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DEVELOPMENT OF AN OPTIMIZATION MODEL BASED ON BUSINESS PROCESS RE-ENGINEERING TO MINIMIZE CONSTRUCTION PROJECTS DELAY

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ABSTRACT

Related decisions can affect project scheduling in a construction supply chain (CSC). After all, the project activities require vital resources and collaboration among project stakeholders. That effects can occur negatively, such as delay, budget overrun, and project performance. These effects are considered wastes in lean construction (LC). The concept of LC is still limited regarding application in CSC. This study aims to develop a decision-making model (LC tool) to minimize project delays using a mixed integer linear programming optimization model. The proposed model is triggered by the business process re-engineering of the scheduling process.

A construction company case example that delivers construction renovation projects to its customers is considered for validation. This approach is applied in two stages. In the first stage, the information process flow of the company is developed to derive the inputs required for the logistics and scheduling optimization model. Then in the second stage, the mathematical model is developed based on the inputs to generate optimal supplier selection, projects schedules, and resource utilization decisions. By using the proposed LC tool, the results show that delays in multiple projects can be minimized. Finally, decision-makers can use this technique to manage concurrent projects and suppliers that leanly provide essential resources to these projects.

KEYWORDS

Lean Construction (LC), Construction Supply Chain (CSC), Optimization, Offsite Construction, Scheduling

INTRODUCTION

Lean construction (LC) or lean manufacturing focuses on the constant effort of removing waste, meeting or exceeding all customer expectations, focusing on the entire value chain, and

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increasing efficiency or productivity in the execution of a construction project or manufacturing process (Eldeep, Farag, & Abd El-hafez; Mossman, 2018) and (Zimmer, Salem, Genaidy, & Shell, 2008). The lean theory has five fundamentals: value, value stream, flow, pull, and perfection. The lean philosophy aims to increase customer value while eradicating waste. Lean construction considers the construction processes as a flow of activities, and all non-value-adding activities are considered as "waste" (Eldeep et al., 2022).

The objective of lean philosophy is to minimize waste. In LC, the activities or events considered as "waste" are defects, overproduction, waiting, over-utilized talent, transportation, inventory, motion, and extra processing (Igwe, Hammad, & Nasiri, 2022). Therefore, any approach or tool that minimizes these wastes can be considered an LC tool. Based on the literature, LC tools for construction supply chain management (CSCM) can be qualitative such as just in time (JIT), or only quantitative such as mathematical optimization (Uriarte, Ng, & Moris, 2018), or hybrid method (Li, Fan, & Wu, 2010).

CSCM manages communication and actions among project stakeholders who collaborate to ensure appropriate responses to the varying demand and supply signals across supply chain functions (Mello, Gosling, Naim, Strandhagen, & Brett, 2017). An efficient construction supply chain (CSC) enables cost savings, schedule compression, decreased material lead time, and high-quality construction projects (Le, Elmughrabi, Dao, & Chaabane, 2020). CSCM is a promising approach to successfully integrating several internal and external players (suppliers, designers, vendors, contractors, subcontractors, and internal and external clients) (Le, 2020).

Lean supply chain management is an important field of research. Different frameworks have been proposed and applied successfully in many industries (automotive, retail, etc.) and service sectors (healthcare, financial, etc.) (Jasti & Kodali, 2015). Lean and construction supply chain management needs a better understanding ((Le & Nguyen, 2022) ; (Zimmer et al., 2008)). More research will help develop LC tools that improve CSC at different construction project phases and deal with CSC issues, such as delays in projects in both breadth and depth (Liu & Lu, 2017). Therefore, this research proposes a lean construction tool to minimize delays in construction project scheduling activities by combining two Lean supply chain management pillars: business process re-engineering (Information technology) and logistics optimization (Logistics Management).

LITERATURE REVIEW

CSCM is a popular and emerging topic. A recent literature review study shows six established research clusters: logistics and SCM for prefabricated construction, construction procurement, CSC integration, green construction SCM, reverse logistics in construction, and onsite construction logistics (Nguyen & Le, 2022).

