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ASSESSMENT OF TRANSPORTATION EFFICIENCY FOR THE DELIVERY OF CONSTRUCTION MATERIAL IN NORTH-CENTRAL NIGERIA

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ABSTRACT

In Nigeria, knowledge on the management of construction material logistics system, especially in transportation, is inadequate. This article assesses construction material manufacturers' transportation efficiency for the delivery of construction material, in order to improve manufacturers' transport operation in North-Central Nigeria. A total of 32 construction material manufacturers delivered their material to 42 distribution centres/warehouses and retailer stores, and 30 construction sites were purposely selected. The selected construction materials manufacturers produce six types of materials, namely cement, reinforcement bars (steel), ceramic tiles, crushed stones, masonry hollow sandcrete blocks, and sand (fine and coarse). A case study research design method was used, in which quantitative data were collected and analysed. An observation (quantitative) guide was used as the research instrument. The quantitative data collected were analysed, using descriptive statistical tools such as frequencies and percentiles. The results revealed that transportation efficiency levels are low in their vehicles' dwell time, loading and off-loading vehicles at the warehouses, retailer stores, and construction sites. It was also revealed that no technology was used in the transport system to integrate the manufacturers' warehouses with the other logistics partners in the supply chain. The article concludes that manufacturers should address transportation operations along the delivery nodes to help ensure that the construction material arrives at its final destination at optimal quality, time and cost.

Keywords: Construction material, efficiency, manufacturer logistics, technology, transportation

ABSTRAK

In Nigerië is kennis oor die bestuur van die logistieke stelsel vir konstruksiemateriaal, veral in vervoer, onvoldoende. Hierdie artikel evalueer die doeltreffendheid van die vervoer vir die aflewering van konstruksiemateriaal deur konstruksiemateriaalvervaardigers, ten einde die vervaardigingsvervoer in Noord-Sentraal Nigerië te verbeter. Altesaam 32 konstruksiemateriaalvervaardigers wat hul materiaal by 42 verspreidingsentrums/pakhuise en kleinhandelaarswinkels aflewer, asook 30 konstruksieterreine is doelbewus vir hierdie studie gekies. Die gekose konstruksiemateriaalvervaardigers vervaardig ses soorte materiaal, naamlik sement, wapeningstawe (staal), keramiekteëls, gebreekte klippe, messelwerk, hol sandbetonblokke en sand (fyn en grof). 'n Gevallestudie navorsingsontwerpmetode is gebruik, waarin kwantitatiewe data versamel en ontleed is. 'n Waarnemingsgids (kwantitatiewe) is as navorsingsinstrument gebruik. Die kwantitatiewe data wat versamel is, is geanaliseer met behulp van beskrywende statistiese instrumente soos frekwensies en persentiele. Die resultate het getoon dat die doeltreffendheid van vervoer laag is in terme van voertuigverblyftyd, asook tydens die op- en aflaai van voertuie by die pakhuise, kleinhandelaarswinkels en terreine. Resultate toon ook dat daar nie van tegnologie in die vervoerstelsel gebruik gemaak word om die vervaardigerspakhuis met die ander logistieke vennote in die verskaffingsketting te integreer nie. Die aanbeveling is dat vervaardigers vervoerbedrywighede langs die afleweringsnodusse moet aanspreek om te verseker dat konstruksiemateriaal by die finale bestemming teen optimale kwaliteit, tyd en koste kom.

Sleutelwoorde: Doeltreffendheid, konstruksiemateriaal, tegnologie, vervaardigerslogistiek, vervoer

1. INTRODUCTION

Construction material is a basic constituent in construction projects and can make an important contribution to the cost-effectiveness of projects (Kasim, Latiffi & Fathi, 2013: 7; Abhilin & Vishak, 2017: 911). Research has revealed that the usual cost of construction material is roughly 50%-60% of the total cost of a project (Kasim, Liwan, Shamsuddin, Zainal & Kamaruddin, 2012: 450; Duiyong, Shidong & Mingshan, 2014: 353). The logistics cost accounts for between 17% and 35% of the cost of material (Duiyong *et al.*, 2014: 353). Transportation costs account for between 39% and 58% of the total logistics costs (Ying, Tookey & Roberti, 2014: 262). Thus, transportation costs of construction material represents a greater percentage of the total cost in the construction industry.

The importance of transportation of construction material in the execution of a project cannot be overemphasised, because projects are made difficult by material inadequacies, delays in supply, increment in cost, material wastage and damage, and the absence of storage space (Kasim *et al.*, 2013: 7; Abhilin & Vishak, 2017: 911). The management of the storage and flow of construction materials and related information between the point of production (manufacture) and the point of utilisation is the essential element of logistics management (CSCMP, 2013: online). Therefore, a small percentage reduction in transportation costs could lead to a significant reduction in the price of materials (Ying *et al.*, 2014: 264).

