Article

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Investigating the Efficiency of Ready-Mix Concrete Adoption in Minimizing Lean Construction Waste on Space-Constrained Sites in Nigeria

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Abstract: Over the past few decades, the quantity of construction waste has steadily risen in tandem with the expansion of construction activities and the rapid pace of development and urbanization. This problem is rooted in the practice of delivering materials to construction sites without totally using them for their intended purpose. The primary aim of the JIT tactic is to ensure that the precise materials required for production are available at the precise location, exact time, and appropriate quantity, thereby facilitating timely production. Presently, the use of ready-mix concrete is the most typical instance of a just-in-time construction process Developed countries have benefitted immensely from the use. However, the reverse is the case in developing countries like Nigeria, where indigenous contractors still employ traditional in-situ concreting even when faced with restrictive site space. This study focuses on investigating Ready-mix concrete, to project its immense benefits and efficiency in minimizing lean construction waste. A survey research design and case study were adopted for this study, with the population being the management staff of construction firms in Lagos State, Nigeria. The questionnaire was used to collect data and the targeted respondents were purposively selected from the population. A total number of 112 questionnaires were administered with a response rate of 51%. Percentage, mean, standard deviation, and ANOVA were used to analyze the data. The mean value is above 3 on a Likert Scale of 5, while faster construction speed and uniform quality of concrete are the topmost benefits derived from adopting Ready-mix Concrete in Nigeria. The Case study also revealed the effectiveness of Ready-mix concrete in minimizing the two lean construction wastes that were examined, namely; waste of overproduction and waste of waiting. It is recommended Just-in-Time technique should be extended to other construction materials aside from concrete to improve waste minimization through the adoption of an overall JIT policy for the construction process.

Keywords: ready-mix concrete; just-in-time technique; lean construction waste; restrictive site space

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Introduction

In both developed and developing countries, the Construction Industry is a sector that is integral to the economy and is characterized by the delivery of complex and dynamic projects. It is noteworthy, as Isa, et al. (2013) pointed out, that similar to other industries, the construction industry thrives on the transformation of various resources in the development of its output.

Space—a pivotal resource to the delivery of construction projects (Dawood, Scott, Sriprasert & Mallasi, 2005)—is one resource that has been affected commensurably by the rapid growth rate of construction activities. Space is considered to be a tangible limitation that can impede, restrict, or modify the efficient design and implementation of the sequence of construction operations. Especially for construction in highly congested areas, restrictive site area is a major technical constraint (Ellen & Janet, 2002). In the event of a restrictive site condition, the prevalent problem that arises is the unavailability of storage space for materials.

The just-in-time (JIT) approach is a tool of lean construction that originated from the need to mitigate the impact of Japan's inherent limitations in terms of space and material resources on the

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manufacturing sector. (Swapnil, Prashant, & Chetan, 2014). The primary aim of the JIT tactic is to ensure that the precise materials required for production are available at the precise location, exact time, and appropriate quantity, thereby facilitating timely production. Due to the significant advantages that JIT offers in enhancing productivity and reducing waste in manufacturing, despite severe space limitations, professionals and researchers in the construction sector have sought to investigate the feasibility of implementing this technique to address challenges in construction. (Bresnen and Marshall, 2001; Bates et al., 1999; Bertelsen, 2002).

Over the past few decades, the quantity of construction waste has steadily risen in tandem with the expansion of construction activities and the rapid pace of development and urbanization. (Onososen et al., 2023). Oladiran (2008) opined that construction waste refers to surplus materials supplied beyond the necessary quantity required for construction purposes. This problem, as lamented by Enshassi (1996), is rooted in the practice of delivering materials to construction sites without totally using them for their intended purpose. In the Nigerian construction industry, construction waste is a menace that has posed negative effects on the industry and consequentially, on the environment. Jamilus, Rahman, and Memon (2013) suggested that the foregoing challenges necessitated a rethink for practitioners towards the improvement of the construction process and technology, thus, the need for the adoption of lean construction approach.