Hatmoko & Scott (2010) defined construction SCM as a system where suppliers, contractors, clients, and their agents work together to install and utilize information to produce and deliver materials, plant, temporary works, equipment, labor and/or other resources for construction projects. The concept of the construction SCM implicitly provides the opportunity for substantial improvements in client and stakeholder value through a strategic look at profitability. Lean construction is more effective if it integrates with supply chain collaboration, especially long-term collaboration. In other words, supply chain collaboration facilitates lean application and accelerates lean transformation (Meng, 2019)

Lean construction(LC) provides principles and tools that support companies to recognize and remove non-value addition activities or tasks from processes, improve productivity, and provide value to customers. Optimum results could be obtained by continuously striving for improvement (Plenert, 2011). LC can work with other construction technologies, and there is an increase in the integration of (LC) and Building Information Modelling (BIM) to derive benefits(Marte Gómez, Daniel, Yanquing, Oloke, & Gyoh, 2021). There is little literature regarding applying business process re-engineering and mathematical optimization to achieve lean construction (LC) in CSC. The following table shows the search results of different keywords used in the Scopus database.

Table 1: Search Keywords Result

Query	Keywords	Results
1	lean construction AND supply chain AND scheduling	22
2	lean construction AND supply chain AND performance improvement	30
3	supply chain AND lean construction AND business process AND optimization	6
4	supply chain AND lean construction AND business process AND optimization AND scheduling	2

The two papers combining the fourth query keywords do not focus on CSC, and the papers resulting in the third query keywords combination is six. Out of six, only two were relevant to CSC. They developed a software platform system and integrated project stakeholders and Building Information Modelling (BIM) technology to collaborate to achieve lean construction digitally and improve project performance collectively (Yungui, Kuining, Yongbin, & Tao, 2014). One study proposed a methodology to integrate principles of lean construction and constraints of resource scheduling into a constraint programming optimization formulation to improve construction productivity and logistical efficiency (Liu & Lu, 2017).

Some papers deal with construction supply chain optimization, including supplier selection and minimization of project delays. However, none are linked with lean construction, as evaluated above in the literature search results.

For the mathematical model to give output, it requires input data, which are parameters. This paper applies LC methodology to minimize waste and attain the parameters necessary to minimize project delays. Some papers applied optimization in construction project scheduling and supplier selection.

Mirghaderi & Modiri (2021) developed a heuristic-based multi-objective mathematical model under uncertainty investigated for construction material supply chain design. The considered supply chain comprises a primary supplier and a number of projects (i.e., customers) demanding different construction materials in different periods depending on the technical specifications of the demanded product in terms of lifetime.

A mathematical model is conceived in this study to design and optimize risk-averse logistics configurations for modular construction projects under operational uncertainty. The model considers the manufacturing, storage, and assembly stages, along with the selection of optimal warehouse locations, but supplier selection was missing in their model(Hsu, Aurisicchio, & Angeloudis, 2019).

García-Nieves, Ponz-Tienda, Ospina-Alvarado, & Bonilla-Palacios (2019) proposed a mathematical model that practitioners can easily use to optimize construction schedules considering to the largest extent the time and space conditions repetitive projects offer.

RESEARCH METHOD

This section provides details of the problem and justification of the solution proposed to solve the problem.

PROBLEM DESCRIPTION

A construction consultancy company based in Montreal, Canada, delivers construction projects modular or traditional for Canada based in Montreal. We named the company XYZ in this paper to protect their privacy. The XYZ company provides optimal foundation and structural repair solutions as well. The problem they faced was assigning resources to different projects and managing different project schedules. They were looking for mathematical solutions to optimize their project scheduling and assignment of resources to multiple projects. Initially, they did not have any process mapping of their processes, and many processes needed to be more varied or waste that did not add any value to their work.

SOLUTION APPROACH

The reason for choosing the business process management (BPM) technique to identify redundant processes is that it helps to align your strategic objectives with business processes, demonstrate executive commitment, and empower employees. The chances of improvement in business processes will be amplified (Hung, 2006). The BMP technique helped the XYZ company set its lean objective to minimize multiple project completion times.

To optimize the project schedules, different techniques can be applied. We selected a single-time minimization objective because the single-project approach identifies better solutions than the multi-project approach. (Kannimuthu, Raphael, Ekambaram, & Kuppuswamy, 2020). We selected solver-based optimization over simulation-based optimization for project scheduling because it is fast convergence (for small problems), time constraints modeling, and makes exact solutions possible. In contrast, in simulation, it is slow convergence and not always the optimal solution reached. (Klemmt, Horn, Weigert, & Wolter, 2009).Therefore in this research, we utilize both BPM and mathematical optimization techniques to achieve the best results.

