

LEAN CONSTRUCTION PRINCIPLES FOR WASTE REDUCTION AND SUSTAINABILITY IN BUILDING PROJECTS

Godswill Mark Ogbaragu^{1*}, Emeka Ndukwe Uchendu², Victor Onu Ajike² and Kalu Ofuche³.

¹Department of Building Technology, Akanu Ibiam Federal Polytechnic Unwana, Ebonyi State, Nigeria.

²Department of Civil Engineering Technology, Akanu Ibiam Federal Polytechnic Unwana, Ebonyi State, Nigeria.

³Department of Building Technology, Nigerian Army College of Environmental Sciences and Technology, Makurdi, Nigeria.

*Corresponding Author: smart.godswill@yahoo.com

Abstract

The paper is on assessment of lean construction waste reduction principles in view of enhancing construction sustainability. Determination of the population of the study was through purposive sampling technique to intentionally select 118 participants among building construction professionals to whom questionnaires were administered. Taro Yamane formula was used to obtain the sample size of 91. Quantitative and descriptive statistics such as frequency tables, content and narrative analysis, simple percentages, mean score index (Mx), relative importance index (RII), and component factor analysis were used to successfully analyse and present the data obtained from the questionnaire survey. It was revealed from the results of the study that implementing the lean principle of waste elimination and optimize the whole ranked highly significance with RII (0.93) as ways to ultimately enhance waste reduction on construction sites through team collaboration. This paper concluded that the integration of lean principles in the construction process through development of checklist and following the steps are easy ways to enhance waste reduction and construction sustainability and increase productivity across all construction process. It was recommended that since lean construction principles can be used to achieve higher efficiency, reduce costs, improve quality, and enhance client satisfaction, professional bodies in the construction industry should prioritize integrating lean construction principles for waste reduction into construction process through development of checklist to serve both as a guide and a reminder on the steps for the sustainability of building projects.

Keywords: Lean construction, Lean principles, Project Management, Sustainability, Safety, Waste reduction

Introduction

Emas, Nascimento and Almeida (2021) admit that the built environment is a major contributor to global waste. Ogbaragu, Uchendu, Ofuche, Ajike and Igboekulie (2024) observe that construction wastes are generated during building and construction activities involving the use of materials such as concrete, wood, metals, plastics, blocks and others for completing a construction project. Once the required quantities of these materials have been taken, the rest are now turning to construction waste. In line with Dutum (2024), these construction wastes may be turned to eco-friendly materials through adoption of waste management best practices like

developing waste management plan; segregating waste at the source; disposing hazardous waste properly; reduction and minimizing waste; conducting waste audits; providing adequate waste storage facilities and providing training and awareness to construction workers. However, Emas, *et al* (2021); UCEM (2024); Dan (2024) and Ogbaragu *et al* (2024) emphasize that adoption of lean practices such as specify value; optimize the whole; eliminate waste; make product flow and continuous improvement can assist organizations and project managers further manage construction waste thereby reducing environmental impact, and contributing to a more sustainable construction industry.

A recent article by MacroFab (2017) and UCEM (2024) uphold that implementing lean principles can help minimize delays, waiting times, over processing, and unnecessary features, thus enhancing overall efficiency in construction processes. In line with this, Rodriguez (2022) insists that adoption of the waste elimination practice of lean construction can make construction sites safer and more efficient and with the capability to augment operational safety, thus reducing construction accidents drastically. In view of this, the paper aims to examine key principles of lean construction, perceived ways lean construction principles reduce waste, perceived ways lean construction principles enhance construction sustainability, perceived prevalent waste management practices and needs for developing principles of lean construction.

Statement of the Problem

In line with Ogbaragu, *et al* (2024), such construction activities as preparing formwork, casting concrete, installing iron reinforcements, block laying, tiling and screeding, among others, are all necessary to complete a building project. However, once the required quantities of these materials have been taken, the rest turn to waste. These wastes create significant unsightly situations and can lead to huge economic losses and reduce groundwater quality with possibility of occurrence of accidents leading to various degrees of injuries. Hence, the need to carry out assessment on lean construction waste reduction principles in view of enhancing construction sustainability cannot be overstated as this is crucial to reducing waste and enhancing sustainability of building construction site.

