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Novel method for building construction cost estimation using lean rules

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ABSTRACT

cost of building construction based on the lean concept is a design of a construction system that combines the material information with the internal cost alternatives to improve construction productivity and reduce waste. The main challenges in this research are the optimal distance and material handling and movement based on different cost types. The lean solution was to specify the optimal distance used for collecting and storing materials and the centroid will be utilized as a central point to build the inventory of other items such as electrical and plumbing materials. This strategy will eliminate waste during the transportation of materials. The Delphi technique has been employed and the factors have been established and tested using Weighted Product Model (WPM) (WPM). The improvement percentage for total material handling reached 34%. This optimization decreases operating costs, variable costs, inventory costs, and indirect costs, making this position between the three buildings advantageous.

Keywords: Weighted Product Model, building site position, different costs.

Introduction

One of the key factors for facing the global competition challenges is by improving building construction productivity. Productivity improvement is the best method for enhancing product quality and cost. Various methods have been to improve productivity such as KANBAN system, lean manufacturing, redesign of equipment, reducing setup time, improving manufacturing system design, enhancing product design and operations [1][2]. Lean Production improves project outcomes. The traditional Design, Bid, Build method is based on a false assumption: the least luxurious construction results from selecting the lowest bid after a contractor, the one who received the total lowest bids from subcontractors[3]. Better opportunities are created by combining project delivery. Aligning welfares, lowering uncertainty, shifting money across conventional borders, enabling for buildability, and irritated trade crews all contribute to a reduction in squandering generated by traditional practice[4]. Blink by reading academic Identifiers, joining groups among like rebels, establishing internal schooling groups, speaking with experienced Lean professionals, visiting sites, and then completing that with consulting firms who have been there. Interview for expertise, perspective, and teamwork ability[5]. The latest optimization based method contains lots of other newly suggested procedures for instance Firefly algorithm[6][7] . Simulation results of these approaches show the most efficient optimal explanation for network planning (RNP). (DBSCAN) Density Based SCAN algorithm was developed by Elewe et al, crossbreeding using firefly algorithm resulting a high quantity performance algorithm. Hasnan, et al, improved gradient cuckoo search algorithm and its application in large scale network layout [8]. The current paper has developed a new system to monitor the construction project site layout to enhance the building implementation productivity.

CONSIDERATIN OF LEAN METHODOLOGIES

Lean is a component of the production industry since its inception. Even as the fabrication and construction enterprises are becoming increasingly intertwined, a number of the lean benefits are finding their way into building work, processes, and developments [9]. Innovative schemes in which Lean construction organizational principles and methods, team members integrate thru the collaborating tools, and efforts are made to eliminate waste. Sides strive to constantly recover through reflection. Lean processes are intended to eliminate variation and create a constant workflow, resulting in significant improvements in predictability and a strong sense of respect for all parties involved [10]. The principles of lean concept are:

i. Early Involvement of Stakeholders

That secret that stakeholder information jeopardizes endeavor success. Partnering between road crews and service providers, on the other hand, occurs far too early on in the process. Lean Enterprise social organizations have been among these stakeholders from of the beginning. Contractors are no longer chosen solely based on cost. Somewhat more, the selection is influenced by the information they may provide during the combined planning phase. [11][12].

ii. Pull Planning

Pull planning addresses roughly half of the common issues with linear preparation. First, the team decides on a closing date. They after which work backward to determine key milestones, techniques for making, and handoffs. Groups can emphasize most tasks and afterwards identify any task dependencies. To keep the project's progress on track, every day and weekly sessions, as

well as discussions, are used [13].

iii. Preparation and Percent Plan Whole

Industry players necessitate an effective method of monitoring limits and identifying potential risks of surpassing timelines as well as budgets. After all, 70percent of building projects are finished on time and that on budget[14]. Weekly effort planning, as well as the percent strategic planning complete technique, can be beneficial. Include all stakeholders on all levels to get the best outcomes. As a consequence, each side could well receive the direction and information required to remain agile and adapt quickly in order to reduce diversions.[15].

