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# EFFICIENT UTILISATION OF AUTOMATION IN CONSTRUCTION MATERIALS-HANDLING ROCESSES

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**Abstract:** There is a limited understanding of automation in construction materials-handling processes utilized by manufacturing firms in Nigeria. This article evaluates the level of utilization of automation in construction materials-handling operations by manufacturing firms in North-Central Nigeria, to improve operational efficiency and reduce operating costs. Using a case study research design, quantitative data (observation guide with measurements) were collected from 32 purposively selected construction material manufacturers. A total of 72 customers' orders were observed and recorded to be representative of deliveries from the sampled (n=32) manufacturers' warehouses to other terminals. The descriptive method of data analysis was employed using percentages and results presented in a form of bar charts. The study reveals low-level utilization of automation in the combined processes of order picking, storage, loading, and offloading of material. These imply increasing material costs and causing a delay in delivery. The article concludes by providing construction-material manufacturers with areas that require automation to optimize material-handling Operations. A recommendation is made for further study to explore why automation is not utilised despite its advantage.

**KEYWORDS:** Automation, construction materials, efficiency, material handling

## 1. INTRODUCTION

Construction materials are a fundamental component of projects in the construction industry and can significantly affect the cost-effectiveness of projects (Abhilin & Vishak, 2017: 910). According to studies, materials account for approximately 60% of the total project cost (Kumar & Nayak, 2018: 1371). Apart from the direct cost, the cost of materials also includes handling costs. Material handling is typically a high-cost, non-value adding activity, accounting for between 30% to 75% of the total material manufacturing costs (Horňáková *et al.*, 2019:2). In a typical manufacturing company, material handling takes up 25% of the workforce, 55% of all factory space, and 87% of production time (Horňáková *et al.*, 2019: 2). Ineffective materials and equipment management is one of the main causes of construction project delays (Kumar & Nayak, 2018: 1376). Construction companies are becoming increasingly concerned about the tracking and location of items on construction sites. This is due to the difficulty in tracking and locating materials when they are needed, as a result of the inappropriate handling and storage of resources in construction sites (Abhilin & Vishak, 2017: 910).Construction waste has been identified as one of the main problems facing Nigeria's construction sector, with serious repercussions for both the efficiency of the sector and its detrimental effects on the environment (Muleya & Kamalondo, 2017: 2). The following are some of the sources of waste: poor materials handling, resulting in damages; inaccurate cuttings, increasing the quantities of waste; improper or faulty equipment, delaying project completion; poor storage facilities, making it difficult to coordinate the storage requirements for the various subcontractors; poor workmanship, impacting negatively on the quality standard set up by management, and inaccurate measurements, leading to poor accounting for materials (Aziz & Hafez, 2013: 683). The distance between the materials storage area and the work site is an essential cause of waste because of the movement frequently done by skilled workers (Said & El-Rayes, 2014: 110). Despite the construction industry's growth in science and technology, it is nonetheless well-known for its client dissatisfaction, project delays, and cost overruns (Sanni & Eyiah, 2022: 12). Most of these problems can be attributed to poor material handling, which causes delays, cost overruns, and subpar workmanship (Kevin, 2013: 82). In Nigeria, a few studies on the cement industry focused only on the inventory and challenges in transportation (Adebumiti & Muhammed, 2014: 235; Adebumiti *et al.*, 2014: 242). For chemical and paint manufacturing companies, only customer satisfaction was appraised and the challenges facing the transportation system were highlighted (Obiegue, 2010: 8). The other studies include an evaluation of materials-management strategies in the Nigerian Construction Industry (Kevin, 2013: 82); the effect of poor materials-management on construction site in Abuja (Albert, Shakantu & Ibrahim, 2021: 42), and materials-management practices on construction site in Nigeria (Sanni & Eyiah, 2022: 12). Firms that manufacture construction materials are external to the organisation of the project and are thus observed to be of lesser significance in the project approach (Seppänen & Peltokorpi, 2016: 75). Consequently, the material-handling function of manufacturing companies, even though critical, has been largely ignored. There is limited knowledge and understanding of automation in construction-material handling in Nigeria. Thus, this study aims to evaluate the types and level of utilization of automation in some selected construction-material handling operations by the manufacturing firms in North-Central Nigeria, with a view to operational efficiency and reducing operating costs.

## 2. LITERATURE REVIEW

### 2.1 Material management

Material management is the process of delivering the right material to the right place on time and in the right quantity, to reduce the project costs (Kulkarni, Sharma & Hote, and 2017: 475). A seamless flow of materials from the time they are ordered until they are consumed is the primary objective of materials management. An appropriate integrated material handling procedure that covers the planning, identification, sourcing, storage, receipt, and distribution of material should be in place, in order to make materials management on site effective (Dallasega & Rauch, 2017: 1888). Material management is a crucial task to increase efficiency in a construction project. The definition of the materials-management function includes takeoffs, vendor evaluation and selection, purchasing, expenditure, shipping, receiving, storage and inventory, and material distribution (Ashika, 2019: 53).This suggests that material handling is a subset of material management. Hence, to understand the utilization of automation in construction-materials handling processes in North-Central Nigeria, it is important to introduce the present theory on automation included in this article. The current theory focuses on material handling, by explaining the automation principle of material handling, and introduce automation in terms of order picking, material-handling equipment, as well as storage equipment.