MODEL DEVELOPMENT METHODOLOGY

The mathematical model is developed in two steps to achieve LC (minimize project delay). First, the business process of XYZ is studied and improved based on the information required as inputs to minimize delays in their ongoing project schedules.

After fixing their business process information flow, a mixed integer linear programming mathematical model is developed to minimize the project delays based on supplier selection and project activities optimization. The explanation of these steps is shown in Figure 1.

The first step concerns improving the organization's information flow process to gather inputs for the mathematical model. The second step is related to mathematical model implementation and the generation of optimized schedules.

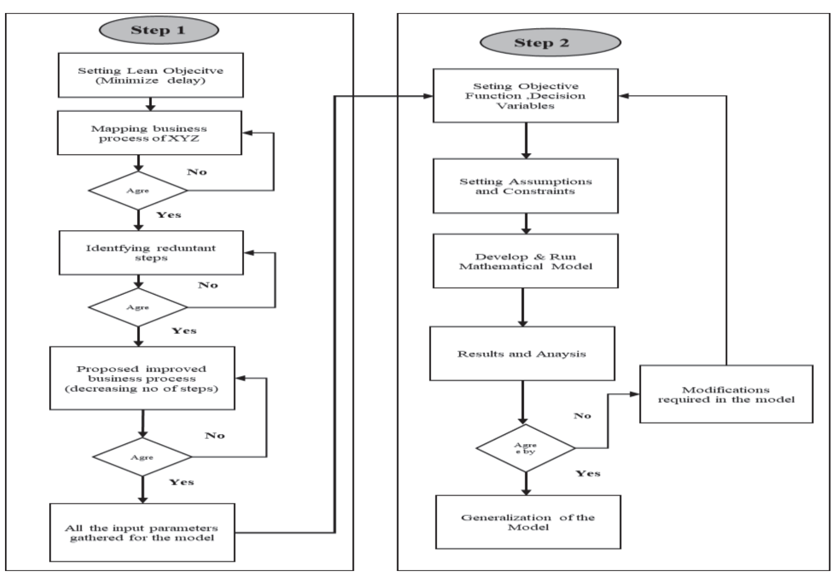

Figure 1: Working Methodology

FIRST STEP IMPLEMENTATION

The company's business process is analyzed and improved in the first step to get the required data to generate schedules. The following figure 2 shows company XYZ's proposed information flow process for managing schedules. There are two departments: administration and technical, along with three people involved in generating and managing schedules of projects. The company manager is from the administration department, and the project manager and team lead are from the technical department. The information flow system is integrated, and the information, whether input or output of the process, is shared by these three people through an IT system named the scheduling system in the figure.

The information generated in these processes includes the number of projects scheduled to optimize, the type of resources required for the project, supplier's information, project activities duration, cost of resources by suppliers, activities precedence to each other, and due date of project completion. These inputs are shown in green borders in the below figure. This input information will be stored in an integrated system that will allow them to manage and view it. The "XOR" gate used in the team lead pool shows the decision he has to take for the resources. If the company has enough resources for the project, it will proceed without suppliers. Still, if company resources are insufficient, he has considered the cost and time associated with suppliers for providing resources. This paper considers projects that require supplier resources for their completion. Then after receiving the input information from the team lead about the projects, the project manager will assign relative importance weights to these projects based on priority. These weights will be critical as the model in the second step will optimize the project schedules based on these weights.

After having this information, the project manager will finally use the mathematical model to generate optimized project schedules in real time. This administration and other departments will receive updated information about the project schedules, as shown in the last process of Figure 2.