Presently, the use of ready-mix concrete is the most typical instance of a just-in-time construction process (Iris & Annie, 1999), which implies the supply of concrete at the correct quantity and quality, precisely when needed for placement. It is noteworthy that developed countries like Singapore (Dulaimi and Tanamas, 2001); the UK (Callen et al. 2000); Brazil (Silva & Cardoso, 1999); Chile (Alarcon & Ashley, 1999), and so on, have benefitted immensely from the use. However, as Oladiran & Kilanko (2022) opined, the reverse is the case in developing countries like Nigeria, where indigenous contractors still employ traditional in-situ concreting even when faced with restrictive site space. This problem is believed to be rooted in the drought of knowledge as regards the effectiveness of ready-mix concrete or JIT delivery of materials generally, as shown by the work of Oladiran (2008).

Against this backdrop, this study aims to explore the impact of ready-mix concrete delivery on the construction process in Nigeria. The main objectives are: to examine the known benefits of ready-mix concrete delivery enjoyed by present adopters and to investigate the efficiency of Ready-mix concrete in managing waste on space-constrained sites in Nigeria. This study contends that the limited utilization of just-in-time concrete delivery stems from misunderstandings and inadequate knowledge regarding its significant advantages. Therefore, this research aims to address this problem. Given the potential of ready-mix concrete, it becomes imperative that a study to project its broad effectiveness is carried out to ensure the industry exploits the widely acclaimed benefits in line with global best practices. It is based on the foregoing that this study focuses on examining the efficiency of Ready-mix concrete in the construction process, with a particular focus on space-constrained sites.

LITERATURE REVIEW

Since the early 1970s, the Just-in-Time method has been a lean tool utilized by numerous Japanese manufacturing firms. Taiichi Ohno, the then manager of Toyota Manufacturing Limited initially developed and refined it within their manufacturing plants as a strategy to satisfy consumer needs with minimal delays. (Goddard, 1986). Over time, the Just-in-Time approach has become a fundamental tool for streamlining the production process by effectively managing materials. This is achieved by delivering the correct materials, at the proper quantity and quality, precisely when needed for production.

Low and Chan (1997) were among the first researchers to apply the Just-in-Time method to the construction sector. They employed JIT in the prefabrication industry in Singapore, creating a framework for its deployment.

The utilization of Just-in-Time in the construction industry differs significantly from its application in manufacturing due to the distinctive nature of production involved. Ballard and Howell (1995) observed that the complexity and unpredictability of construction projects also make a difference. Akintola (1995) shared similar thoughts through his observation that construction is further distinguished by complex communication and coordination environments that encompass numerous individuals and interdependent functions. Akintola (1995) observed that despite the obvious disparities between the two industries, the similarity lies in the fact that both manufacturing and construction require the active transportation of materials from suppliers to the production area. Consequently, these factors prompted the need for modifications to the Just-in-Time method when applied to construction. In line with Akintola's (1995) perspective, waste is viewed as any activity or process that does not contribute value to the overall delivery process, as described by the lean philosophy. Similarly, Low and Chan (1997) defined waste as anything beyond the minimum amount of essential equipment, materials, workers, and time required for production, which should be eliminated since they are non-value adding. In lean construction, waste is classified into seven distinct types, which include:

Waste of overproduction

The first type of waste in lean construction is the waste of overproduction. This occurs when goods are produced more than immediate demand, or when they are produced at a faster rate than necessary. Such goods are often viewed as assets, but in reality, they may become obsolete and lead to unnecessary expenses for the company. This type of waste can be easily overlooked, and it is important to eliminate it to avoid future losses.

Waste of waiting

Waiting waste can be defined as the unproductive time spent by materials, machines, or manpower due to delays caused by incomplete or late preceding activities. It also includes the time spent by operators waiting for materials or instructions when there is no productive work to do. This type of waste is caused by unsynchronized processes, line imbalances, inflexible workforce, over-staffing, unscheduled machine downtime, long set-up times, material or manpower shortages, or delays.

Waste of movement

This refers to the movement of materials, tools, or equipment that is unnecessary. It often occurs due to poor planning of routes, suppliers located at a distance, complex material flows, disorganized workplaces, and line imbalance. Whenever something such as people, equipment, tools, supplies, documents, or materials are transported from one location to another without any necessity, it generates transport waste.