THE WELFARES OF LEAN CONSTRUCTION

On which benefits can the consultant expect from the central tenets of Lean and the practice as The benefits will vary based on application, current state of processes, firm scope, but even location. Nonetheless, the most prevalent benefits are typically classified [4]. In the construction biosphere, the consultant is what the construction company builds. Numerous factors need to be in sync in order to achieve a higher yield. Cooperation early in the project procedure helps to prevent rework, dispute, and costly issues on-site, all of which slow down manufacturing and have a deleterious impact on the output quality[16]. A small manufacturing company's most valuable resource is its employees. The industry has taken steps to improve care and decrease risks to workers' well enough and security[17]. Leading companies recognize that what a safe place of work is often a profitable jobsite. Lean Production assists these employees by highlighting interaction, cooperation, and a secure, efficient workplace [18]. Lean going to plan methods aid in risk reduction by allowing teams to monitor progress, categorize potential risks, as well as mitigate them as soon as possible. On the other hand, judgment is required to address these issues quickly when they have lengthy repercussions for the project. To reduce offensive keep pace with changes, such methods combine both manual and automated assessment processes [19].

Lean process for Cost Control

The service provider can increase productivity and generate cost savings by standardizing Lean Building techniques as the structure processes. The reduction in left-over improves scheme efficiency, allowing for tighter price controls and higher profit margins. Lean Building reduces downtime while waiting for materials, equipment, and information, while also rooting out inefficiencies in processes[20]. The emphasis on prefabrication aids in the prevention of physical waste and the efficient use of all resources [21]. Based on Activities. Construction businesses may utilize knowledge of these cost elements in advance to regulate and manage their economic investment on the job site, as well as to assess costs and advantages according to the level at which operations are organized. [22][23]. The inputs and outputs in the construction sector are created by the needed resources and the products that arise from the construction process, the most important of which is the building itself. In reality, by making process information apparent to building participants, these models are meant to enhance other estimate models. [24][25].

i. Improved Preparation and Scheduling

Inadequate worker preparation is one of the leading causes of productivity loss. Techniques such as jerk planning help to reduce conflicts by improving the plan-to-actual ratio. Even though agendas have been planned back into the past to satisfy the final limit, stakeholders can reflect on and address potential snags ahead of time to better coordinate. [26]. In the pull planning tool,

use reverse making plans. Specify the task order using signs, which will contribute to the final timetable. Use last organizers for tasking when creating coordination agendas. To keep things on track, development and milestones must be evaluated on a regular basis. [27].

ii. Customer satisfaction is more than employee satisfaction.

As a consequence of a Lean Project, the number of jobs completed on time and then within budget increased, improving client satisfaction and the building firm's reputation. Advanced levels of customer and employee satisfaction have a direct effect on the company's current long-term success [28].

iii. Assemble the Side

Begin by assigning clear roles and responsibilities to every member of the team, ensuring that they understand what is expected of them. Allow for clarification questions and spend time answering questions about preparation, planning, and accessibility. Next, use onboarding sessions to help the team become acquainted with any cooperative technology that will be used. Finally, with the owner's approval, establish milestones and then input data. [29].

iv. Involve Subcontractors

Highlight the personal benefits sub - contractors dedication receive through Lean Building to form transparency. To have them on board, tailor it to them and their role. Incorporate these construction companies early in the preparation and train them to work quickly on the collaborative talent. [30].

System methodology

The proposed system mainly concerns with building cost improvement based on lean concept using developed systematic layout planning SLP correlated with lean system for monitoring the building cost processes. The quantitative and qualitative factors considered by using systematic layout planning SLP. SLP has three macro steps; they are analysis, research and selection. The criteria for layout alternative selection used in this paper for simplifying SLP is explained in Table 1.

TABLE 1. Proposed method

	Data collection	Tools used
1	Determine plant capacity	PQRST approach
2	Site Layout Analysis	1. site geometry and building positions. 2. lean principle. 3. Material Movement and directions 4. building and site centroid
3	Special requirement	1. material quantities 2. handling method
4	Effective lean factors	1. Root of waste in building construction 2. Effective lean cost factors
5	Calculation method	1. Weighted Product Model (WPM)

The main problem of this study was that the waste of building construction. This waste belong to the over processing, over calculation, motion, waiting and transportation[31][32]. There are two basic challenges in layout design problems, material and quantity (or volume). These two challenges underlie all other conditions PQRST analysis present a significant solution to study these two elements. This includes P (product), Q (quantity), R (routing), S (supporting) and T (time) [33][34][35]. In this study, the Product (P) or

material means the used material in the building. The term Quantity (Q) or volume represents the material quantities needed for building construction. The R (routing) or process refers to purchased material processes. Supporting Services (S) are the activities or functions such as maintenance, machine repair, locker rooms, toilets, cafeteria; these areas. Finally, Time (T) represents how long the material will have moved and used in the site.