Studies on construction material logistical systems in Nigeria focus mainly on Supply Chain Management (SCM), but with deprived knowledge on vital top subsections such as transportation (Shakantu & Emuze, 2012: 661). For example, construction material and transport providers/waste removal still operate as independent trades. In Nigeria, a few studies on the construction material-manufacturing industry focus on mode of transport, the inventory, and challenges in transportation condition in the cement-manufacturing firms (Adebumiti & Muhammed, 2014: 234; Adebumiti, Muhammed, Faniran & Yakubu, 2014: 242). Obiegue (2010: 8) appraised customer satisfaction and the challenges facing the transportation system of chemical and paint manufacturers. Similarly, Oludare & Oluseye (2015: 18) studied the influence of construction materials supply chain network structures and strategies on project delivery and the impact of logistics factors on material procurement for construction projects (Tunji-olayeni, Afolabi, Ojelabi & Ayim, 2017: 1142). Furthermore, Isah, Shakantu & Ibrahim (2020: 22) observed that the technological aspect of construction logistics, especially the forecasting, is ignored and barely understood in the Nigerian construction industry.

Hardly any study has been done on the Nigerian construction material manufacturers' transport system operational performance, showing that, currently, knowledge on the management of construction material logistics systems is inadequate. It is, therefore, important to assess construction material manufacturers' transport efficiency. The article assesses the load/offload period of vehicles at terminals, the number of vehicles loading at a time, the equipment/method used to load/offload vehicles, and the time and cost to load/offload vehicles, in order to improve the transport system of construction material manufacturers in North-Central Nigeria.

2. LITERATURE REVIEW

To understand transportation efficiency for the delivery of construction material in North-Central Nigeria, it is important to introduce the present theory on transportation included in this article. The current theory focuses on transportation systems, transportation efficiency, vehicle loading method/equipment, loading and offloading periods at the terminals, dwell time and idling, as well as the use of technology in transportation.

2.1 Transportation system

The transportation system is the spatial link that joins customers, raw material suppliers, distribution centres/warehouses and supply chain partners in the management of construction material logistics systems (Andrejić, Bojović & Kilibarda, 2016: 99). Normally, transportation is a key cost element of the logistics supply chain (Shakantu & Emuze, 2012: 664).

Contrary to the construction industry, the manufacturing industry can choose where they should conduct their productive operations. The companies are sited on fixed locations, hence the need to move their products to where their customers are. This brings transport into the core of the city and built-up areas (Pienaar, 2016: 386). The geographical region's network is the key component responsible for the performance of transportation within the logistics service (Kamali, 2018: 199). Using an efficient and effective transportation network, a firm can obtain more advantages in terms of service level and cost-effectiveness measurements (Chopra & Peter, 2007: 156). In addition, Chopra & Peter (2007: 156) defined the types of transportation networks as follows:

- The direct shipment system, where there is a direct transportation to one customer from a single merchant to a customer without a third party.
- The transportation method that a few manufacturers utilise to fulfil their customers' requests through intermediate stations in moving materials from one location to another. The strategy works by setting up distribution centres as an approach to attain the economies of scale in transportation.
- The indirect transportation technique is handled by a Third Party Logistics (3PL) company, in which their jobs are known as a helpful supply chain partner.

In contemporary business, various kinds of 3PLs service companies offer transportation services such as customised logistic solutions, joint logistic solutions, and in-house logistic solutions. Even though there are few benefits with 3PLs, a manufacturing firm can focus on its main business rather than on transportation services (Kamali, 2018: 199). Poor cost performance by manufacturers and suppliers can significantly increase the Total Acquisition Cost (TAC) of construction material which, through rising material purchase prices, results in higher construction costs (Vidalakis & Sommerville, 2013: 473). Transport efficiency is critical for timely delivery of construction material.

2.2 Transportation efficiency

According to Pienaar and Havenga (2016: 22), efficiency means realising an objective at the minimal cost. Andrejić *et al.* (2016: 99) recognised two factors in their evaluation of the efficiency of transport systems. The first factor is fleet efficiency, which is focused on senior level decision-making, and the second factor is vehicle efficiency at the operational level of decision-making. Understanding transportation economics and pricing is fundamental for efficient logistics management. The essential components of transportation costs are distance, volume, handling, liability, and market factors. These components control transportation prices, which are included in the budget as rates for performing specific services (Bowersox, Closs, Cooper & Bowersox, 2013: 203). Pienaar (2016: 388) identified the following key factors of road transport efficiency: cost level, the economies of fleet size, the economies of vehicle size, the economies of infrastructure extension, and the economies of distance.