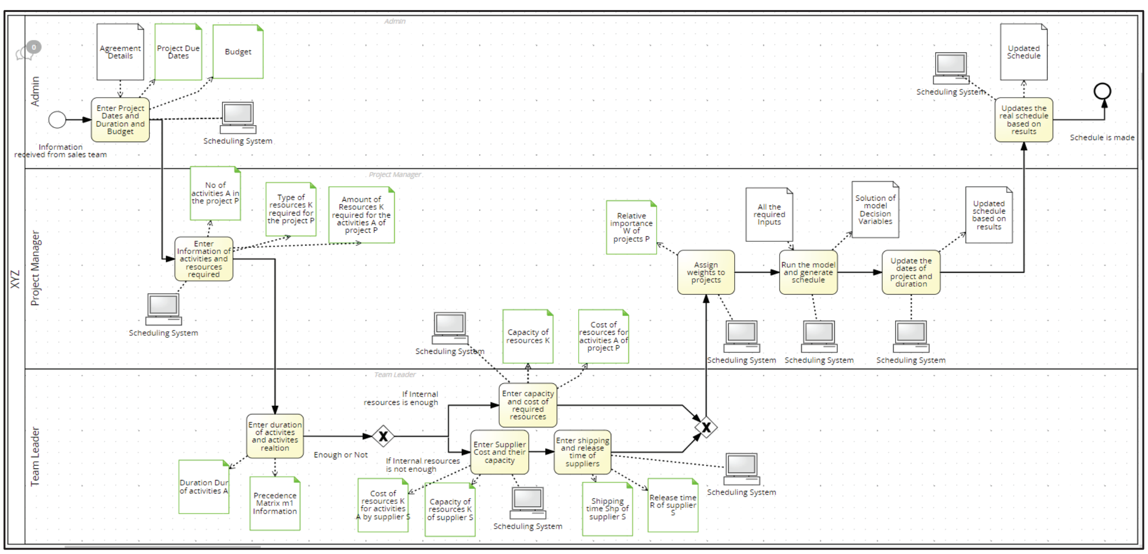

Figure 2: Proposed XYZ Information Flow Process for Managing Project Schedules

SECOND STEP IMPLEMENTATION

A mixed integer linear programming model is developed to optimize project schedules. This model is inspired by the study of (Chen, Lei, Wang, Teng, & Liu, 2018) with small modifications such as adding a precedence matrix approach as a constraint. The assumptions taken for this model include the following: projects are independent of each other regarding activity dependence, but they can share suppliers and resources. No uncertainty factors are included in the model; the raw materials are always available in the right quantities in the supplier's warehouse; they do not produce a surplus, and the elements are transported in shipments whose sizes were fixed before.

The details of the model are given as follows:

Sets)

P	Set of Projects
S	Set of Suppliers
A	Set of Activities within each Project
K	Set of Nonrenewable Resources

Parameters)

$Q_{\mathrm{P}AK}$ Quantities required by each activity A of each resource K of each project P

Cap_{SK} Total capacity of each supplier S for resource K

R_{SK} Release time of supplier S for resource K

Shp_{SP} Shipping time of supplier S to project P

Co_{SKA} Supplier S cost of supplying resource K

Dur_{PA} Duration of activity A of project P

W_p Relative weight of project P

DD_P Due date of project P

$Bud = \$10000$

$M = 50000$

m_P The precedence binary matrix for each activity of project P

Decision Variables)

X_{PSAK} Binary variable representing the supplier selection for resource k of activity A of project P

Z_{PSAK} Quantity supply of resource k for activity A of project P by supplier S

ST_{PA} Starting time of activity, A of project P

TD_P Tardiness (delay) of project P

CT_P Completion time of project P

Objective Function)

The objective function is to minimize the delay of multiple projects simultaneously based on their importance weights.

$$\text{minimize} \qquad \sum_p W * P \tag{1}$$

Constraints)

$$\sum_{p \in P} \sum_{a \in A} Z_{pska} \le Cap_{sk} \forall s \in S, k \in K \tag{2}$$

The equation 2 constraint is related to the capacity of the supplier. Each supplier has different capacity for resource k and its total supply for each resource must be equal or less than its capacity.

$$\sum_{s \in S} Z_{pska} \geq Q_{pak} \forall p \in P, a \in A, k \in K \tag{3}$$

The equation 3 constraint is related with quantity of resources k required by each activity. The total units of resource k supply by supplier S should be greater than or equal to required quantity of activity a of project p

$$\sum Z_{pska} \leq M \times X_{psak} \forall p \in P, a \in A, s \in S, k \in K \tag{4}$$

The equation 4 constraint is related to big M. It implies that the quantity of resources k should only be supplied by supplier s that are selected for that activity a.

$$\sum_{p \in P} \sum_{s \in S} \sum_{k \in K} \sum_{a \in A} Z_{pska} \times Co_{ska} \leq Bud \tag{5}$$

The equation 5 constraint is related with budget of projects. The total cost of resources k required by activity a of project p should be less than or equal to the budget.

$$\sum_{s \in S} (R_{sk} + Shp_{ps}) \times X_{psak} \leq ST_{pa} \forall p \in P, a \in A, k \in K \tag{6}$$