## 2.2 Material handling

Material handling is a vital element of the supply chain that involves a variety of operations including the movement, storage, protection, and control of materials and products throughout the processes of manufacturing and distribution (Horňáková et al., 2019: 1). Material handling includes short distance movement that normally takes place inside a building, for example, a plant or a distribution center and between a building and a transportation organization (Kay, 2012: 21). Each point of stockholding encompasses the handling of the materials and the more several handling of materials, the more the overall logistics costs, as procedure comprises both equipment and human effort (Michael, 2015: 16). This is the cost of labors in the warehouse/store and automation used to receive, put away, move, check, and count inventory. Having efficient material-handling systems is crucial to construction firms for maintaining and facilitating a continuous flow of materials through the workplace and guaranteeing that required materials are available when needed (Leung & Lau, 2018: 23). The characteristics of materials determine the type of storage, handling, stowage, carriage, and packaging that they require (Hannan, 2011: 24; Michael, 2015: 13).

## 2.3 Automation principle of material handling

The automation principle of material handling is that the operations should be "mechanised and/or automated where feasible to improve operational efficiency, increase responsiveness, improve consistency and predictability, and reduce operating costs, to eliminate repetitive or potentially unsafe manual labor" (MHI, 2000: 22). At the point when a warehouse or distribution centre is automated, it activates the systems upon dispatch, while simultaneously bringing up-to-date the records automatically, consequently orders are placed on time (Kim, 2006: 23). There is thus a necessity for efficient materials handling with the purpose of control, productivity, and cost saving in construction projects (Patel, Pitroda & Bhavsar, and 2015: 480). However, there are monetary trade-offs between high capital costs of mechanized systems, and increased labor costs in manual systems and types of manual handling that occur in such places (Webster et al., 2014: 16).

## 2.4 Order picking methods

Technology advancements in automation have considerably enhanced accuracy and productivity, while transforming the order-picking process. Barcoding, voice technology, and pick-by-light systems have all been introduced, and have improved warehouse-picking processes and generated a respectable return on investment (Gwynne, 2014: 93; Vishu 2016: 166). Paper-pick list, pick-by-label, pick-by-voice, barcode scanning, radio frequency identification, pick light/pick to light, put to light, and automated picking are all currently used in warehouses (Gwynne, 2014: 93). Barcoding alludes to the fixing of computer decipherable codes on items, cartons, containers, and trucks. These barcodes increase efficiency in three ways: speed, accuracy, and reliability (Sople, 2010: 77). A study by Biju and Faisalu (2013: 147) established that most of the ceramic tiles manufacturers now use barcoding. The factors that impact on the measure of manual handling inside warehouses and distribution centres are multifaceted and interlocking. The main element is the strategy of the order-picking system, especially how much automation is utilized and whether pickers move between pick spaces or whether items are automatically delivered to them (Webster *et al.,* 2014: 17). Order picking typically accounts for 50%-75% of the total operating expenses for a warehouse (De Koster, Le-Duc & Roodbergen, and 2007: 484). Any inefficiency in order picking can lead to unsatisfactory service and high operational expenses for the warehouse, and the entire supply chain (De Koster *et al.*, 2007: 484). Manual order-picking methods are slower, as the picker must handle and read the paper, while if picking orders are given by a pick-by-voice method, this operation is removed. For example, systems that pick-to-light shows automatically where the picker can expect to locate the next item to pick, are likewise faster since they remove the operation of searching for the correct pick slot (Webster *et al.,* 2014: 17). When order pickers must travel from a storage region, the movement time and trip distance are increased (De Koster *et al.*, 2007: 484). In addition, construction firms are becoming increasingly concerned about tracking and locating materials on construction sites. It is challenging to monitor, track, and locate materials when they are needed, due to the inappropriate handling and storage of materials on construction sites and in warehouses (Abhilin & Vishak, 2017: 910). Automated methods are beneficial, as the Warehouse Management System (WMS) documents the processes of both order pickers and operatives moving new stock to storage locations. The Aberdeen Group (2009: 22) reported that 70% of Best-in-Class construction material-manufacturing companies are more likely than all other companies to receive goods without using paper documents. All have moved to the utilization of barcodes, Radio Frequency Identification (RFID), or voice technology. A similar study by Gwynne (2014: 93) indicated that various producers have presented a joined voice and automated guided vehicle (AGV) or laserguided forklift truck system. By implementing both systems simultaneously, productivity improved by up to 70%. A related investigation by Tambovcevs (2012: 67) establishes that Enterprise Resource Planning (ERP) system merchants need to work with manufacturing and construction industry professionals to improve more customised results for manufacturing and construction companies. In addition, Tambovcevs (2012: 67) recommended that the application of ERP can give considerable benefits. These benefits include, among other things, enhanced company operation through streamlining, improving, and controlling business processes of major importance such as procurement, customer offers, customer complaints, equipment maintenance, marketing campaigns, and others. In addition, significant cost reductions and time-savings in all the above-mentioned business processes.

### 2.5 Material-handling equipment (MHE)

Researchers have discussed warehouse automation from different perspectives. These include warehouse technology, workshop equipment, warehouse systems, and factory equipment (Kay, 2012: 20). Rushton, Croucher and Baker (2006: 124) and Gwynne (2014: 220) noted industrial doors and gates, forklift trucks and accessories, as well as automated guided vehicles (AGVs). AGVs are extensively used and are efficient and appropriate ways to move goods and materials to different parts of a manufacturing plant. Autonomous mobile robots (AMRs) are fundamentally different, although they will eventually allow automation to a great extent to keep the flexibility and versatility of human-operated vehicles (Ghaffarzadeh, 2018: 22). AMRs are different from AGVs in their level of autonomy (FoodMach, 2019: 16):