Transportation cost efficiency and customer responsiveness have been identified as the two most prominent supply chain performance measures (Vanteddu, Chinnam, & Gushikin, 2011: 205; Vidalakis & Sommerville, 2013: 473). They further asserted that, in order to minimise transport-related costs, distance and weight, as transportation cost drivers, should be considered. Bowersox, Closs and Cooper (2007: 174) opined that the bigger the overall shipment and the longer the distance it is transported, the lower the transportation cost per unit. Delivery consolidation is crucial to increase distance and weight per shipment and, in this manner, reduce the number of vehicle movements, while increasing loading efficiency. But there is always a trade-off between loading efficiency and operational frequency (Geunes & Taaffe, 2008: 184). In fact, even though the former guarantees low unit transportation costs, the latter can reduce lead times by delivery in less truck load. This is also supported by Errasti, Beach, Oduoza & Apaolaza (2009: 261) who refer to it as the task of balancing efficiency and responsiveness. Construction material transport costs include capital and operating costs. The capital cost depends on the model and type of vehicle. Apart from capital or purchase price, vehicle owners also have operating costs, which can be classified as fixed (overhead) and variable costs (Pienaar, 2016: 386).

Another transportation performance metrics is responsiveness, meaning a supplier’s aptitude to react to customer requests reliably and timely (Vanteddu *et al.*, 2011: 206). This holds especially right for construction logistics, since last-minute requests are likely to happen, due to the absence of an inventory control system and poor storage capacity on-site (Vidalakis, Tookey & Sommerville, 2011: 67).

For efficient delivery of material, transportation consolidation should be relied upon to bring about bigger total shipments and, hence, improved vehicle utilisation. Vidalakis and Sommerville (2013: 474) affirmed that, in order to give a total perspective on vehicle utilisation efficiency, three parameters must be considered, namely vehicle shipping efficiency (VSE), vehicle journey efficiency (VJE), and vehicle weighted efficiency (VWE). They established that vehicle loading efficiency levels were significantly lower for construction material than those assessed in other sectors. It also reveals the frequency of empty vehicle runs during backhauling (Vidalakis & Sommerville, 2013: 474).

Similarly, On Time Delivery (OTD) is vital for efficient delivery. OTD is defined as a measurement based on the percentage of customer orders delivered “On Time and In Full” (OTIF) (Kamali, 2018: 188). The OTD shows that manufacturers and suppliers could fulfil the delivery terms based on the agreed upon time, which is known as the delivery date (Kamali, 2018: 198). Thus, if they are unable to achieve the delivery on time, it will reduce the efficiency, considering that the OTD process could be realised if all variables involved in the process work out effectively (Kamali, 2018: 198). A study by Kamali (2018: 2004) recommended that, based on the findings, to be able to tackle the OTD issues, the following actions must be considered: full utilisation of the Enterprise Resource Planning (ERP) systems, improving management performance, and considering a 3PL partner as a strategic goal.

Ruamsook and Thomchick (2012: 130) noted that the commonly used transport performance metrics in terms of efficiency are ‘costs’ (transport costs, inventory carrying costs, material handling costs); ‘quality’ (on-time and damage-free delivery, complete order), and ‘time’ (order cycle time length and variability, response time). However, the sustainability of these metrics in terms of material transportation is not sufficiently addressed.

The absence of materials, when needed, is one of the main causes of loss of productivity at a job site. Inefficient transportation of materials can lead to an increase of 50% in work hours (Hasim, Fauzi, Yusof, Endut & Ridzuan, 2020: 020049-3). In addition, Ahmadian, Akbarnezhad, Rashidi and Waller (2014: 460) studied the significance of transportation in the procurement of construction materials. The results revealed that material-handling processes adopted in industry are highly disorganised and that transportation variables are ineffectively articulated. The results also established the need for methods to plan, monitor and control the transportation system as an independent activity in the material’s life cycle. In addition, the travelling distance, weight, dimension, mode of transportation, and terms of delivery were identified as the main factors affecting the transportation efficiency of the construction materials.

2.3 Vehicle loading method/equipment

Having efficient material-handling systems is crucial for maintaining and facilitating a continuous flow of materials through the workplace and guaranteeing that required materials are available when needed (Leung & Lau, 2018: 34). There is a need for efficient materials handling, with the purpose of control, productivity and cost in construction projects (Patel, Pitroda & Bhavsar, 2015: 3). However, there are monetary trade-offs between high capital costs of mechanised systems, and increased labour costs in manual systems and types of manual handling that occur in such places (Webster, Dalby, Fox & Pinder, 2014: 7).