Waste of inventories

Inventory waste is defined as any surplus supply of materials or goods beyond the current production demand. It results from purchasing, issuance, and storage of excess resources. Overproduction can also lead to the accumulation of surplus materials and work-in-process inventory. Lack of planning and failure to match purchases with actual consumption or usage rates of a particular resource are common causes of inventory waste.

Waste of motion

Motion waste is characterized as the superfluous and avoidable movement or motion of workers during the production process. It arises due to factors such as inadequate workspace layout and organization, unclear or non-standardized work instructions, and unclear process and material flow. This waste occurs when workers make unnecessary body movements while performing their tasks.

Waste of making defects

It can be defined as the waste generated by the production of defects, rework, or repairs. This waste includes the materials used due to defects and rework. Factors that cause this type of waste include unclear customer specifications, incapable processes, lack of process control, unskilled personnel, departmental quality rather than total quality, and incapable suppliers (Oladiran & Onatayo, 2019). Quality is achieved by doing the right thing right the first time, which involves prevention and planning, rather than correction and inspection. Defective items not only lead to customer dissatisfaction and damage to the company's image but also result in waste due to additional costs and time required for recalls, rework, repair, and replacement. The most effective way to reduce defect waste is through continuous quality improvement and preventive measures.

Processing waste

Unnecessary processing that does not add value to the end product or service is referred to as processing waste. This waste includes additional steps that do not improve quality, double-handling, added communication, double-checking, and reprocessing. Sometimes, processes include unnecessary steps that add excessive-quality which customers do not require. To eliminate processing waste, it is important to identify value-adding and non-value-adding activities in the process. Techniques such as value stream analysis and the waterfall diagram can be used to identify and eliminate non-value-adding activities in the process.

Ready-mix Concrete

According to Iris and Annie (1999), the use of Ready-mix concrete is a typical example of a just-in-time construction process. Ready mix concrete, as defined by Amiyangshu and Sen (2016), is a concrete mixture that is produced in a factory or batching plant, following a set recipe or specification, and then transported to the construction site by truck-mounted in-transit mixers. To simplify this definition, Abhishek, Jayeshkumar, and Bhavsar (2014) refer to it as a pre-determined mixture of cement, sand, aggregate, and water that is ready-to-use and produced according to the customer's specifications. Balgaonkar (2011) adds that the use of ready-mix concrete is particularly beneficial in congested construction sites where there is limited space for mixer sitting and aggregate stockpiling.

Ready-mix concrete is typically bought and sold in large volumes, usually measured in cubic meters (or cubic yards in the US). Nowadays, concrete production is computer-controlled and takes place in a factory or batching plant, with the final product transported to the construction site using specialized truck mixers capable of mixing the concrete while in transit (Oladiran et al., 2019). To further facilitate its use on-site, a truck-mounted boom placer can be utilized to pump the product directly from the mixer to where it is needed, with the ability to reach heights of up to 70 meters.

Balgaonkar (2011) reports that in developed countries, almost 70% of cement consumption is in the form of ready-mix concrete, while 25% is in the form of precast concrete. However, the utilization of ready-mix concrete in developing countries is less than 10%, with as much as 72% of cement consumption being in the form of site-mixed concrete. Oladiran and Kilanko (2022) opined that indigenous contractors in Nigeria still prefer site-mixed concreting, despite the limited site space. This is believed to be due to the lack of knowledge about the effectiveness of just-in-time delivery of materials, as there is a low level of awareness about its benefits and effectiveness, as demonstrated in Oladiran's work (2008).

RESEARCH METHOD

This study utilized a survey research design and case study methodology. The survey involved self-administered questionnaires to gather information on the level of awareness and barriers to the JIT technique in Nigerian construction projects. The population consisted of professionals who had experience with Ready-mix concrete. Purposive sampling was used to select the respondents. The questionnaire included demographic information, as well as questions related to the benefits and effectiveness of Ready-mix concrete in minimizing waste. Respondents were asked to rate their level of agreement on the benefits of ready-mix concrete and its effectiveness in minimizing construction waste using a scale of 1 to 5, where 1 represented low significance and 5 represented high significance. Data analysis involved mean, mode, percentage, standard deviation, and ANOVA.

