aspect of the construction supply chain. However, there is still a lack of research that identifies the best decision-making tool for each supply chain aspect. For example, Fuzzy AHP is most recommended for supplier selection as identified from the literature review (Su, 2020) but it is not adequate for other processes such as demand prediction where stochastic models may work well. Therefore, research is needed to find the best decision-making tool for each supply chain construction process that can incorporate uncertainties and scenarios of that process.

RESEARCH OPPORTUNITY 2

"Framework for Optimizing Overall Construction Supply Chain"

There is a need for a framework to identify the best practice to optimize the overall construction supply chain. That framework will include phases and processes like mentioned in this research and the best tools for each process mentioned in research gap that framework will also identify how to integrate each process's best results to optimize the overall construction supply chain to produce the most effective results.(S.-Y. Kim & Nguyen, 2020) also identified factors that are barrier in effective CSC implementation , some barriers were lack of involvement in active participation from parties and lack of knowledge of applied SCM etc , so their study can be helpful for this research opportunity.

RESEARCH OPPORTUNITY 3

"Standardizing Supply Chain processes through Lean Construction."

Recent trend shows that researchers have recommended lean construction. The research can be done on standardizing construction supply chain processes. Lean management is about removing things that do not add value to the cause; that can be an operation or/an excess of anything such as cost, time utilized in executing any function. Therefore, standardization of construction supply chain processes through lean management tools such as Value Stream Mapping (VSM) can be a critical first step before optimizing or improving those processes.Similar opportunity was identified by (Dana Broft, 2020) where they proposed combine usage of SC and lean pricnicples for effective CSCM.

CONCLUSION

An attempt has been made in this research to identify and analyze the papers related to the application of optimization tools to maximize performance or minimize the cost of CSC. Forty-one papers were analyzed against 12 processes of CSC, and none of them were covering all the processes in their optimization model. Design-level processes are qualitative and not easy to incorporate them into the model. Still, their factors and effects can be incorporated in future optimization tools to comprehend all the processes and optimize CSC effectively. This is the major research opportunity identified in this research. However , to achieve this effectively, it is needed to identify the best decision-making tool for each process (RO 1) and then incorporate all the processes and their effects, especially design level qualitative processes, in a mathematical model (RO 2).

This research has some limitations. Indeed, only the Scopus database has been used to explore papers, so a web of science database could be added for future research. Finally, this research focuses only on CSC optimization.Therefore, doing the same research from different methodology/technique perspective could also be done in the future.

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