Aim and Objectives of the Study

The aim of this research is to examine lean construction principles for waste reduction and sustainability in building projects in view of enhancing building construction site sustainability. Based on the aim of the study, the objectives are as follows:

- i. To identify perceived ways lean construction principles, reduce waste and enhance construction sustainability.
- ii. To analyse perceived prevalent waste management practices in the study area.
- iii. To appraise the needs for developing principles of lean construction checklist for construction sustainability.

Key Principles of Lean Construction

Lean construction is a management philosophy derived from lean manufacturing principles, aimed at maximizing value while minimizing waste in construction projects. In line with University College of Estate Management, UCEM (2024), lean construction is a relationship-based approach to construction and an integrated project delivery process that seeks to emphasis collaboration between teams and maximizes stakeholder value with the goal of increasing the

profit, innovation and productivity resulting from a project. LCI (2024) states that lean construction are a set of practices and principles designed to optimize construction processes. It emphasizes delivering maximum value to the client by eliminating waste, improving efficiency, and fostering collaboration among stakeholders.

According to the UCEM (2024), “the lean philosophy has its origins in the work of Henry Ford and aided the production of the Ford Model T in the early 1900s, but it was pioneered most notably by Toyota and their famously efficient production system after the Second World War. This same author maintains that the success of the likes of Toyota led to lean production being adopted in other capacities, with the construction industry just one of many to replicate this approach. Lean practices have also been adopted by companies across industries like retail, printing and customer service (LCI 2024). In line with UCEM (2024); Dan(2024) and Ogbaragu *et al* (2024), the principles of lean construction have been found to include:

- i. Specify Value: Establish clearly defined value proposition of a project and make it available to enable all team members regularly check their performances against established value proposition.
- ii. Optimize the Whole: This fosters teams’ collaboration leading to effective work practices by avoiding a potential clash or accident involving workers during and after work on site.
- iii. Eliminate Waste: This encourages teams to work collaboratively to identify wastes that impact projects and educate on ways to work as a team to eliminate them and create value.
- iv. Make Product Flow: This encourages teams to work collaboratively to identify processes and work as a team to forestall disruption for whatever reason and focus on enhancing flow and ensure attainment of project goals.
- v. Continuous Improvement: Dan (2024) states that lean encourages teams to come together to create a log of constraints that are limiting productivity on a project and to eliminate them so as to ensure a more productive project environment over time as well as simultaneously enabling all the other tenets of Lean.

Percieved Ways Lean Construction Principles Reduce Waste

The need to reduce wastes during and after construction cannot be overstated as Beth (2024) observes that building and construction works account for up to 40% of solid waste generation and 30% of global raw materials. Dutum (2024) asserts that the growing amount of waste generated on the construction sites poses a significant threat to the environment, the health and safety of workers and the public. (LCI 2024). UCEM (2024), states that one of the primary goals of lean construction is the reduction of waste. LCI (2024), identifies eight different ways in which lean principle of waste elimination can be applied during project delivery to reducing different types of waste.

- i. Avoid over/under production: This implies making sure that materials are requested and received only when needed and only obtaining the right quantity as may be required for production. This is certainly a way to prevent waste on site.

- ii. **Avoid wastes of waiting:** The waste of waiting occurs when work-in-progress or people are waiting on the next step in production. Daily hurdles are an excellent tool for eliminating waiting waste, since they allow people the daily opportunity to address issues with the team. It is vital to practice identifying causes of waste in the construction process.
- iii. **Avoid unnecessary transportation:** Unnecessary transportation occurs when pull planning is poor or when there is not a plan for the storage of materials for safekeeping until they are needed. Proper pull planning in a Lean manufacturing process eliminates unnecessary transportation waste since materials, equipment, and the like are only moved as they are needed for the next stage of the process.
- iv. **Avoid excess inventory.** Excess inventory waste occurs when product, materials, work-in-progress or information quantities go beyond supporting the immediate need. It can also lead to unnecessary motion if workers are taking time to sift through the entire inventory to find the materials they need at the moment.
- v. **Avoid unnecessary motion:** Unnecessary motion can be described as unnecessary movement by people or movement that does not add value
- vi. **Minimize defects:** Defects occur when there is a production of defective parts, work or information that causes the work to be scrapped or redone. This leads to rework, one of the biggest causes of waste
- vii. **Use creativity in team members:** Unused creativity of team members occurs when a team loses time, ideas, skills, improvements and learning opportunities by not engaging or listening to employees.