The equation 6 constraint is related to release time, shipping time of supplier *s* of resource *k* and starting time of activity a. The starting time of activity a should be greater than or equal to the summation of release and shipping time of supplier *s* for resource *k*.

$$ST_{pa} + Dur_{pa} \leq CT_p \forall p \in P, a \in A \tag{7}$$

The equation 7 constraint is related to the construction time completion of the project. The starting time of the last activity of project p and its duration must be less than or equal to the construction completion of the project.

$$TD_p \geq CT_p - DD_p \forall p \in P \tag{8}$$

Equation 8 is related to the tardiness of the project. It states the difference in time between the due date of the project(input) and the construction completion of the project (decision variable).

$$ST_{pi} + Dur_{pi} \leq ST_{pj} \forall p \in P, i \in A, j \in A, i \neq j \tag{9}$$

Equation 9 is related to precedence matrices of projects. It provides information on activities dependence on other activities via binary format.

IMPLEMENTATION

All the input parameters are fed into the Python model through Excel sheets. Some of these are shown below. The relative importance weights W of projects chosen randomly as P1 = 0.4, P2 =0.2, and P3 = 0.4. Each project has its precedence matrix, and in Table 2, the precedence matrix, namely "m1" of project 1 is shown below. This table is read as horizontal number depends upon vertical number; for example, in the table, activity 2 is dependent upon completion of activity 1 and similarly, activity 7 is dependent upon all activities from 1 to 6 and will not start until these activities are complete.

Table 2: Precedence Matrix for Activities of Project 1

m1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1		1					1											
2							1											
3							1											
4							1											
5							1											
6							1											
7								1										
8									1									
9										1		1						
10											1	1						
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18																		

Another input Q, the resources required by activities of different projects are shown in Table 3. This parameter is in three dimensions where "A" represents activities of a project, "K" represents resources required for that activity, and "P" represents projects.

Table 3: Resources Required by Activities of Different Projects

		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18
P1	K1	5	4	4	5	4	4	5	4	4	5	4	4	5	4	4	5	4	4
P1	K2	2	6	1	2	6	1	2	6	1	2	6	1	2	6	1	2	6	1
P1	K3	5	0	2	5	0	2	5	0	2	5	0	2	5	0	2	5	0	2
P2	K1	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5
P2	K2	4	8	4	4	8	4	4	8	4	4	8	4	4	8	4	4	8	4
P2	K3	6	0	0	6	0	0	6	0	0	6	0	0	6	0	0	6	0	0
P3	K1	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5
P3	K2	4	8	4	4	8	4	4	8	4	4	8	4	4	8	4	4	8	4
P3	K3	6	0	0	6	0	0	6	0	0	6	0	0	6	0	0	6	0	0

RESULTS

The optimization model for logistics management was implemented using Python and solved with the Gurobi solver. The model generated contains 986 constraints and 1,086 variables (486 binary variables, 972 integer variables, and 372 continuous variables). Solutions for the different cases are obtained within two seconds. The objective function minimizes the total delay of all projects based on their relative importance in the form of weights given as inputs.

Figure 4 shows the number of units supplied (nonrenewable resources) to different projects. Supplier 3 supplies most of the resources in total 315 units, followed by supplier 1, while supplier two supplies the least number of resoruces:206 units. It can also deduce from the figure that for project 1, supplier 1 is the most important; however, for projects 2 and 3, supplier 3 is the most crucial. Figure 4 also shows the amount of nonrenewable resources provided by each supplier. Supplier 2 and Supplier 3 supply zero units of K1, and all the units of K1 are supplied by Supplier 1. Supplier 3 is the only supplier of resource K3 and supplies 114 units of K3 and 201 units of K2, and supplier two only provides 206 units of resource K2. Based on these results, the construction manager can prepare a better collaboration plan with the different suppliers to ensure reliable relationship-building throughout the different projects and avoid delays that might be caused by the lack of flexibility in providing the different resources (e.g., only one supplier selected for K1 and K3)