The on-site materials handling, monitoring and locating are made difficult, due to the manual handling process that is labour intensive, inclined to mistakes, resulting in the delay in timely execution and increase in cost of construction projects (Kasim *et al.,* 2012: 448).

In order to achieve the maximum benefits of specialisation, handling tools at the nodes ought to offer fast loading and offloading of products to make best use of the quantity of full vehicle load kilometre per unit of time. Economies of density require the optimal use of big, strong equipment over as long a period as possible (Pienaar, 2016: 381). These include automatic loaders, high-level cranes, forklifts, manual, loader shovels, excavators, overhead gantries, and the utilisation of saddle carriers.

Furthermore, a wide range of attachments is accessible for fitting to forklift trucks so that they can handle materials that cannot be moved by forks. These truck attachments links can permit additional grades of movement for handling unit loads (Hannan, 2011: 32). Masonry hollow sandcrete block manufacturers usually utilise self-loading vehicles with cranes mounted on the edge or on a removable mounting. Big quarry trucks are usually loaded by loader shovels, while vehicles are often stacked by an excavator. Manual loading may utilise less effort by means of a low truck and body. Detachable bodies or containers can be left on the ground for loading and lifted onto the truck by a hydraulic or mechanical crane (Rushton, Oxley & Croucher, 2001: 370).

It is important to note Michael's (2015: 16) submission that each point of stockholding comprises handling of the material and, the more numerous handling of material, the more the total logistics expenses would be. The reason for this is that the process includes both equipment and human effort. This represents the cost of workforce in the warehouse and automation utilised to receive, put away, move, check, and count the inventory (Parvini, 2011: 32). It should be noted that efficiency of offloading processes could be enhanced by 61% with information system advances (Andrejić & Kilibarda, 2016: 145).

2.4 Period of loading and offloading at the terminals

Several customers receive products not only within working hours, but very early in the morning and later in the evening. The use of a vehicle that usually runs from 08h00 to 16h30, or for 8.5 hours, can be significantly improved if it can deliver goods between 07h00 and 08h00, thus avoiding peak traffic hours in the cities. The same would apply if deliveries can be made at night (Vogt, 2016: 342). Regardless of whether the delivery is optimised by a system or not, extended hours and flexible delivery times would significantly improve productivity. These times are bargained between the manufacturers, the distribution centres/warehouses, customers, suppliers, and facilities within the logistics chain. Again, the reduction of restrictions, in this case customer receiving times, improves the potential for increased efficiency (Vogt, 2016: 342). A few cities in the United States of America (USA) and the European Union (EU) have implemented day-time restrictions on truck deliveries in their downtown core areas (Ruamsook & Thomchick, 2012: 142). This has a negative impact on logistics efficiency, as it creates longer waiting times for vehicles at the terminals.

2.5 Dwell time and idling

Vehicles are not dispatched to their various locations, except when they are fully loaded or offloaded. The vehicle may wait at a plant, distribution centre/warehouse and a retailer store before it is sent to the next destination (Eskigun, Uzsoy, Preckel, Beaujon, Krishnan & Tew, 2005: 185). The whole of the load waiting time, the time wasted due to overcrowding, and other issues make up the total waiting time, or dwell time of the vehicle.

Idling differs by trip duration, season, geographic location, and trucking operation, making it difficult to quantify hours of truck idling for the truck population. Idling is classified as discretionary (non-essential, though desirable) or non-discretionary (*i.e.*, essential). Discretionary idling includes overnight idling and delivery idling, and mainly serves to maintain driver comfort levels; it could be eliminated using a fuel cell (Brodrick, Lipman, Farschchi, Lutsey, Dwyer, Sperling, Gouse, Harris & King, 2002: 307). Furthermore, there might be some idling time, due to managerial problems or ineffectiveness in the system. This may be unrelated to the volume of vehicles passing through these destinations (Eskigun *et al.,* 2005: 185; Gwynne, 2014: 73). Without proper scheduling of vehicle delivery, the workload in the facility will vary excessively. The burden on the operating staff increases during peak times and this reduces efficiency and the accuracy of the receipt (Vogt, 2016: 334).