- Automated systems are designed to perform a set of repetitive tasks by following pre-defined instructions with minimal or no human intervention.
- Autonomous systems, on the other hand, are not only able to perform defined tasks automatically but also have the intelligence to make independent decisions in 'never-seen-before' scenarios.
- For the maximum benefits of specialisation to be achieved, handling equipment at the nodes ought to offer fast loading and offloading of material to make the best use of the quantity of full vehicle load kilometre per unit of time (Pienaar, 2016: 354). Furthermore, economies of density require the optimal use of big, strong equipment over as long a period as possible. These include automatic loaders, high-level cranes, forklifts, manual, loader shovels, excavators, overhead gantries, and the utilisation of saddle carriers (Hannan, 2011: 32). This vehicle equipment permits additional grades of movement for handling unit loads. It should be noted that the efficiency of offloading processes could be enhanced by 61% with the use of automated information systems (Andrejić, Bojović & Kilibarda, and 2016: 102). A list of the material-handling and pallet-storage equipment used in United Kingdom warehouses was evaluated in a study by Baker & Perotti (2008: 72-74). According to the study, the picker-to-goods method has been widely adopted, with the usage of pallet trucks, lift trucks, as well as shelving and racking as storage choices. In addition, organisations used a combination of equipment to handle different types of materials and order profiles. The significance of appropriate utilisation of MHE cannot be overemphasised. As indicated by Rajes and Subbaiah (2015: 117), the utilisation of MHE helps reduce the labour of workers, by reducing forces in lifting, handling, pushing, and pulling material. Furthermore, it increases efficiency to control costs and optimises productivity (Bouh & Riopel, 2015: 461). In addition, there is a reduction in damage to material through human error and negligence, and a reduction in fatigue and injury when the environment is insecure or inaccessible (Kay, 2012: 20). The more times material is handled, the more the overall logistics costs add up, as the process still comprises both equipment and human effort (Michael, 2015: 16). Despite the benefit of picking equipment, Rogers' (2012: 18) study revealed that 70% of the respondents in the United States planned to spend less than USD250, 000 on warehouse equipment in 2013, with only 11% contemplating the purchase or evaluation of automated systems.

## 2.6 Storage equipment

Storage equipment is utilised for stockpiling or keeping materials over a period. Some storage equipment may include those used for transporting material such as Automated Storage and Retrieval Systems (AS/RSs) or storage carousels. Roodbergen and Vis (2009: 343) recognised that insignificant consideration has been given to the relationship between AS/RS and other material-handling systems

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in production or distribution centres. When no storage equipment is required, then the material is block stacked directly on the floor. Storage racks are utilised to give support to a load and to make the load accessible (Kay, 2012: 22). But interestingly, even in modern warehouses, the most popular forms of storage noted for the group of companies surveyed was floor storage and standard aisle racking (Baker & Perotti, 2008: 64). The advantages associated with block stacking include access, damage, stock rotation, and space utilisation (Gwynne, 2014: 221). The warehouse height of 15m creates double volume to allow for optimal aisle width for forklift trucks and cube-method space utilisation (Gwynne, 2014: 21).

## 3. RESEARCH METHODOLOGY

### 3.1 Research design

This article evaluated the level of utilisation of automation in constructionmaterial handling for operational efficiency by the manufacturing firms in North-Central Nigeria. This study adopted a quantitative case study research design method because it allows for examining reality 'out there' and is something that can be examined objectively, an environment (standard manufacturer warehouse processes and transportation operations) not designed by the researcher (Scott & Garner, 2013: 122). It also allows for the use of structured observations and descriptive analysis to understand automation and the process of on-time delivery performance implemented by the firms that participated in the case study (Kamali 2018: 198). In this study, the structured observation included watching and recording the automation used in orders piking method, material handling, storage equipment, as well as method of loading and offloading material, whilst the time for loading and offloading material in vehicles was also recorded. The node versus links method is by far the most suitable way to observe the logistics system in a construction context (Shakantu & Emuze, 2012this particular paper reports on a multi case study investigation conducted in the City of Cape Town. Present knowledge of logistics in general and transportation in particular, within South African construction is relatively limited. Emphasis is more frequently placed on supply chain management (SCM: 667). Thus, the unit of analysis was the current material-handling operations at the manufacturers' warehouse (node) and their transport delivery (link) to the distribution centres/warehouses, retailers' stores, and construction sites.

### 3.2 Population and sampling methods

The study area is the North-Central geo-political zone of Nigeria, and includes five of the six states, namely (Lokoja) Kogi State, (Lafia) Nasarawa State, (Minna) Niger State, (Jos) Plateau State, (Makurdi) Benue State, and (Abuja) in the Federal Capital Territory (FCT). North-Central zone is one of the fastest developing regions, with a high concentration of construction activity, near FCT. In Nigeria, it is hard to identify precise locations of either private or commercial builder merchants (BM) or material suppliers. The Nigerian business directory (2019) showed that there were 156 construction-material manufacturers, 96 distribution centres/warehouses, retailer stores, and 120 construction sites operating the North-Central zone. From these, 32 construction-material manufacturer firms, 42 distribution centres/warehouses, retailer stores, and 30 construction sites were randomly selected, with at least two for a particular building material. In total, the eight companies visited were identified as manufacturers of cement, reinforcement bars, ceramic tiles, and crushed stones, with two companies

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for each material. Their products were produced within and distributed across the six States of North-Central Nigeria and the FCT, Abuja. In addition, 12 companies producing masonry hollow sandcrete blocks and 12 companies producing sand were visited with two in each of the five State capitals and Abuja. Chosen construction sites were carefully and logistically selected, instead of statistically, significant in the population (Shakantu & Emuze, 2012: 668). The sample selected in each construction site gave adequate transportation operations and automation processes for analysis within a reasonable time. Table 1 shows the type of material, the number of deliveries per each State capital and FCT, the distribution centres, as well as the warehouse and construction sites observed.