RESULT AND DISCUSSION

Organizations' and respondents' profiles

Table 1 shows the profile of the organizations in the study. It indicates that 3.6% of the respondents work in consulting firms, 58.9% work in contracting firms, and 37.5% work in construction/contracting firms. The majority of the respondents, which is 87.3%, work in fully indigenous-owned firms, while 1.8% work in fully expatriate-owned firms, 5.5% work in partly indigenous-owned firms, and another 5.5% work in partly expatriate-owned firms. In terms of years of experience in the construction industry, 21.4% of the respondents work in firms that have between 1-5 years of experience, 8.9% work in firms with 6-10 years of experience, 14.3% work in firms with

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11-15 years of experience, 10.7% work in firms with 16-20 years of experience, while 44.6% of the respondents work in firms that have above 20 years of experience in the construction industry.

Table 1. Organizations' profile.

Nature	Ownership & Management	Age (in years)
Consulting (3.5%) Contracting (59%) Consulting/Contracting (37.5%)	Fully indigenous (87.3%) Fully expatriate (1.8%) Partly indigenous (5.5%) Partly expatriate (5.5%)	1-5 (21.4%) 6-10 (8.9%) 11-15 (14.3%) 16-20 (10.7%) Above 20 (44.6%)

Table 2 shows the profile of the respondents, where 18% are designated as Project Managers, 34% are Site Engineers, 12% are Builders, 14% are Site Managers, 8% are Quantity Surveyors, and 14% are Architects. In terms of educational qualifications, 1.8% hold an Ordinary National Diploma (OND), 16% hold a Higher National Diploma (HND), 44.6% hold either a B.Sc. or a B.Tech degree, 34% have an M.Sc. qualification, while only 3.6% have a Post Graduate Diploma (PGD) qualification. Regarding professional memberships, 22% are members of the Nigerian Institute of Building (NIOB), 20% are members of the Nigerian Institute of Quantity Surveyors (NIQS), 14% are members of the Nigerian Institute of Architects (NIA), 42% are members of the Nigerian Society of Engineers (NSE), while 2% of the respondents are members of the Project Management Institute (PMI). In terms of work experience, 37.5% have between 1-5 years of experience, 23.2% have 6-10 years, 35.7% have 11-15 years, and 3.6% have above 20 years of experience. Finally, 15% of the respondents are in the Architecture profession, 22% are in Building, 18.5% are in Quantity Surveying, 40.5% are in Civil Engineering, and 2% each are in Project Management and Mechanical Engineering.

Table 2. Respondents' profile.

Position	Highest academic qualification	Professional body	Professional Background	Years of Experience
Project Manager (18%) Site Engineer (34%) Builder (12%) Site Manager (12%) Quantity surveyor (10%) Structural Engineers (14%)	OND (1.8%) HND(16 %) BSc./B.Tech(44.6%) MSc.(34%) PGD(2)	NIOB (22%) NIQS (20%) NIA (14%) NSE (42%) PMI (2%)	Architecture (15%) Building (22%) Quantity Surveying (18.5%) Civil Engineer(40.5) Mechanical Engineering(2) Project Management(2)	1-5 (37.5%) 6-10 (23.2%) 11-15(35.7%) 16-20(3.6%)

Note that NIOB means Nigerian Institute of Building; NIQS means Nigerian Institute of Quantity Surveying; NIA means Nigerian Institute of Architect; NSE means Nigerian Society of Engineers; PMP means Project Management Professional.

Benefits of Ready-mix concrete

Table 3 displays the benefits that were obtained from utilizing Ready-mix concrete based on the viewpoint of the respondents. The table shows that faster construction speed and uniform quality of concrete were ranked as the topmost benefits derived from adopting Ready-mix concrete in Nigeria, with mean scores of 4.64 and 4.62, respectively. These were closely followed by the availability of concrete of any grade, reduction in material wastage, and elimination of labor associated with the production of concrete having mean scores of 4.51, 4.47, and 4.47, respectively. This indicates that the above benefits were considered the most significant benefits derived from the adoption of JIT. The benefits that were considered fairly important include the elimination of procurement/hiring of plant and machinery, higher durability and superior performance of structures built with ready-mixed

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concrete, the elimination of storage needs for basic materials, easy addition of admixtures, the possibility of mix design documentation, eco-friendly and sustainable product, a streamlined organization at the site, and reduction of noise and dust pollution, with mean scores of 4.44, 4.44, 4.44, 4.36, 4.35, 4.22, 4.16, 4.18, and 4.16, respectively. However, it is noteworthy that the means of all the benefits are above 4, which is considered good on the scale of measurement. This implies that Ready-mix concrete is achieving all the stated benefits in Nigeria very well.