There are also economic reasons to reduce idling. Previous studies by the US Environmental Protection Agency (EPA) (cited in Ruamsook &

Thomchick 2012: 131) revealed that an average long-haul trailer truck idles for approximately eight hours per day for at least 300 days per year, consuming roughly 0.8 gallons of fuel per hour or close to 1,900 gallons of fuel per year. In addition, there is some evidence that the average idling time for long-haul trucks may be even higher (Brodrick *et al.*, 2002). The study by Rahman, Masjuki, Kalam, Abedin, Sanjid & Sajjad (2013: 171) confirmed that long-distance trucks can remain idle for between six to 16 hours per day. Hence, to increase operation efficiencies, transporters are also concentrating on reducing idle time (Ruamsook & Thomchick, 2012: 131).

2.6 Technology in transportation

Andrejić, Bojović and Kilibarda (2013: 3927) identified five causes of transportation loss or inefficiency in the logistics system, namely driver breaks, excessive loading time, fill or cargo loss, speed loss, and quality delay. In order to address some of these transportation logistics problems, Ruamsook and Thomchick (2012: 130) highlighted the influence of utilising technology in transportation.

Software for Transport Management Systems (TMS) allows for effective and efficient management of the transportation fleet used in the outbound logistics system (Andrejić & Kilibarda, 2016:143). TMS makes it possible to assess driver performance and vehicle efficiency by remotely monitoring speed, braking, gear-shifting, idle time, and out-of-route miles (Ruamsook & Thomchick, 2012: 135). Intelligent Transportation System (ITS) incorporates Information Technology Communications- (wireless) and Geographic Information Systems (GIS)-based software into roads, trucks, traffic and transport management systems. Furthermore, the technology allows drivers to minimize the chances of getting lost, to keep track of pickup and delivery schedules, and to find out about adverse weather or traffic conditions. ITS guarantees more up-to-date transport managers, customers and prompt response services, thus improving safety, fairness, efficiency, and ecological protection (Kavran, Jolic & Cavar, 2009: 335).

In an investigation into load shipment organisations, Ndonye (2014: 2) advocated that they should utilise information technology to enhance the efficiency and effectiveness of their logistics performance in a bid to achieve a competitive advantage. Andrejić and Kilibarda (2016: 143) recommend that it is important to integrate TMS, Warehouse Management System (WMS) and other systems. A study where RFID is integrated with LEAN Production in both Central Distribution Centre (CDC) and Local Distribution Centre (LDC) revealed a significant improvement in the entire supply chain, thereby saving 89% and 70% on waiting and transportation times, as well as value-added time, respectively (Chen, Cheng & Huang, 2013: 3396). Similarly, Isah *et al.* (2020: 22) observed that the manufacturing industries (100%) adopted ERP technology for forecasting purposes (for material, demand, product, and production forecasts). Unexpectedly, ERP technology was not utilised for forecasting in the retailing and construction sectors.

3. RESEARCH METHOD

3.1 Research design

This study investigated the efficiency of the transportation system being practised and utilised in North-Central Nigeria by the construction material manufacturers to achieve customer satisfaction. Using a case study research design (Yin, 2014: 124), quantitative data were collected and analysed. Karim (2008: 3) considers a case study method as reality "out there" and something that can be examined objectively. In this study, a semi-structured observation template (Kamali, 2018: 192) was used to observe the dynamics of transportation efficiency in the 32 construction material manufacturing firms in aspects such as period of loading/offloading vehicles at the terminals; number of vehicles loading at a time; equipment/ method of loading/offloading vehicles; loading/offloading time, and cost of loading/offloading vehicles. The quantitative data were recorded based on the observation in the case study to determine the transportation efficiency utilised by construction materials manufacturers.

3.2 Population, sampling methods and response rate

The study area is the North-Central geo-political zone of Nigeria, which comprises of six states and the Federal Capital Territory (FCT), Abuja. North-Central is one of the fastest developing regions, with a high concentration of construction activity, near FCT. From this wide zone, 32 construction material manufacturers were purposively selected. From these, 32 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, eight companies visited were identified as manufacturers of cement, reinforcement bars, ceramic tiles, and crushed stones, with two companies 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 processes for analysis within a reasonable time. Table 1 shows the type of material, the number of deliveries per each state capital and FCT, distribution centres, and the warehouse and construction sites observed.

Table 1: Companies and construction sites observed

Materials	*Number of manufacturing companies*	*Transportation (number of deliveries)*	*Location Number of distribution centres/ warehouses and retailer stores*							*Construction sites*
			Abuja	*Minna*	*Lafia*	*Lokoja*	*Jos*	*Makurdi*	*Distribution centres/ Warehouses*	
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)

3.3 Data collection

The researchers collected quantitative data using self-observations on material delivery operations from the construction sites in random order, time and day. The non-participant structured observations of logistics processes were conducted across the various sections of the companies, namely marketing/sales, packaging, warehouse, logistics/transport, and loading bays.