### 3.3 Data collection

Quantitative data was collected using non-participant observations of material-handling operations from manufacturer warehouses and distribution centres/warehouses, and retailer stores, and construction sites in random order, time, and day. The observations were conducted across the various sections of the companies, namely order-picking methods, material handling, storage equipment/methods, as well as method of loading and offloading vehicles. The researcher used items obtained from the literature review and both modified lists of pallet storage equipment used in UK warehouses and material-handling equipment by Baker and Perotti (2008: 74) in the observation template, which includes the utilisation of automation in orderpicking methods (measuring nine variables), material handling (measuring 19 variables), storage equipment/methods (measuring 12 variables), method of loading and offloading vehicle (measuring eight variables), loading and offloading time (measuring six variables), as well as cost of loading and offloading material (measuring six variables).Methods used for order picking, material handling, storage, and vehicle loading/offloading were observed and, where a variable occurs to be utilised, it was ticked off against the same variable on the template. The average loading and offloading time for individual materials (per ton) at the terminals was observed, using a stop clock. The average loading and offloading cost for individual materials (per ton) at the terminals was recorded using the cost per company for equipment used, manual loading and offloading cost per vehicle per worker, and quantity of material transported per vehicle. The observations were made until there was a minimum of six customer orders, one each from the five States and Abuja. All the deliveries were one drop and there was no multi-drop run that accounted for turnaround times at the various preceding delivery locations (see Table 1). A total of 72 vehicle deliveries from material manufacturers to distribution centres/ warehouses, and retailer stores, and construction sites was observed. This number of observations is supported by Shakantu and Emuze (2012: 662), in that 30 is the lowest number of observations on any phenomenon, which is statistically significant and could lead to the generalisable explanation of a phenomenon.

**Table 1: Companies and construction sites observed**

| *Materials* | | | *Location*<br>*Number of distribution centres/ warehouses and retailer stores* | |
|---|---|---|---|---|

| | Number of manufacturing companies | Transportation (number of deliveries) | Abuja | Minna | Lafia | Lokoja | Jos | Makurdi | Distribution centres/ Warehouses | Construction sites |
|---|---|---|---|---|---|---|---|---|---|---|
| Cement | 2 | 12 | 2 | 2 | 2 | 2 | 2 | 2 | 12 | |
| Reinforcement bars | 2 | 12 | 2 | 2 | 2 | 2 | 2 | 2 | 12 | |
| Ceramic tiles | 2 | 12 | 2 | 2 | 2 | 2 | 2 | 2 | 12 | |
| Crushed stone | 2 | 12 | 2 | 2 | 2 | 2 | 2 | 2 | 6 | 6 |
| Hollow sand-crete blocks | 12 | 12 | 2 | 2 | 2 | 2 | 2 | 2 | - | 12 |
| Sand | 12 | 12 | 2 | 2 | 2 | 2 | 2 | 2 | - | 12 |
| Total | 32 | 72 | 12 | 12 | 12 | 12 | 12 | 12 | 42 | 30 |

**Source: Researchers' field survey, 2019**

### 3.4 Method of analysis

The observation data were entered into Microsoft Excel (Bowen, Edwards & Cattel, 2012: 887), in order to compute and report frequencies and percentiles using descriptive analytical tools (Loeb *et al.*, 2017: 8). A percentage is computed by dividing the number of times a variable value is observed by the total number of observations in the population and multiplying the result by 100. The data were first tabulated into three sections using theme analysis. The first section covered warehouse/loading-bay processes at manufacturers' firms; the second section consisted of processes that involved vehicles for delivery (arrival/departure time, quantity loaded, time taken to load/offload), and the final section consisted of offloading (cost/ time) operations in the distribution centres/warehouses, retailer stores, and construction sites. Thereafter, the tabulated data were analysed and classified into conceptual themes, order-picking method, material-handling equipment, storage equipment, method of loading/offloading vehicles, loading/offloading time, and cost of loading/offloading material. After tabulation of the data responses, a bar chart presentation was compiled to show the calculated frequencies and percentages of the observations.

### 3.5 Limitations

The management granted the researchers permission to observe logistics operations and processes with sufficient access. Despite being promised anonymity and confidentiality, the researchers were not allowed access to some sections of operations and transaction records. Managers explained that these steps were intended to protect their company methods and automation from rivals. One of the limitations of this study is that the quantitative method was carried out using observations. In addition, it is possible that the employees did not like being observed while at work and thought the researchers were management spies. The veracity of the data may be jeopardised in such situations because the employees would not act 'normal'. Another limitation of this study is geographical in nature because

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this study covered only one out of the six geopolitical zones of Nigeria. The study focuses on operational performance without considering strategic and tactical performance, which could be a limitation. Another limitation was that the researcher allowed a limited number of assistants to help with the tracking of drivers and the recording of their time of arrival at the various destinations.

## 4. RESULTS

### 4.1 Order-picking method used in manufacturers' warehouses

Figure 1 presents the current (2019) automation utilised for order-picking processes in the construction-material manufacturer warehouses. This established that 88% of the companies used the paper-picking method, while 12% use an automated method. The paper-based order-picking methods are slower, as the picker must handle and read the paper, while automated methods of pick-by-voice or barcodes would have been faster. The finding was that most of the companies used the paper-picking method, which suggests low adoption of automation in the order-picking method.


**Figure 1: Order picking methods adopted in the manufacturer's warehouses**

### 4.2 Automated material-handling equipment used in manufacturer's warehouses

The study evaluates the type of material-handling equipment used in the construction-material manufacturer's warehouses. Figure 2 shows that 13% of the companies used a payloader, while 6% of the companies used mini automated loaders, high-level order-picking cranes, and forklift trucks. In addition, 69% of the companies did not use any of the order-picking equipment. This indicates less automation in material handling to reduce human effort, eliminate offloading charges, and improve the counting time at the warehouse. The finding was that most of the companies did not use any of the automated material-handling equipment.