Perceived Ways Lean Construction Principles Enhance Construction Sustainability

Ogbaragu and Awo (2016) agree that sustainability takes into account how one might live in harmony with the natural world around him, without damaging and destructing it. Dutum (2024) and Ogbaragu *et al* (2024) confirm that lean construction principles improve construction sustainability through:

- i. **Enhanced Site Safety:** Lean construction principles enhances construction sustainability by promoting effective communication; a safer work environment through team collaboration, monitoring and promoting risk management.
- ii. **Enhanced Sustainability:** Lean construction principles enhances construction sustainability by helping construction industry improve its role on reduction of wastage which is a central principle to lean construction, through focused effort on only producing what is required thus reducing environmental damage caused by over production.
- iii. **Improved Product Quality:** Lean construction principles enhances construction sustainability by prompting better resource utilization, waste reduction, and results all stages of production through optimized workflows and lean thinking, thus enhancing the overall quality of a firm's output.
- iv. **Improved Management of the Project:** Lean construction encourages a greater monitoring and a pull approach to resources, thus reducing scheduling conflicts and boost productivity and efficiency and improving project management.

- v. Timely Project Delivery and Enhanced Client Satisfaction: Lean construction fosters greater collaboration among stakeholders while focusing on efficient practices that reduce construction waste and shorten construction times and complete projects more quickly.

The perceived prevalent waste management practices

In line with Dutum (2024), management of construction wastes involving the collection, transportation, processing, recycling, and disposal of waste materials in a way that minimizes their impact on the environment and human health. is now seen as a crucial aspect of environmental sustainability and public health This same author outlines the best practices for waste management on construction sites in Nigeria as:

- i. Develop waste management plan
- ii. Segregate waste at the source
- iii. Dispose hazardous waste Properly
- iv. Reduction and minimize waste
- v. Conduct waste audits
- vi. Provide Adequate Waste Storage Facilities
- vii. Viii. Providing Training and Awareness to Construction Workers

Needs for Developing Principles of Lean Construction Checklist

In line with Greg and Glenn (1998). implementing lean thinking will lead to change in almost every aspect of project and company management, hence the need to develop checklist that capture every step involved in its implementation,

Checklist for Implementing Lean Construction Principles on Construction Project

Steps	Principles	Action to be taken
1	Specify Value	Specifying value. Develop a clearly written value proposition Make it widely available, on the job site to enable all team members regularly check their performances against established value proposition. Regularly check performances against established value proposition
2	Optimize the Whole	Encourage teams to collaboration among others Avoiding potential clash with workers Inspect and evaluate progress of work work during and after execution. Observe workers in any particular site during and after execution as workers want to get their work done and move
3	Eliminate Waste	.Collaborate with team members Identify wastes that impact projects. Review activity to remove any unnecessary steps in any production phase in areas such as transportation, inventory, movement, waiting, skill, over production, over processing and rework Educate other team members on ways to work as a team to eliminate them. Create value.
4	Make Product Flow	Work collaboratively with all teams. Identify processes Work as a team to forestall disruption for whatever reason/ Focus on enhancing flow and ensure attainment of project goals.
5	Continuous Improvement	Work collaboratively with all teams. Identify constraints are limiting productivity on a project. Create a log of constraints. Eliminate them

(Adapted from Dutum, 2024; Greg & Glenn,1998: Ogbaragu & Okolie, 2022).

Methodology

The research design adopted was a field survey study in order to assess on lean construction principles for waste reduction and sustainability in building projects in view of enhancing construction sustainability. This study was conducted in Afikpo Local Government Area of Ebonyi state of the South East geopolitical zone of Nigeria. This is due to the fact that there are many building construction sites within the study area engaged with preparing formwork, casting concrete, installing iron reinforcements, block laying, tiling and screeding, among others and having remnant these materials turn to waste after using the required quantities. The study population comprised of registered building professional contractors (CORBON, QSRBN and ARCON) in Ebonyi State making a total of 118 participants. A sample size of 91 was obtained using Taro Yamane formula. In order to achieve the aim of the study, well-structured close-ended questionnaires were designed to gather information from the professionals on lean construction

principles for waste reduction and sustainability in building projects in view of enhancing construction sustainability.