In this study, the Observation and Measurement Guide was used to record the time period (in hour time slots) for loading and offloading vehicles at the terminals as well as the vehicle dwell time on-site; the number (in frequency) of vehicles that could be loaded at a time; method and equipment (*e.g.* hand, crane, forklift) used for loading and offloading, and the average loading and offloading time for individual materials (per ton) at the terminals 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 types of technology (*e.g.* wireless, GPS, speed limit) installed in vehicles used for delivery were recorded in frequency.

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 deliveries by transport providers was observed. This number of observations is supported by Shakantu & Emueze (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.

The researchers improved the credibility of the observations by communicating directly with personnel involved in transportation operations. Furthermore, the field study took place in an environment (standard manufacturer warehouse processes and transportation operations) not designed by the researchers and had the advantage of a natural real-world view.

3.4 Method of analysis

The observation data were entered into Microsoft Excel (Bowen, Edwards & Cattel, 2012: 887) to calculate and report frequencies and percentiles using descriptive analytical tools (Loeb, Dynarski, McFarland, Morris, Reardon & Reber, 2017: 8). A percentage is calculated by dividing the number of times a value for a variable observed by the total number of observations in the population, then multiplying this number by 100. Using thematic analysis, the data were first tabulated into three sections. The first section comprised warehouse/loading bay processes at the 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, period of loading/offloading vehicles at the terminals, number of vehicles loading at a time, equipment/method of loading/offloading vehicles, loading/offloading time, and cost of loading/offloading vehicles. 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 researchers obtained management's approval for adequate access to observe logistics processes and operations. However, the researchers were denied access to some areas of operations and records of transactions, despite the assurance of anonymity and confidentiality. Managers explained that these actions were taken to safeguard the technology and business strategies from their competitors. In addition, the workers might not like the fact that they were being watched while working and could have assumed that the researchers were a management spy. Under such circumstances, the validity of the data may be compromised, as the workers would not behave 'naturally'.

4. RESULTS

4.1 Period for loading and offloading vehicles at the terminals

The study sought to know how much time a vehicle waited at the manufacturers' warehouse or the distribution centre/warehouse, retailer store and construction site before it was dispatched. Figure 1 indicates that 75% of the manufacturing companies load vehicles between 08:00 and 18:00 hours (10 hours), during working hours only.

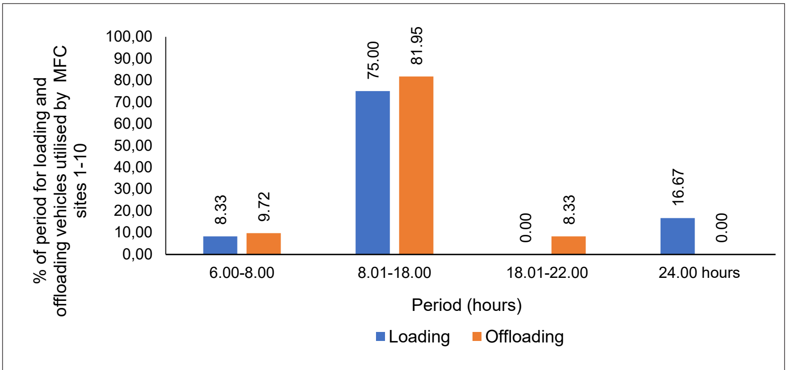

Figure 1: Period for loading and offloading vehicles at the terminals

The significant finding was that most of the company loading time was 10 hours out of the 24 hours per day. As a result, any vehicle that arrived at the plants/warehouses after 18:00 had to wait all night until the next morning before it could be loaded. The implication of this is that there is a longer vehicle dwell time between 18h00 and 08h00, a 14-hour difference. This reduced the vehicle utilisation, thereby increasing lead time. Roughly 8% of the blocks/sand companies loaded between 06h00 and 08h00, and 17% of the cement companies for 24 hours. It was observed that only cement companies loaded for 24 hours per day.

The findings confirmed that 81% of the distribution centres/warehouses and retailer stores had an offloading period between 08:00 and 18:00, which are normal business hours. As explained earlier, all vehicles that arrived after closing time had to wait until the next day to be offloaded. This also increased vehicle dwell time by 14 hours. In addition, 9% of the distribution centres/warehouses and retailer stores offloaded their materials between 06h00 and 08h00, and 8% between 18h00 and 22h00. These are basically hollow sandcrete block and sand companies, which sometimes work slightly beyond normal working hours, as their point of discharge is not constrained by law for offloading. This is unlike for other materials, which are normally offloaded in the market area. Most of the construction material markets have a fixed opening and closing time. This limits operations to working hours of between 08h00 and 18h00. The consequence is underutilisation of vehicles during operational hours, due to a longer dwell time of 14 hours per day at each or both terminals. However, most of the vehicle drivers would have preferred travelling during the night.