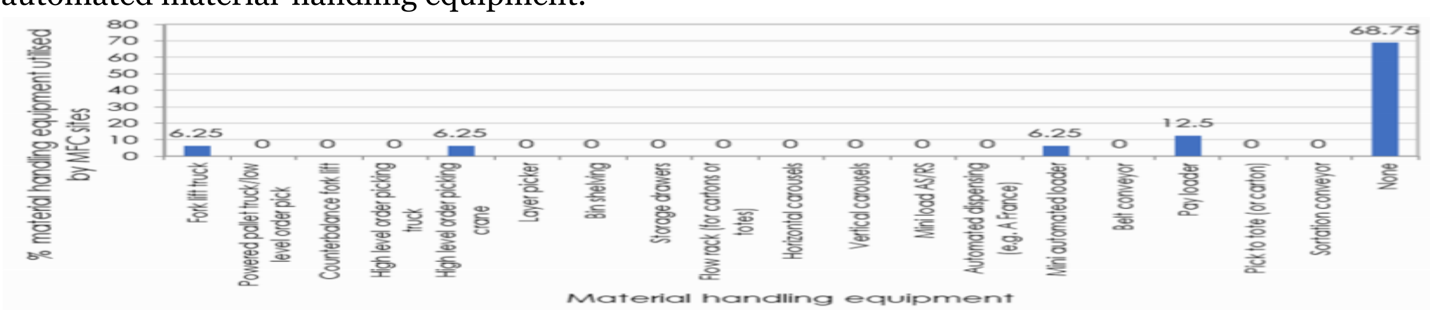

**Figure 2: Automation material-handling equipment used in manufacturer's warehouses**

### 4.3 Storage equipment used in manufacturer's warehouses

The study evaluated the automation of warehouses such as types of storage equipment and efficient utilisation of storage space. Figure 3 shows that 88%, 6%, and 6% of the companies used floor/block, double deep, and pallet floor-racking storage equipment, respectively. Based on the observations, most of the companies used the floor/block-storage method which suggests low take-up of pallet storage equipment in the warehouses. The low level of adoption of storage equipment and racks gives less support to loads and makes load accessibility and automated material handling problematic.

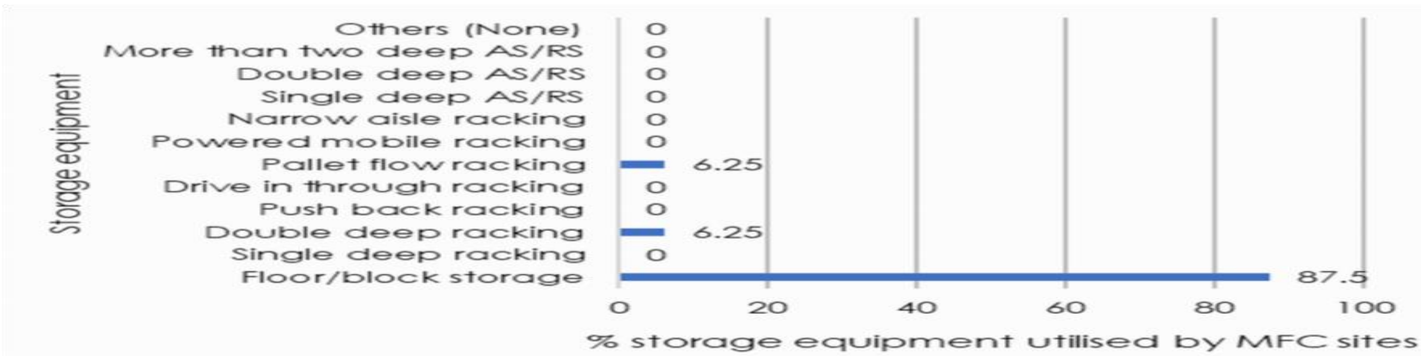


**Figure 3: Storage equipment used in manufacturer's warehouse**

### 4.4 Method of loading and offloading vehicles

Figure 4 shows the results of the method of loading vehicles at the manufacturers' warehouses and offloading of vehicles at the distribution centres/warehouses, retailer stores, and construction sites. This was done to understand the type and level of automation adopted to increase efficiency in loading and offloading vehicles. At the manufacturers' warehouses and construction sites, 40% of the companies used manual methods of loading. The other companies used pay loaders (16.67%), forklift trucks (14.29%), high-level cranes (14.29%), and automatic loaders (14.29%) to load material. The results showed that 60% of the company warehouses were automated. This signifies operational efficiency, in terms of an increase in speed, accuracy, and productivity, while reducing repetitive or potentially unsafe manual labour.