The choice of this survey tool was based on simplicity, clarity and appropriateness of use of questionnaire designed in the language of the respondents to achieve the desired objective of this research study. Also, the fact that comparison of responses received from correspondents although at different times but on same questions appeared to be consistent, lends credence on the reliability of the questionnaire used in this research study. In order to complement a successful data analysis and presentation of the result of this research, relative importance Index (RII) and mean score index (Mx) were used to analyse and present the data collected in tables. No research work of this kind has ever been done without some constraints and difficulties in the course of carrying it out. Some of the main constraints include; time and finance for data subscription and fuelling the power generating system for charging and powering the laptop.

Results

Table 1: Responses of the respondents on ways lean principles enhance waste reduction on construction sites

Ways lean principles enhance waste reduction on construction sites	SA	A	N	D	SD	Na	Total Score	Mx	RII	Rank
	5	4	3	2	1					
Avoid over/under production	36	15	4	0	0	55	252	4.58	0.92	2nd
Avoid wastes of waiting	29	26	0	0	0	55	249	4.53	0.91	3rd
Avoid unnecessary transportation.	44	4	7	0	0	55	257	4.67	0.93	1st
Avoid excess inventory.	32	20	3	0	0	55	249	4.53	0.91	3rd
Avoid unnecessary motion	40	10	5	0	0	55	255	4.64	0.93	1st
Minimize defects	36	15	4	0	0	55	252	4.58	0.92	2nd
Use creativity in team members	40	10	5	0	0	55	255	4.64	0.93	1st

Author's Field Survey (2024)

Table 2: Responses of the respondents on perceived ways lean principles enhance construction sustainability

Perceived ways lean principles enhance construction sustainability	SA	A	N	D	SD	Na	Total score	Mx	RII	Rank
	5	4	3	2	1					
Leads to site efficiency	33	22	0	0	0	55	253	4.60	0.92	1st
Improves product quality.	33	22	0	0	0	55	253	4.60	0.92	1st
Site safety	18	33	4	0	0	55	234	4.25	0.85	2nd
Adopting lean construction practices enhances sustainability	37	14	4	0	0	55	253	4.60	0.92	1st
Improves management of project.	24	24	4	3	0	55	234	4.25	0.85	2nd

Author's Field Survey (2024)

Table 3: Responses of the respondents on the perceived prevalent waste management practices in the study area.

Perceived prevalent waste management practices	SA 5	A 4	N 3	D 2	SD 1	Na	Total score	Mx	RII	Rank
Reduction and minimize waste	21	26	4	4	0	55	229	4.16	0.83	2nd
Dispose hazardous waste Properly	25	18	4	8	0	55	225	4.09	0.82	3rd
Recycle and reuse waste materials.	19	22	1	10	3	55	219	3.98	0.80	4 th
Providing Training and Awareness to Construction Workers	12	23	12	8	0	55	204	3.71	0.74	5th
Conduct waste audits	0	35	12	8	0	55	192	3.49	0.70	6th
Provide Adequate Waste Storage Facilities	19	26	9	1	0	55	228	4.15	0.83	2nd
Develop waste management plan	12	23	12	8	0	55	204	3.71	0.74	5th
Segregate waste at the source.	21	26	4	4	0	55	229	4.16	0.83	2 nd

Author's Field Survey (2024)

Table 4: Reasons for developing checklist in the implementation of lean construction principles on construction Project

Ne Reasons for developing checklist for implementing Le lean construction principles	SA 5	A 4	N 3	D 2	SD 1	Na	Total score	Mx	RII	Rank
Checklist reduces chances of omitting important steps during construction activity	34	21	0	0	0	55	254	4.62	0.93	1st
Checklist makes meeting client needs easier	40	10	5	0	0	55	255	4.64	0.93	1st
Checklist helps to provides that tasks will be completed as planned.	35	15	5	0	0	55	250	4.55	0.91	2nd
Development of checklist involves of those who will participate in the use of it	8	14	0	0	0	55	249	4.53	0.91	2nd
A simple and easy to use tool for site operatives and managers	29	26	4	0	0	55	256	4.65	0.93	1st