4.2 Number of vehicles loading at a time

There was a need to verify if there were queues, due to congestion at the dock or loading bay of the plants, as this may also create waiting time. Therefore, data were collected on the number of vehicles that could be loaded at a time.

Results in Figure 2 established that 37% of the company dock bays have a capacity for 1 to 3 vehicles loading at a set time. In addition, 21% of the dispatch bays have the capacity for 4 to 6 vehicles; 31% for 7 to 10 vehicles, and 6% for 11 to 15 vehicles loading at a time.

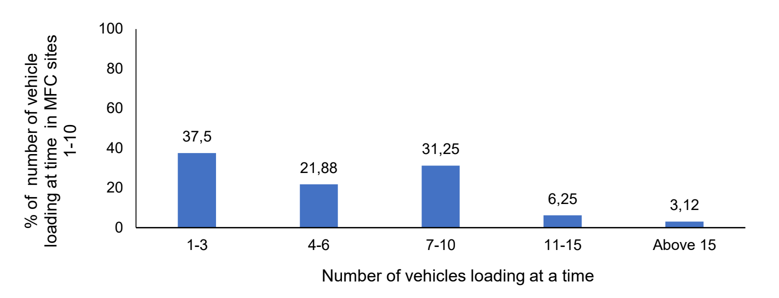

Figure 2: Number of vehicles loading at a time

This established that 58% of the manufacturer dock bays have the capacity for more than 4 vehicles at a time. No traffic congestion was observed at the company dispatch bays. This suggests that most of the time losses were not connected to congestion at the loading bay; they could have been caused by other factors such as administrative issues or inefficiency in the system. This inefficiency in the system may be as a result of paper-based communication, manual handling, and lack of use of technology, thus leading to longer order-processing period and poor efficiency.

4.3 Method of loading and offloading vehicles

The study sought to understand the type and level of automation adopted to increase efficiency in loading and offloading vehicles. Therefore, data on the method of loading vehicles at the manufacturers' warehouses and offloading of vehicles at the distribution centres/warehouses, retailer stores, and construction sites were analysed and are presented in Figure 3.

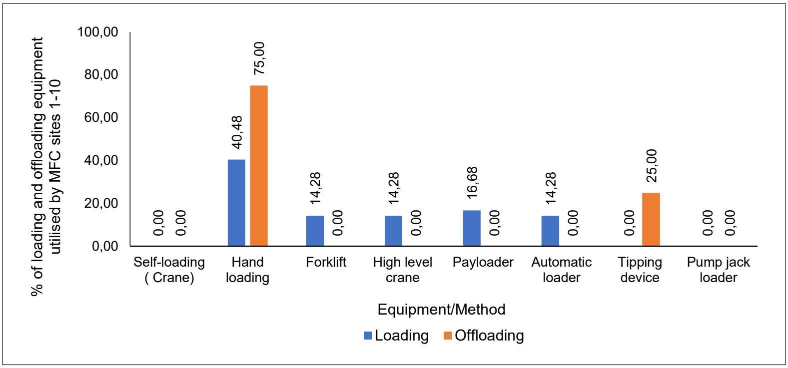

Figure 3: Method of loading and offloading of vehicles

The results indicated that 40% of the companies used manual methods of loading at the manufacturers' warehouses and construction sites. 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 major finding was that more than 60% of the company warehouses were automated. This signifies operational efficiency, in terms of increase in speed, accuracy and productivity, while reducing repetitive or potentially unsafe manual labour.

In addition, the findings established that 75% of distribution centres/warehouses, retailer stores and construction sites used manual methods of 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 also 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.

4.4 Loading and offloading time

The economies of density are enhanced by using high-capacity technology to handle large bulk loads and minimise loading and offloading time and cost. Therefore, the time of loading and offloading individual materials at the terminals was evaluated. The results of the average time taken to load and offload material per ton are presented in Figure 4.