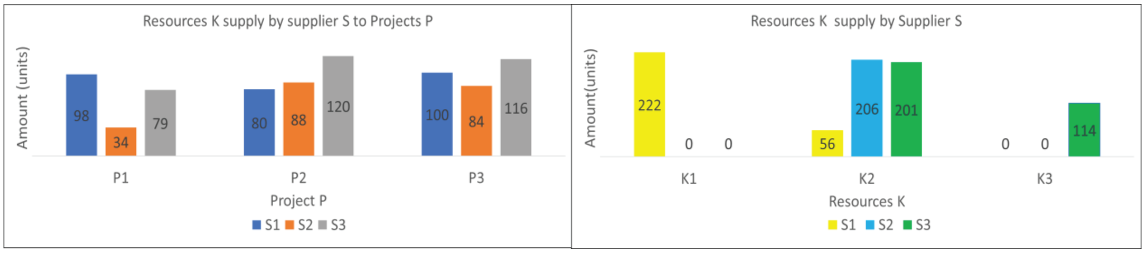

Figure 4: Suppliers "S" Providing Resources Type "K" to Projects "P”

For instance, Figure 5 shows the different suppliers S1, S2, and S3 that have supplied resource types K1, K2, and K3 to different activities of Project 3. The first chart in Figure 5 is for supplier S1, and the second and third charts are for S2 and S3, respectively. For instance, in Figure 5, it can be seen that S1 supplies K1 resources to all activities, S1 supplies K2 resources to some activities: 1, 2, and 8^{th,} and S1 does not supply K3 resources, so there is no grey bar in chart 1 of figure 5. Using the proposed tool, the construction manager can better control the impact of resources on each project's detailed activities and enable efficient management of resources in case of disruptions.

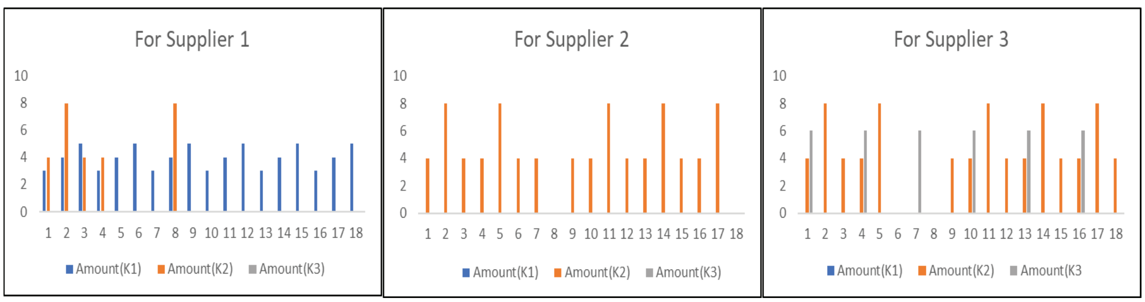

Figure 5: Suppliers Providing Resources K to Activities of Project 3

The model gives the optimal starting time for each activity of each project, and it is shown in Figure 6. Based on the model results, Project 1 should be completed within 12 weeks, Project 2 in 9 weeks, and Project 3 should be completed within 10 weeks. The starting time of activities is also affected because of the difference in precedence relationship among activities of projects.

Figure 6, along with figures 4 and 5, can be utilized collectively to identify the areas to improve decision-making for activities completion time, resources assignment, project idleness, and supplier relationship management.

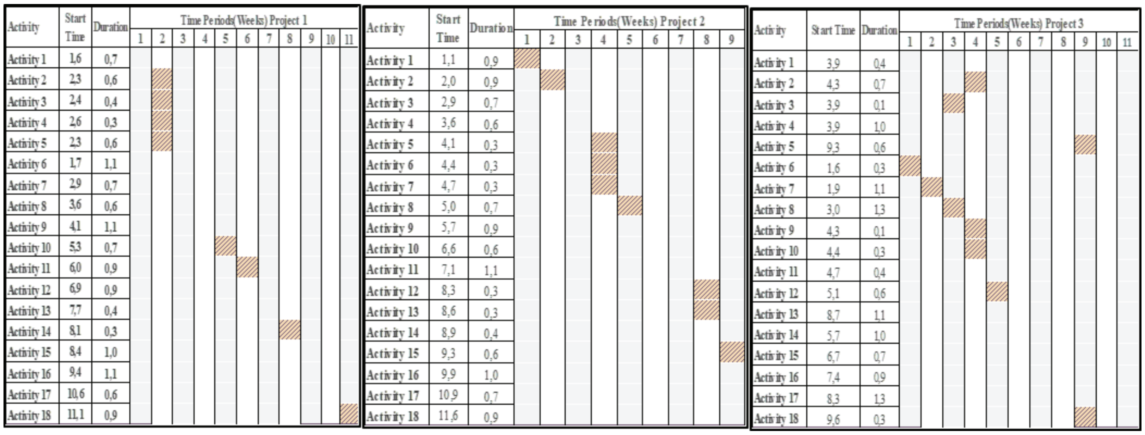

Figure 6: Resultant Gantt Charts of Projects (1,2 & 3)

The completion time and tardiness(delay) of each project are shown in Figure 7. The model can minimize the delay of these projects with respect to the project's due dates. The Project 1 delay is minimized to 2 weeks, the Project 2 delay to a week, and the Project 3 delay to 2.7 weeks. This figure shows the improvement in project time schedules by implementing this model by comparing the before and after conditions.