Benefits	N	1	2	3	4	5	Mean	Rank
Faster construction speed	55	-	-	2	16	37	4.64	1
Uniform and assured quality of concrete	55	-	-	3	15	37	4.62	2
Availability of concrete of any grade	55	-	-	3	21	31	4.51	3
Elimination of labour associated with production of concrete	55	-	1	2	22	30	4.47	4
Reduction in material wastage	55	-	-	4	21	30	4.47	4
Elimination of procurement/ hiring of plant and machinery	55	-	-	6	19	30	4.44	5
Elimination of storage needs for basic materials	55	-	1	4	20	30	4.44	5
Higher durability and superior performance of structures built with ready-mixed concrete	55	-	1	31	22	29	4.44	5
Easy addition of admixtures	55	-	-	7	21	27	4.36	6
Documentation of mix design is possible	55	-	2	6	18	29	4.35	7
Eco-friendly and sustainable product	55	1	2	7	19	26	4.22	8
Reduction of noise and dust pollution	55	-	-	9	17	29	4.18	9
Streamlined organization at the site	55	1	-	10	21	23	4.16	10

Where N: Total number of respondents 1: Total number of respondents that selected very poor, 2 represents poor, 3 represents average, 4 represents good, 5 represents excellent.

Efficiency of the Ready-mix concrete for lean waste minimization on the construction process Case Study.

Case project site: The Aviation Plaza

This case study aims to evaluate the efficiency of a lean construction tool, namely JIT, in reducing waste during construction by examining its application in a real project in Lagos. The project under scrutiny is the proposed aviation plaza in Ikeja, Lagos, which is a six-story mixed-use development featuring a multi-level car park/plaza. Construction Kaiser Limited, a top construction firm in Nigeria, is the main contractor for the project. The development encompasses a total area of 1887.916m2, with a gross floor area of 4296.891m2, and includes a basement floor primarily designated for car parking, while the first and second floors are also used for car parking, and the other floors contain retail outlets, an aviation lounge, and a night club. The construction period is expected to be 18 months, covering only the structural framework. The case study is focused on the adoption of the Just-in-Time technique specifically for concreting works, with Lafarge Concrete, the main supplier, delivering the concrete to the site via mobile truck mixers. Due to the limited space available at the site, some basic materials were stored in smaller quantities on-site to produce minimal volumes of concrete for minor work such as blinding.

Observation

The study commenced with the researcher undertaking nonparticipant observations of the workflow patterns coupled with how site activities were coordinated especially the build-up in preparation for the concrete pour. Questions targeted at ascertaining the available planning, control, and management practice within the organization—that ensured smooth concreting operations—were asked by the researcher. It was also observed that, before a call is placed to the ready-mix concrete supplier (Lafarge), the production team ensured that the following were in place:

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Quality check of placement area: where the concrete is to be poured in a formwork, the quality control engineers always did all to ensure, through proper supervision of the operatives, that the forms were properly braced. Upon completion of the work, the forms were still checked for stability and water-tightness to prevent potential mishaps during the placement operation.

Clearance of access: The access area was always cleared before the trucks arrive to ensure ease of entry and to avoid delays that could occur due to obstruction.

Provision of light: Since the concrete placement operation was mostly carried out late in the evening to avoid traffic hiccups, the safety officer ensured the provision of floodlights to ensure adequate illumination during the operation.

Safety provision: The safety officer also ensured adequate provision of safety boards and caution tapes around the perimeter of the placement area to ensure that the operation is carried out in the safest possible manner.

Operatives to be on the ground for placement operation: Several operatives were usually on the ground to work during the concreting operation usually comprising carpenters and masons. These are on standby not only to ensure that the concreting operation proceeds smoothly but also to curb any mishap that could occur during the operation.

Efficiency of Ready-mix Concrete on case project

The efficiency of Ready-mix concrete for waste minimization on the case project was examined towards the achievement of the second objective of the study.