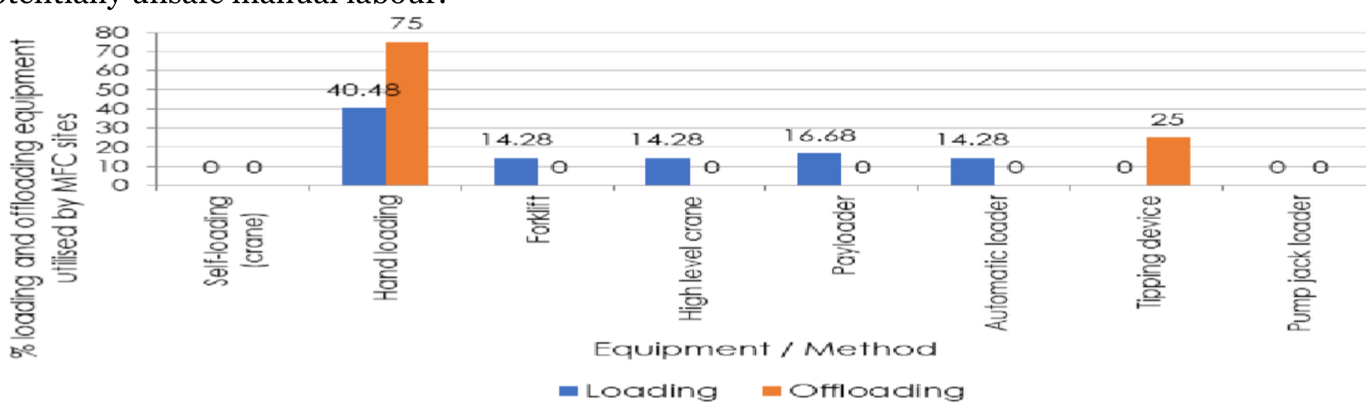


**Figure 4: Method of loading and offloading of vehicles**

Of distribution centres/warehouses, retailer stores, and construction sites, 75% used manual methods for offloading material. However, 25% used the tipping method, which was basically for sand and parts of crushed stones. It was also observed that trailers were used to transport crushed stones. Since they cannot tip off, the material was manually offloaded. This signifies high operating time, cost, multiple handling, and low productivity.

### 4.5 Loading and offloading time

The economies of density are enhanced by using high-capacity technology to handle large bulk loads and minimising loading and offloading time and cost. Figure 5 shows the average time taken to load and offload material (per ton) at the terminals. For cement, the loading time was 0.02 hours/ton, and offloading time was 0.11hours/ton. The average loading and offloading time for reinforcement bars was 0.04 and 0.18 hours/ton, ceramic tiles, 0.07 and 0.17 hours/ton, and for granite, 0.01 and 0.07 hours/ton). Granite offloading time is higher than its loading time because trailer trucks were also used in the delivery of granite. Since they do not have a tip-off mechanism, the material had to be manually offloaded, which led to increased offloading time and cost. The implication of non-automatic offloading is that time and costs are non-value-added items that cannot be recovered when an invoice is made out for the offloading of material.

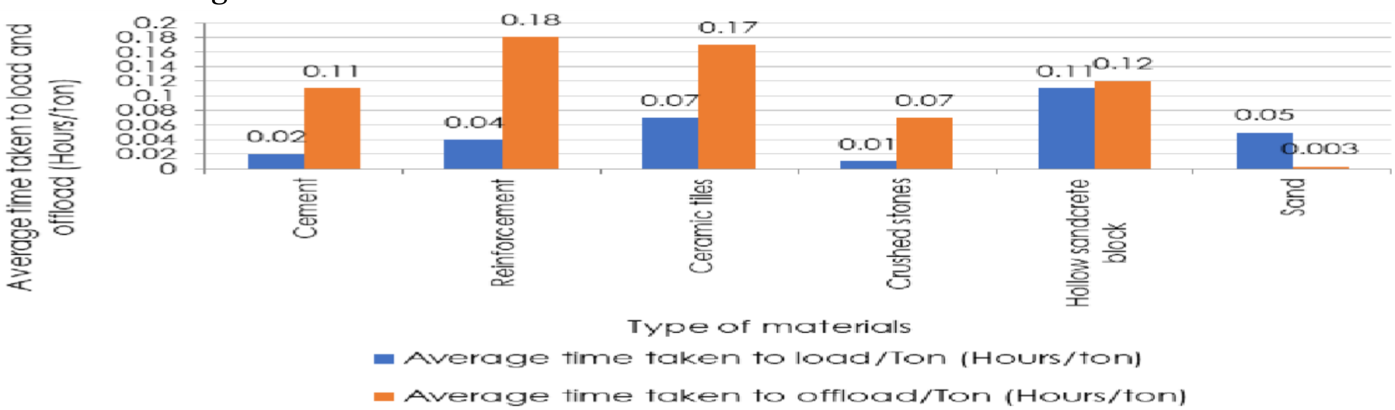


**Figure 5: Average time taken to load and offload materials per ton**

### 4.6 Cost of loading and offloading material

Figure 6 shows the relationship of average cost to load and offload individual material per ton. The average cost of loading per ton at the manufacturer's warehouses was as follows: cement (₦56.62/ton or R2.02/ton); reinforcement bars (₦425.63/ton or R15.20/ton); ceramic tiles (₦507.99/ton or R18.14/ton); crushed stones (₦78.16/ton or R2.79/ton); blocks (₦179.73/ton or R6.42/ton), and sand (₦151.66/ton or R5.42/ton). In addition, the average cost of offloading at the distribution centres, warehouses, retailers stores, and construction sites was as follows: for cement (₦274.70/ton or R9.81/ton); reinforcement bars (₦861.24/ton or R30.76/ton); ceramic tiles (₦537.31/ton or R19.19/ton); crushed stones (₦150.07/ton or R5.36/ton); blocks (₦179.37/ton or R6.41/ton), and sand (₦25.53/ton or R0.91/ton). The average cost of offloading reinforcement bars per ton was the highest, probably because this involves offloading, bending, and stacking them. However, it should be noted that ceramic-tile companies used both forklift trucks and manual labour when loading at the manufacturers' warehouses. Table 6 show that the average cost of offloading materials/ton was higher than the average cost of loading, except for blocks and sand. This may be explained by the fact that blocks are both loaded and offloaded manually. The cost of loading sand is higher because most of the companies did this manually, but they offloaded mechanically by tipping off. The implication is that lack of utilisation of automation in loading sand in vehicles leads to higher cost of handling.