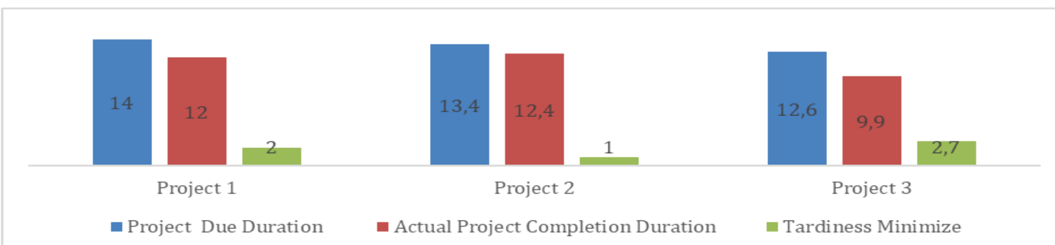

Figure 7: Comparison of Projects Completion Time Before & After Model Implementation (In Weeks)

RESULTS SIGNIFICANCE

The work we proposed here is the interpretation for BPR and logistics optimization to achieve LC. There are many papers available in the literature that provides mathematical optimization solutions for CSC, such as (Zhu, Dai, Liu, Xu, & Alwisy, 2021), (Elmughrabi, Sassi, Dao, & Chabaane, 2020)and (Hsu et al., 2019) but do not provide the way how the mathematical model will be used to achieve LC. By using BPR, we could derive the mathematical model's specifications from reducing waste and facilitating lean practices within CSC (Le & Nguyen, 2021).

Additionally, based on the case study in this paper, the proposed study improves the whole system of a CSC by combining BPM and optimization techniques, which aligns with the goal of lean tools, such as 'The Last Planner System' (Daniel, Pasquire, & Ameh, 2014; Le & Nguyen, 2021).

CONCLUSION

This research provides a methodology to minimize the delay (lean) of multiple construction projects simultaneously for the company. This methodology consists of two steps. The first step is related to streamlining the organization's information processes that generate the required inputs for managing and creating schedules. After the generation of these inputs, they are fed to the mathematical mixed integer linear programming model in the second step to give the optimal project schedules and minimize the delay of the projects.

The limitation of this paper is that it only considers nonrenewable resources for projects. Most of the time, real-world projects involve renewable resources such as employees, cranes, and other equipment. Therefore, the addition of these elements to the model will dramatically enhance the capability of the model.

However, this research brings a novel lean methodology that utilizes qualitative and quantitative methods to minimize construction project delays and generate optimal schedules. This will help the project-delivering company manage its resources, project tasks, and suppliers in real-time.

The future steps of this study are to include decisions related to renewable resources in the model and assignment of renewable resources to different activities based on their availability by the model. The decisions related to inventory management can also be included in the model to enhance its capability further.

REFERENCES

Daniel, E., Pasquire, C., & Ameh, O. J. (2014). *The magic of the last planner system for Nigerian construction.* Paper presented at the Annual Conference of the International Group for Lean Construction: Understanding and Improving Project Based Production.

Eldeep, A. M., Farag, M. A., & Abd El-hafez, L. (2022). Using BIM as a lean management tool in construction processes–A case study. *Ain Shams Engineering Journal, 13*(2), 101556.

Elmughrabi, W., Sassi, O. B., Dao, T.-M., & Chabaane, A. (2020). Collaborative supply chain planning and scheduling of construction projects. *IFAC-PapersOnLine, 53*(2), 10761-10766.

García-Nieves, J. D., Ponz-Tienda, J. L., Ospina-Alvarado, A., & Bonilla-Palacios, M. (2019). Multipurpose linear programming optimization model for repetitive activities scheduling in construction projects. *Automation in Construction, 105*, 102799. doi:https://doi.org/10.1016/j.autcon.2019.03.020

Hatmoko, J. U. D., & Scott, S. (2010). Simulating the impact of supply chain management practice on the performance of medium-sized building projects. *Construction Management and Economics, 28*(1), 35-49.