Source: Field survey (2024)

Discussion

It is noted from Table 1 that there are several ways lean principles enhance waste reduction on construction sites. Avoid wastes of waiting; avoid unnecessary transportation and use of creativity in team members ranked as highest influencing ways of reducing waste on site with relative importance index, (RII) as 0.93. Avoid over/under production and minimize defects ranked second with relative importance index (RII) as 0.92. While avoid excess inventory and void unnecessary motion ranked third with relative importance index (RII) as 0.91 The results (See Table 1) offer credence to the views of UCEM (2024) who states that one of the primary goals of lean construction is the reduction of waste on site. This is in agreement with LCI (2024) who

maintained that lean construction is designed to optimize construction processes and delivering maximum value to the client by eliminating waste, improving efficiency, and fostering collaboration among stakeholders.

Table 2 presents the perceived ways lean principles enhance construction sustainability, improving product quality and site efficiency ranked as the highest with the relative importance index (RII) as 0.92. Site safety and improving management of project ranked second with relative importance index (RII > 0.8) which is assessed to be of very high significance. The results (See Table 2) supports the view of Dutum (2024) and Ogbaragu *et al* (2024) who maintain that lean construction principles improve site efficiency; product quality; enhances site safety and sustainability and improves management of project

Table 3 presents the perceived prevalent waste management practices during building construction project in the study area. Reduction and minimize waste, provide adequate waste storage facilities and segregate waste at the source ranked second with the relative importance index (RII) as 0.83. The result (See Table 3) emphasizes the need for construction stakeholders who mean well for the industry to continually follow best practice for waste management in order to enhance construction sustainability and reduce construction waste. On the other hand, dispose hazardous waste properly ranked third with relative importance index (RII) as 0.82 which is also assessed to be very high significance. This (See Table 3) supports the view of Dutum (2024) who emphasizes the need for construction stakeholders to adopt proper waste management practice for environmental protection, public health, and sustainable development

Table 4 presents the reasons for developing checklist in the implementation of lean construction principles on construction project. Checklist reduces chances of omitting important steps during construction activity; it makes meeting client needs easier and provides a simple and easy to use tool for site operatives and managers ranked highest with relative importance index (RII) as 0.93. Whereas development of checklist requires involvement of those who will participate in the use of it and checklist helps to provides that tasks will be completed as planned ranked second with relative importance index (RII) as 0.91. This result (See Table 4) further buttress the need to strictly adhere to all necessary steps involved in the implementation of lean construction principles on construction project as a checklist of what must be done should be provided to serve both as a guide and a reminder for waste reduction and sustainability of construction.

Conclusion

In line with the pursued objectives of the research, the following conclusions were reached in the light of the results:

- i. As the result indicate (See Table 3) majority of professionals in the study area were not fully adhering to best practice in their construction sites pointing to a gradually progressing level of awareness in the study area.
- ii. The integration of lean principles in the construction process through development of checklist and following the steps are easy ways to enhance waste reduction and construction sustainability and increase productivity across all construction process.
- iii. The principle of waste elimination emphasizes maximizing value while minimizing construction waste. By understanding and applying lean principles, construction professionals can achieve higher efficiency, reduce costs, improve quality, and enhance client satisfaction. Consequently,

integrating lean principles into the construction process not only improves efficiency but also promotes safety and increases productivity across all phases of construction.

Recommendations

- i. Awareness of waste management best practice should be encouraged to receive focused attention since level of its adoption is still progressing gradually with majority of professionals in the study area not fully adhering to best practice in their construction site.
- ii. Since lean construction principles can be used to achieve higher efficiency, reduce costs, improve quality, and enhance client satisfaction, professional bodies in the construction industry should prioritize integrating lean construction principles for waste reduction into construction process through development of checklist to serve both as a guide and a reminder on the steps for the sustainability of building projects.
- iii. Since lean construction is designed to enhance waste reduction, improve site efficiency and foster collaboration among stakeholders, professional bodies in the construction industry should through regular seminars and workshops activities educate their members on the best practice so as to be able to fully implement lean principle during construction process.