Results and discussion

The present study combines the construction material information with the cite layout based on material movement, quantities and different costs. The quantitative analysis of the construction site observes a three building places in different positions. The system analysis starts with the identification of each building place and the centroid of these buildings. The reason of specifying the building center is to find the optimum distance to use it as a place to collect and save the materials such as sand, brick and cement. The centroid will be used as a middle point to build the inventory of other materials such as electrical and plumbing materials. This method will eliminate the waste in time of materials traveling and that represent the first step in lean method. Table 2 present the basic data of the building site.

Table 2. the building site distances

	x-coordinate(m)	y-coordinate(m)	x-centroid(m)	y-centroid(m)	distance (m) of centroid	distance (m) from building 1	distance (m) from building 2	distance (m) from building 3
position of building 1	15	15	38.3	30	27.7108	0	35	35
position of building 2	50	15	38.3	30	19.023	35	0	45
position of building 3	50	60	38.3	30	32.2	57	45	0

The next step is to analyze the main factors that cause the cost overrun and the type of costs. The Delphi method have been used and the factors have been specified and tested using Weighted Product Model (WPM). The analysis data will be the input representation for calculating the material movement details. The production processes in the specified building position are done in batch quantities. The material quantity is calculated using Revit software for each building and based on the center and centroid value Two types of solutions are presented by this method. the cost and WPM results are shown in table 3.

Table 3. the cost and WPM results

factors	operating cost	variable cost	inventory cost	indirect cost	WPM
Error in contract documents.	4%	5%	4%	1%	0.24
documents incomplete at the commencement of work.	1%	1%	12%	9%	0.26
Changes to design.	1%	12%	5%	4%	0.32
Ordering error.	11%	9%	1%	2%	0.31
Suppliers error.	1%	2%	1%	4%	0.14
Handling Damaged during transportation to the site.	4%	1%	2%	2%	0.16
Material handling and Inappropriate storage lead to deterioration to damage.	4%	5%	3%	12%	0.42
An error by a tradesperson or laborer.	1%	1%	2%	1%	0.10
Equipment malfunction.	1%	1%	5%	4%	0.17
Inclement Weather.	5%	4%	1%	2%	0.21
Accidents.	1%	2%	3%	12%	0.24
Use of incorrect material requiring replacement.	4%	2%	2%	13%	0.31
Conversion wastes from cutting uneconomical shapes.	1%	2%	2%	1%	0.12
Waste from the application process.	1%	2%	12%	5%	0.27
Criminal waste due to theft.	1%	3%	4%	2%	0.18
Lack of on-site material control and waste management plan.	12%	10%	2%	2%	0.38

The variation in cost has been calculated and the lean cost shown in able 4. It is observed that the cost based of second building is the lowest cost and represent the optimum solution.

Table 4. the cost results o the buildings for different materials

material	total quantity (m3)	quantity (m3)/travel	quantity/building	number of travels	cost based building 1 IQD	cost based building 2 IQD	cost based building 3 IQD
sand	building 1	0.2	20	100	0	350000	350000
	building 2	0.2	40	200	700000	0	900000
	building 3	0.2	30	150	855000	675000	0

	total cost				1555000	1025000	1250000
brick	building 1	0.12	25	208.33	0	729166.6667	729166.6667
	building 2	0.12	35	291.67	1020833	0	1312500
	building 3	0.12	30	250.00	1425000	1125000	0
	total cost				2445833	1854166.667	2041666.667
cement	building 1	100	2200	22	0	77000	77000
	building 2	100	4650	46.5	162750	0	209250
	building 3	100	3750	37.5	213750	168750	0
	total cost				376500	245750	286250

The improvement percentage reached to 34% from the total material handling. This optimization reduces the operating cost, variable cost, inventory cost, indirect cost, and it will be helpful to use this position between the three buildings.

Conclusion

The present paper introduces a framework for solving the problem of cost enchantment in a site construction project involving three buildings. The application of the lean approach to develop material monitoring and handling based on varied utilization with varying cost processes. The purpose of specifying the building center is to determine the optimal distance to use it as a location for collecting and storing resources such as sand, brick, and cement. The centroid will be utilized as a central point to build the inventory of other items such as electrical and plumbing materials. This strategy will eliminate waste during the transportation of materials, which is the first phase in the lean method. The next stage is to assess the primary factors and types of costs that led to the cost overrun. The Delphi technique has been employed and the factors have been established and tested using Weighted Product Model (WPM). The analytical data will serve as the input for the calculation of the material movement particulars. The production procedures in the specified building position are done in batch amounts. Each building's material quantity is estimated with Revit software utilizing the center and centroid values. The improvement percentage for total material handling reached 34%.