Hsu, P.-Y., Aurisicchio, M., & Angeloudis, P. (2019). Risk-averse supply chain for modular construction projects. *Automation in Construction, 106*, 102898.

Hung, R. Y.-Y. (2006). Business process management as competitive advantage: a review and empirical study. *Total quality management & business excellence, 17*(1), 21-40.

Igwe, C., Hammad, A., & Nasiri, F. (2022). Influence of lean construction wastes on the transformation-flow-value process of construction. *International Journal of Construction Management, 22*(13), 2598-2604.

Jasti, N. V. K., & Kodali, R. (2015). A critical review of lean supply chain management frameworks: proposed framework. *Production Planning & Control, 26*(13), 1051-1068.

Kannimuthu, M., Raphael, B., Ekambaram, P., & Kuppuswamy, A. (2020). Comparing optimization modeling approaches for the multi-mode resource-constrained multi-project scheduling problem. *Engineering, Construction and Architectural Management, 27*(4), 893-916.

Klemmt, A., Horn, S., Weigert, G., & Wolter, K.-J. (2009). Simulation-based optimization vs. mathematical programming: A hybrid approach for optimizing scheduling problems. *Robotics and Computer-Integrated Manufacturing, 25*(6), 917-925.

Le, P. L. (2020). *Optimization of integrated construction supply chain and BIM-based logistics planning.* École de technologie supérieure, Le, P. L., Elmughrabi, W., Dao, T.-M., & Chaabane, A. (2020). Present focuses and future directions of decision-making in construction supply chain management: a systematic review. *International Journal of Construction Management, 20*(5), 490-509.

Le, P. L., & Nguyen, N. T. D. (2021). Prospect of lean practices towards construction supply chain management trends. *International Journal of Lean Six Sigma*.

Le, P. L., & Nguyen, N. T. D. (2022). Prospect of lean practices towards construction supply chain management trends. *International Journal of Lean Six Sigma, 13*(3), 557-593.

Li, S., Fan, M., & Wu, X. (2010). *Lean construction techniques and individual performance.* Paper presented at the Proc. 27th Annual Conference of the International. Group for Lean Construction (IGLC).

Liu, J., & Lu, M. (2017). *Optimization on supply-constrained module assembly process*.

Marte Gómez, J. A., Daniel, E. I., Yanquing, F., Oloke, D., & Gyoh, L. (2021). Implementation of BIM and lean construction in offsite housing construction: evidence from the UK.

Mello, M. H., Gosling, J., Naim, M. M., Strandhagen, J. O., & Brett, P. O. (2017). Improving coordination in an engineer-to-order supply chain using a soft systems approach. *Production Planning & Control, 28*(2), 89-107.

Meng, X. (2019). Lean management in the context of construction supply chains. *International Journal of Production Research, 57*(11), 3784-3798. doi:10.1080/00207543.2019.1566659

Mirghaderi, S. D., & Modiri, M. (2021). Application of meta-heuristic algorithm for multi-objective optimization of sustainable supply chain uncertainty. *Sādhanā, 46*(1), 52. doi:10.1007/s12046-020-01554-4

Mossman, A. (2018). *What is lean construction: another look-2018.* Paper presented at the 26th Annual Conference of the International Group for Lean Construction. Chennai, India.

Nguyen, D. T., & Le, P. L. (2022). Twenty-year application of logistics and supply chain management in the construction industry. *Construction Management and Economics, 40*(10), 796-834. doi:10.1080/01446193.2022.2110273

Plenert, G. J. (2011). *Lean management principles for information technology*: CRC Press.

Uriarte, A. G., Ng, A. H., & Moris, M. U. (2018). Supporting the lean journey with simulation and optimization in the context of Industry 4.0. *Procedia Manufacturing, 25*, 586-593.

Zhu, M., Dai, J., Liu, R., Xu, J., & Alwisy, A. (2021). Two-period based carbon-economy equilibrium strategy for modular construction supply planning. *Journal of Cleaner Production, 290*, 125674.

Zimmer, E., Salem, O., Genaidy, A., & Shell, R. (2008). *Case study: lean supply chain management in construction projects.* Paper presented at the 16th Annual Conference of the International Group for Lean Construction, IGLC16.