References

- Broujeni, M., Omrani, G., Naghavi, N., & Afraseybi, M. (2016). Construction and demolition waste management (Tehran case study). *Journal of Solid Waste Technology & Management*, 6(6), 1249-1252. <https://doi.org/10.5281/zenodo.225510>
- Beth. S (2024). Sustainability in Construction: Why It Matters. Available from: <https://compliancechain.com/sustainability-in-construction-why-it-matters/> [Assessed 9/11/2024]
- Designing Buildings Ltd. (2023). Construction waste. *Designing Buildings Wiki*. https://www.designingbuildings.co.uk/wiki/Construction_waste
- Dutum(2023).Best Practices for Waste Management on Construction Site in Nigeria. Available from: <https://dutumgroup.com/best-practices-for-waste-management-on-construction-sites-in-nigeria/> [Assessed 9/11/2024]
- Dan.H(2024). 6 Tenets of Lean- LCI Tenets. Available from: <https://leanconstruction.org/about/lean-tenets/> [Assessed 9/11/2024]
- Emas, R., Nascimento, L. F., & Almeida, A. T. (2021). Lean construction: A strategy for reducing waste and improving sustainability. *International Journal of Construction Management*, 21(6), 523-534. <https://doi.org/10.1080/15623599.2021.1881072>
- ETM Services. (2023). How does construction waste affect the environment? *ETM Recycling*. <https://www.recyclingbristol.com/the-effect-of-construction-waste-on-the-environment/>
- Greg H. & Glenn. B(1998) Implementing Lean Construction: Understanding And Action. Available from:https://leanconstruction.org/wpcontent/uploads/2022/08/Implementing_Lean_Construction_Understanding_and_Action.pdf [Assessed 9/11/2024]
- LCI. (2024). Lean construction. *Lean Construction Institute*. <https://leanconstruction.org/>
- MacroFab. (2017). The 8 wastes of lean manufacturing and how to fight them. *MacroFab Blog*. <https://www.macrofab.com/blog/the-8-wastes-of-lean-manufacturing>

- Mohamed, O. (2011). Construction waste. *ScienceDirect*. <https://www.sciencedirect.com/topics/earth-and-planetary-sciences/construction-waste>
- Ogbaragu, G., & Awo, G. U. (2016). A green economy: A sustainable approach to environmental challenges in Nigeria. *African Journal of Environmental Studies*.
- Ogbaragu G. M & Okolie K.C. (2022). Application Of Quality Management Systems In The production of Concrete in Abakiliki and Afikpo, Ebonyi State, Nigeria- A Thesis Submitted For Faculty Defence In Partial Fulfillment Of The Requirements For The Award Of Master Of Science (M.Sc.) Inbuilding Construction Technology.
- Ojinga, G. O. (2017). What is sustainable national development? *IGI Global*. <https://www.igi-global.com/dictionary/deploying-ict-to-enhance-small-businesses-and-achieving-sustainable-development/58788>
- Ogbaragu, G.M, Uchendu, E. N, Ofuche. K, Ajike, V. O. & Igboekulie, I. E(2024). Application of the Principle of Lean Construction – A Sustainable Approach To Reducing Construction Waste - A Review-A paper accepted for presentation at the Upcoming SEDT Conference, 2024
- Rodriguez, R. J. (2022). Drones in construction: How robots are changing the way we build. *Master Builders Solutions*. <https://blog-master-builders-solutions-com.cdn.amproject.org>
- Srivastava, S. (2024). How is drone technology changing the construction space? *Appinventiv*. <https://appinventiv.com/blog/drones-technology-in-construction-industry/>
- Salah, M., & El-Haggar, P. E. (2007). Sustainability of construction and demolition waste management. *ScienceDirect*. <https://www.sciencedirect.com/topics/earth-and-planetary-sciences/construction-waste>
- Tahi, N., & Syed, M. H. (2020). Types, sources, and management of urban wastes. *ScienceDirect*. <https://www.sciencedirect.com/topics/earthand-planetary-sciences/construction-waste>
- UNESCO. (2015). Sustainable development. *UNESCO*. <https://www.unesco.org/en/sustainable-development>
- University College of Estate Management (UCEM). (2024). What is lean construction (and why should you adopt it)? *UCEM Blog*. <https://www.ucem.ac.uk/whats-happening/articles/what-is-lean-construction/>