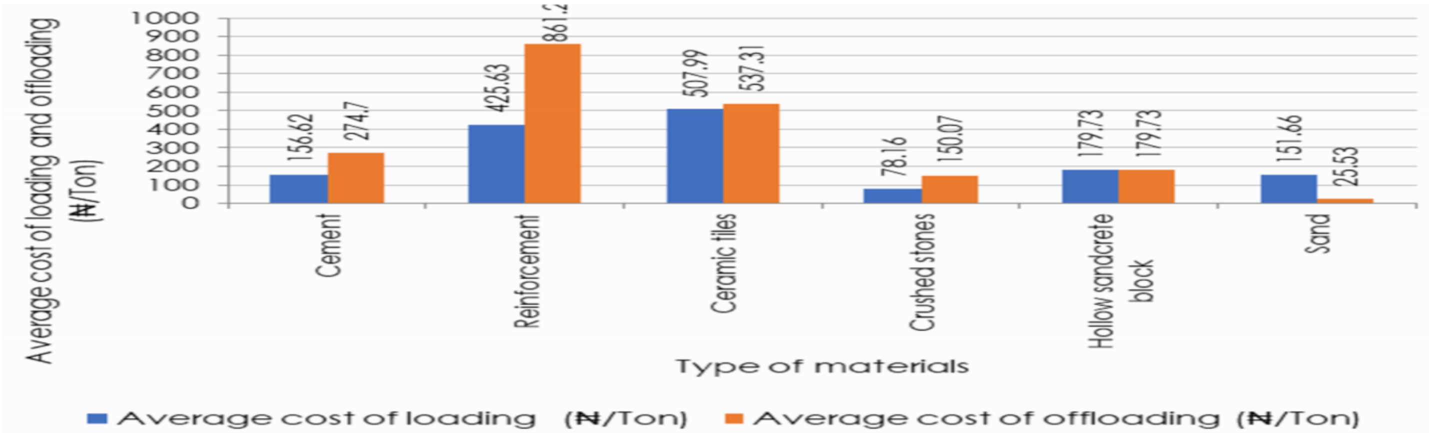


**Figure 6: Average loading and offloading cost per ton**

## 5. DISCUSSION OF RESULTS

### 5.1 Order-picking method used in warehouses

The study found that most of the companies used the paper-based picking method for materials handling. Webster *et al*. (2014: 16) confirmed that manual order-picking methods are slower, as the picker must handle and read the paper. This could lead to errors if the writing is illegible or if there is confusion over the way it is written. Slow manual operation is time consuming that leads to low throughput, long lead time, and high labour costs in warehouse operations (Gwynne, 2014: 138). In addition, manual order picking creates problems in monitoring and locating of materials on construction sites because materials always come in bulk without proper identification (Kasim *et al*., 2012: 450). This is contrary to the use of bar codes that will lead to a reduction in human mistakes, and an increase in speed, accuracy, and dependability (Sople, 2010: 77). De Koster *et al*. (2007: 484) noted that inefficiency in order picking can lead to unsatisfactory service delivery and high operational expenses for the warehouse and the entire supply chain. Therefore, the inference is that the order-picking processes adopted by North-Central Nigerian construction-material manufacturing companies are sub-optimal and inefficient. However, technology advancements in automation such as barcoding, voice technology, and pick-by-light systems can be introduced (Gwynne, 2014: 93; Vishu, 2016: 166). These have improved warehouse order-picking processes and generated a respectable return on investment ( Vishu, 2016: 166).

### 5.2 Material-handling equipment used in warehouses

The observation results showed that, although most of the manufacturing companies did not use any handling equipment in their warehouses, a few companies did use material-handling equipment such as pay loaders, mini automated loaders, high-level order-picking cranes, and forklift trucks. The implication is that multiple handling of material causes low productivity in the warehouse. The findings contradict the Baker & Perotti (2008: 64) results on a survey of the type of equipment used in UK warehouses. They found that most of the companies use a combination of equipment to handle different types of materials. Furthermore, the findings are contrary to the use of MHE to increase efficiency, control costs, and optimise productivity (Bouh & Riopel, 2015: 463). The implication of using materialhandling equipment is a reduction in worker manual labour and boosting of worker morale (Rajesh & Subbaiah 2015: 117). It also reduces damage to materials, possibly through human error or negligence, and reduces fatigue (Kay, 2012: 20). Observations showed that automation of the materialhandling processes in warehouses in the North-Central Nigerian zone was minimal and inefficient. For that reason, the study proposes the adoption of mechanisation/automation of warehouses. This can be achieved through incentives such as changes in legislation, contracts to facilitate reverse logistics, and tax relief on the importation of plants and equipment by enterprises (Pienaar, 2016: 354).

### 5.3 Storage equipment used in warehouses

Based on observation results, most of the manufacturing companies used floor/block storage methods in their warehouses. This finding was supported by Baker & Perotti (2008: 64), who study of the modern warehouses of a group of companies is revealed that the most popular form of storage was floor storage and standard wide aisle racking. This finding also confirmed the study by Roodbergen and Vis (2009: 343), which established that insignificant consideration has been given to the utilisation of automated storage and retrieval systems and other material-handling systems in warehouses and distribution centres. The finding is in contrast with Gwynne's (2014: 221) submission that most of the mechanical handling- and storage-equipment manufacturers do have sophisticated systems, including simulation software that can assist companies with planning as to what type of racking and MHE will efficiently suit their operations. The study revealed that the use of storage equipment was minimal and inefficient in the North-Central Nigerian zone warehouses. This is contrary to the assertion by Leung and Lau (2018: 24) that many types of special equipment have been designed to reduce labour costs and/or increase space utilisation. Storage and retrieval equipment can reduce labour costs.