Structural element	Date Cast	Volume required based on measurement	Quantity ordered	Allowance	Over-order waste
Columns Base footings	19/07/2017	60m^3	63m^3	3m^3	No
Columns base footing	20/07/17	90m^3	96m^3	6m^3	No
Columns base footings	27/07/17	82m^3	87m^3	5m^3	No
Basement floor slab phase 1	14/09/17	130m^3	137m^3	7m^3	Yes
Basement floor slab Phase 2	23/09/17	178m^3	184m^3	6m^3	None
Retaining wall	19/10/17	120m^3	124m^3	4m^3	Yes
Basement floor slab phase 3	21/11/17	150m^3	156m^3	6m^3	Yes
Ground floor slab phase 2	15/11/17	160m^3	168m^3	8m^3	No
Ground floor slab phase 3	16/12/17	142m^3	147m^3	5m^3	No
Ground floor slab phase 4	23/12/17	210m^3	214m^3	8m^3	Yes
Ground floor ramp	28/12/17	58m^3	61m3	3m^3	No
First floor slab phase 1	23/01/18	130m^3	136m^3	6m^3	No
First floor slab phase 2	26/01/18	110m^3	115m^3	5m^3	

Waste of waiting

Table 5 shows the breakdown of the study of waiting time experienced on the case project during the concrete pour. The waiting time was calculated as being the period between the arrival of the

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trucks and the beginning of the placement process. Because the capacity of each truck was 8m3, the trucks drive out upon complete discharge and headed for the batching plant for a refill. The time between when the trucks arrive and the discharge starts were accounted for each truck and summed up as the waiting time. The duration of placement depends on the method of placement. Where a boom pump is to be used for a continuous pour, the average discharge time for each truck is 30 minutes. Where the method of placement requires labourers to convey to the point of placement, it takes an average of 52 minutes depending on the number of operatives conveying the concrete. The observed causes of waste of waiting on the case project include: Set-up time required for fixing the boom pump to the mobile truck mixers

Date	Volume of concrete delivered	Waiting time before placement	Duration of placement	Number of labour involved in placement operation	Challenges encountered
19/07/2017	60m^3	23 minutes	4 hours	9 operatives	None
20/07/17	90m^3	29 minutes	6 hours	9 operatives	None
27/07/17	82m^3	44 minutes	5hours:14minutes	6 operatives	Expansion of column formwork
14/09/17	130m^3	60 minutes	7 hours	12 operatives	None
23/09/17	178m^3	72 minutes	8hrs:32min	12 operatives	None
19/10/17	120m^3	40 minutes	8hrs	14 operatives	None
21/11/17	150m^3	52 minutes	8hrs	12 operatives	None
15/11/17	160m^3	60 minutes	7hrs:38min	12 operatives	None
16/12/17	142m^3	55 minutes	7hrs	10 operatives	None
23/12/17	210m^3	93 minutes	9hrs	12 operatives	None
23/01/18	58m^3	28 minutes	3hrs:12min	10 operatives	None
26/01/18	130m^3	55 minutes	7hrs	12 operatives	None

CONCLUSIONS

This study set out to investigate JIT in concrete delivery on construction projects. The objectives are to assess the benefits enjoyed by the adoption of Ready-mix concrete in building contracting firms and to investigate the efficiency of Ready-mix concrete in minimizing lean construction waste. The study was carried out and the following conclusions are made based on the findings: Faster construction speed and uniform quality of concrete are the topmost benefits derived from adopting Ready-mix Concrete in Nigeria. It is however noteworthy, that the mean score of all the benefits is above 4; connoting that Ready-mix concrete is doing very well in achieving all the stated benefits in Nigeria.

The Case study also revealed the efficiency of Ready-mix concrete in minimizing the two lean construction wastes that were examined, namely; waste of overproduction and waste of waiting.

RECOMMENDATIONS

Just-in-Time technique should be extended to other construction materials aside from concrete to enhance workflow improvements and waste minimization. This can be achieved by adopting an overall JIT policy for the construction process.

Professional bodies, researchers, and institutions of higher learning should give attention to enlightening Nigerians and companies on the JIT technique, to improve awareness and adoption. This can be done through organized seminars, workshops, and other sensitization programs.

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