References:

[1] S. C. Nwanya and A. Oko, “The limitations and opportunities to use lean based continuous process management techniques in Nigerian manufacturing industries - A review,” *J. Phys. Conf. Ser.*, vol. 1378, no. 2, pp. 0–12, 2019, doi: 10.1088/1742-6596/1378/2/022086.

[2] A. A. Alghazi, A. A. Alghazi, " Alsayed, and S. Balancing, “Balancing and Sequencing of Mixed Model Assembly Lines Recommended Citation,” 2017.

[3] O. Ogunbiyi, A. Oladapo, and J. Goulding, “An empirical study of the impact of lean construction techniques on sustainable construction in the UK,” *Constr. Innov.*, vol. 14, no. 1, pp. 88–107, 2014, doi: 10.1108/CI-08-2012-0045.

[4] A. A. Salunkhe, “General overview of Lean Management in Construction Industry,” *Int. Res. J. Eng. Technol.*,

vol. 5, no. 7, pp. 1999–2004, 2018.

[5] E. S. A. A. , Fayhaa abdullah yaqoob, "The Role Of Integration Between Lean Construction Tools In Rationalizing Construction Project Costs," *Psychol. Educ. J.*, vol. 58, no. 1, pp. 5877–5896, 2021, doi: 10.17762/pae.v58i1.1999.

[6] A. M. Elewe, K. Bin Hasnan, and A. Bin Nawawi, "Hybridized firefly algorithm for multi-objective Radio Frequency Identification (RFID) Network planning," *ARPN J. Eng. Appl. Sci.*, vol. 12, no. 3, pp. 834–840, 2017.

[7] A. M. Elewe, K. Bin Hasnan, and A. Bin Nawawi, "Hybridized firefly algorithm for multi-objective Radio Frequency Identification (RFID) Network planning HYBRIDIZED FIREFLY ALGORITHM FOR MULTI-OBJECTIVE RADIO FREQUENCY IDENTIFICATION (RFID) NETWORK PLANNING," no. February, 2017.

[8] N. Talib *et al.*, "GRADIENT-BASED CUCKOO SEARCH (GBCS) AND (MC-GPSO) TECHNIQUES FOR OPTIMAL RFID NETWORK PLANNING," no. March, 2019.

[9] A. Jaaron and C. J. Backhouse, "A methodology for the implementation of lean thinking In manufacturing support services," *Int. J. Serv. Oper. Manag.*, vol. 9, no. 4, pp. 389–410, 2011, doi: 10.1504/IJSOM.2011.041239.

[10] A. Karim and K. Arif-Uz-Zaman, "A methodology for effective implementation of lean strategies and its performance evaluation in manufacturing organizations," *Bus. Process Manag. J.*, vol. 19, no. 1, pp. 169–196, 2013, doi: 10.1108/14637151311294912.

[11] A. Aapaoja, H. Haapasalo, and P. Söderström, "Early Stakeholder Involvement in the Project Definition Phase: Case Renovation," *ISRN Ind. Eng.*, vol. 2013, no. September 2014, pp. 1–14, 2013, doi: 10.1155/2013/953915.

[12] L. Mandongwe and S. Murairwa, "Stakeholder Engagement : Achieving Wholesome Profitability in Manicaland Province Companies , Zimbabwe," no. September, p. 24, 2020.

[13] W. Albalkhy, Z. Lafhaj, and C. Lille, "IMPACT OF LEAN PRACTICES IN THE PLANNING OF DESIGN TASKS : EVIDENCE," no. June, 2022.

[14] M. Celikag and S. Naimi, "Building construction in North Cyprus: Problems and alternatives solutions," *Procedia Eng.*, vol. 14, no. December 2011, pp. 2269–2275, 2011, doi: 10.1016/j.proeng.2011.07.286.

[15] F. R. Hamzeh, "The lean journey: Implementing the Last Planner® system in construction," *19th Annu. Conf. Int. Gr. Lean Constr. 2011, IGLC 2011*, no. July, pp. 561–572, 2011, doi: 10.13140/RG.2.1.3648.7522.