### 5.4 Loading and offloading equipment

The study revealed that two-thirds of the manufacturer warehouses used equipment such as automatic loaders for loading cement, high-level cranes for loading reinforcement bars, pay loaders for loading granite/sand, and forklift trucks for loading ceramic tiles. These findings are supported by the automation principle of material handling that the operations should be mechanised and/or automated, where feasible, to improve operational efficiency, reduce operating costs, and eliminate repetitive manual handling of material (MHI, 2000: 22). However, the remaining companies used manual labour in the loading of ceramic tiles (semi-mechanised), blocks, granite, and sand. The observation results revealed that offloading was done manually at the distribution centres/warehouses, retailer stores, and construction sites. These findings contradict Pienaar's (2016: 381) assertions that, to reap the optimum rewards of specialisation, handling equipment at terminals should be provided for rapid loading and offloading to save time and cost. More so, they also contradict the view that block manufacturers normally use selfloading vehicles with cranes mounted on the edge or removable mounting (Vidalakis & Sommerville, 2013: 478). This truck equipment allows for extra grades of movement for handling unit loads (Hannan, 2011: 36). Based on the observation results, the use of loading equipment at the manufacturer warehouses was minimal, while there was no offloading equipment at the distribution centres/warehouses, retailer stores, and construction sites. Hence, loading processes at the manufacturer plant/ warehouses, and offloading of vehicle processes at the distribution centres/ warehouses, retailer stores, and construction sites in the North-Central Nigerian zone were inefficient. But to realise the maximum benefits, provision of handling equipment at the nodes or terminals would offer fast loading and offloading of materials and make best use of the quantity of full vehicle load kilometre per unit of time (Pienaar, 2016: 381). Economies of density require the optimal use of big, strong equipment over as long a period as possible.

### 5.5 Loading and offloading time

The observations results revealed disparity in the average time taken per ton for loading and offloading each material. It took lesser time per ton to load at the manufacturing plants where the loading was done mechanically. On the contrary, it took more time per ton to offload at the distribution centres/warehouses, retailer stores, and construction sites where most offloading was done manually. These processes combined used fewer machines, but more manual labour that involved multiple handling. These findings contradict the assertion by Pienaar (2016: 381) that using high-capacity technology to carry and handle large bulk loads can help minimise loading and offloading times. However, the offloading process can be more efficient and enhanced by 61% if it improves its information systems (Andrejić & Kilibarda, 2016: 147). The implication is an increase in waiting time and lead time for delivery of materials. This cannot be recovered when an invoice is made out for the offloading of material (Pienaar, 2016: 384). However, using automation in material loading and offloading can increase efficiency, control costs, and optimise productivity (Bouh & Riopel, 2015: 463).

### 5.6 Loading and offloading costs

The study showed disparity in average cost per ton for loading and offloading individual materials. It costs less per ton to load than to offload in companies where most of the loading was done mechanically at the manufacturer's warehouse, as against most of the offloading being done manually at the distribution centres/warehouses, retailer stores, and construction sites. This finding supports the fact that the use of automation in material handling can increase efficiency, control costs, and optimise productivity (Bouh & Riopel, 2015: 461). The findings corroborate Michaels' (2015: 16) submission that the more multiple handling of material, the more the overall logistics expense. The implication is that the touch time costs are non-value-added costs that will never be recovered when an invoice is calculated for the load (Niggi, 2017: 52). The implication is that this leads to increased labour cost, which invariably increases the price of construction material. But to realise the maximum benefits of automation, provision of handling equipment at the nodes or terminals would offer fast loading and offloading of materials (Pienaar, 2016: 381).

## 6. CONCLUSION AND RECOMMENDATION

This article assessed the level of utilisation of automation in construction material-handling operations by the manufacturing firms in North-Central Nigeria. Fundamentally, any non-utilisation of automation in construction material-handling operations will result in inefficiency in operations, such as prone to error, long lead time, and high labour cost. This assumption is well founded on the concept of non-value-added costs and strongly connected with the general perception that poor material-handling operations of construction-material manufacturers can add significantly to the non-value-added costs of construction materials, which, by increasing labour time and cost, results in inefficiency, higher construction-material prices and delays in delivery to prospective customers.

Using the dynamics of material-handling operations as guidance for data collection, the evidence provided in the case study establishes significant non-utilisation of automation in construction-material handling. The main problems observed on-site were low utilisation of automation in order-picking methods, material-handling equipment, and the use of storage equipment, loading and off-loading vehicles at the warehouses, distribution centres, retailer stores, and construction sites. The implication of the findings is increasing construction costs and causing delays in project execution. This article concludes by providing the construction-material manufacturers with areas that require addressing, in order to improve material-handling operations along the nodes (terminals) to help ensure that the construction material arrives at its final destination at optimal quality, time, and cost. To mitigate the inefficiency in material-handling processes, there is a need for the use of standard pallets or containers for the transportation of material (cement, ceramic tiles, and blocks) to create a unit load. This will assist in eliminating multiple handling during loading and offloading, minimising the risk of material damage, and making the best use of space in the vehicle. It can also reduce loading and offloading time and cost and improve productivity. The pallet or container should be reusable (recycle) to enhance sustainability. In addition, the use of a combination of, or separate equipment to handle different types of materials and order profiles will improve productivity and enhance efficiency. The study suggests automation of the manual process and the use of equipment such as forklifts, high-level cranes, power pallet jacks, and pay loaders to mitigate inefficiency in handling operations at the terminals (nodes). Due to the small sample of participating companies, performance values estimated in this article are relevant to these companies and should not be considered as industry benchmarks. A recommendation is made for further study to explore why automation is not used, despite its purported advantage in improving the efficiency of material-handling operations. This study was conducted using observations, which is one of the limitations of this study. The sample size of 72 orders processed can also be increased in further studies. Another limitation of this study is the geographical aspect. Since this study covered only one out of the six geopolitical zones of Nigeria, other zones should be studied, and the results compared.

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