[16] M. Pech and D. Vaněček, "Methods of lean production to improve quality in manufacturing," *Qual. Innov. Prosper.*, vol. 22, no. 2, pp. 1–15,

2018, doi: 10.12776/qip.v22i2.1096.

[17] S. NAIMI and M. A. KARIMI, "Pavement Management System Investigation in Case of Afghanistan," *Cumhur. Sci. J.*, no. March, 2019, doi: 10.17776/csj.471334.

[18] S. Moaveni, S. Y. Banihashemi, and M. Mojtahedi, "A conceptual model for a safety-based theory of lean construction," *Buildings*, vol. 9, no. 1, pp. 1–11, 2019, doi: 10.3390/buildings9010023.

[19] X. Wu, H. Yuan, G. Wang, S. Li, and G. Wu, "Impacts of lean construction on safety systems: A system dynamics approach," *Int. J. Environ. Res. Public Health*, vol. 16, no. 2, 2019, doi: 10.3390/ijerph16020221.

[20] S. Naimi and M. Celikag, "Problems of Reinforced Concrete Building," no. April 2010, 2014.

[21] P. Nowotarski, J. Pasławski, and J. Matyja, "Improving Construction Processes Using Lean Management Methodologies - Cost Case Study," *Procedia Eng.*, vol. 161, pp. 1037–1042, 2016, doi: 10.1016/j.proeng.2016.08.845.

[22] P. Quesado and R. Silva, "Activity-based costing (ABC) and its implication for open innovation," *J. Open Innov. Technol. Mark. Complex.*, vol. 7, no. 1, pp. 1–20, 2021, doi: 10.3390/joitmc7010041.

[23] S. Briciu and S. Căpuşneanu, ""Effective Cost Analysis Tools Of The Activity-based Costing (abc) Method "," *Ann. Univ. Apulensis Ser. Oeconomica*, vol. 1, no. 12, pp. 25–35, 2010, doi: 10.29302/oeconomica.2010.12.1.2.

[24] M. V. Montes, R. M. Falcón, and A. Ramírez-de-Arellano, "Estimating Building Construction Costs by Production Processes," *Open Constr. Build. Technol. J.*, vol. 8, no. 1, pp. 171–181, 2014, doi: 10.2174/1874836801408010171.

[25] U. S. D. of Energy, "Cost Estimating Guide," *Office*, p. 177, 2011.

[26] H. Elzarka, "Planning and Controlling Lean Construction Projects," no. Ashley 1980, 1999.

[27] R. M. Olano, L. F. Alarcón, and C. Rázuri, "Understanding the relationship between planning reliability and schedule performance: A case study," *Proc. IGLC17 17th Annu. Conf. Int. Gr. Lean Constr.*, no. November, pp. 139–152, 2009.

[28] M. Höök, "Customer value in lean prefabrication of housing considering both construction and manufacturing," *Underst. Manag. Constr. Process Theory Pract. - 14th Annu. Conf. Int. Gr. Lean Constr. IGLC-14*, no. August, pp. 583–594, 2006.

[29] F. S. D'Aureliano, A. A. F. Costa, I. F. Júnior, and R. A. Rodrigues, "Application of lean manufacturing in construction management," *Procedia Manuf.*, vol. 38, no. 2019, pp. 241–247, 2019, doi: 10.1016/j.promfg.2020.01.032.

[30] S. Maturana, L. F. Alarcón, P. Gazmuri, and M. Vrsalovic, "On-Site Subcontractor Evaluation Method Based on Lean Principles and

Partnering Practices," *J. Manag. Eng.*, vol. 23, no. 2, pp. 67–74, 2007, doi: 10.1061/(asce)0742-597x(2007)23:2(67).

[31] A. Rchives, M. Kučerová, and M. Gejguš, "Eliminating waste in the production process using tools and methods of industrial engineering," pp. 30–34, 2015.

[32] L. J. Koskela and R. Sacks, "A BRIEF HISTORY OF THE CONCEPT OF," no. February 2015, 2012.

[33] R. Muther and L. Hales, *Systematic Layout Planning - A total system of layout planning*. 2015.

[34] R. S. Inglay, O. Park, and E. Andheri, "Application of Systematic Layout Planning in Hypermarkets," *Appl. Syst. Layout Plan. Hypermarkets*, pp. 185–189, 2010.

[35] K. Hee Han, S. Moon Bae, and D. Min Jeong, "A matrix-based approach to the facility re-layout problem," *Int. J. Math. Model. Methods Appl. Sci.*, vol. 7, no. 5, pp. 584–591, 2013.