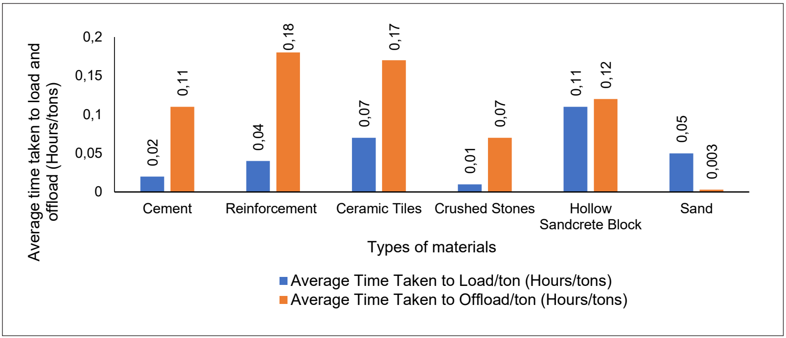

Figure 4: Average time taken to load and offload materials per ton

It was established that, for cement, the loading time was 0.02 hours/ton and offloading time was 0.11 hours/ton. Records confirmed the average loading and offloading time for reinforcement bars (0.04 and 0.18 hours/ton); ceramic tiles (0.07 and 0.17 hours/ton, and crushed stones (0.01 and 0.07 hours/ton). It is interesting to note that crushed stones offloading time is higher than its loading time. The reason for this is that trailer trucks were also used in the delivery of crushed stones. Since they do not tip off, the material had to be manually offloaded, thus resulting in increased offloading time and costs. The implication is that time and costs are non-value-added costs. This cannot be recovered when an invoice is made out for the offloading of material. On the other hand, it achieved load consolidation by transporting a larger quantity in a single trip.

4.5 Cost of loading and offloading material

The time taken for loading and offloading construction material was analysed. However, it also has cost implications. The cost of loading and offloading individual materials at the terminals was thus evaluated. Figure 5 shows the relationship of average cost to load and offload individual materials per ton.

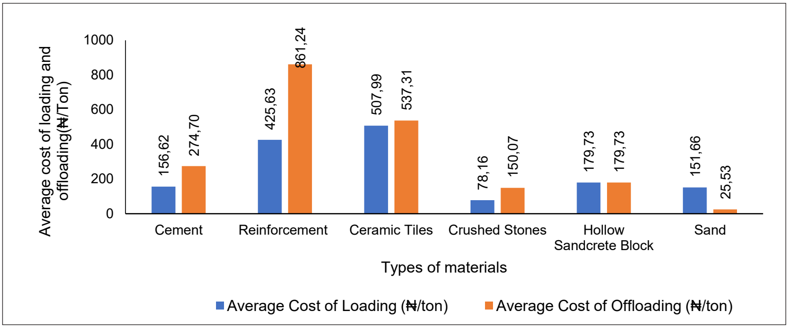

Figure 5: Average cost to load and offload materials per ton

The results confirmed that the average cost of loading per ton at the manufacturers' 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).

Figure 5 also reveals that the average cost of offloading at distribution centres/warehouses, retailer stores and construction sites was as follows: 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.

The major finding was 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.

4.6 Technology used in vehicles

Technology in vehicles is required to integrate the transport subsystem with the warehousing subsystem and customers, in order to improve efficiency, and to monitor and track the load in transit. This forms the basis for which data were collected on the types of technology installed in the vehicles.

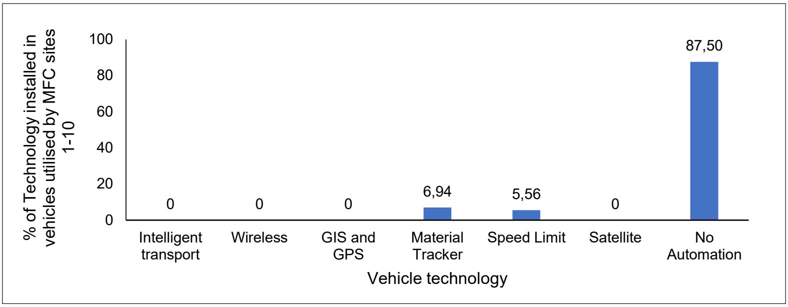

Figure 6: Types of technology installed in vehicles

Figure 6 indicates that 87% of the vehicles used for the shipment of construction material do not have any of the identified technology installed in them. About 7% of the vehicles had a material tracker, and 6% a speed limit tracker installed in them. This signifies that most of the vehicles do not have any of the technology installed in them. This further implies that the transport system is not linked to the manufacturers' plants, distribution centres/warehouses, retailer stores and construction sites. The vehicles cannot be tracked and monitored while in transit.

5. DISCUSSION OF RESULTS

5.1 Loading and offloading periods

Most of the company loading took place between 08h00 and 18h00, a time when vehicles were loaded and offloaded at the terminals. Similarly, most of the offloading times at the distribution centres/warehouses, retailer stores and construction sites occurred between 08h00 and 18h00. This means that vehicles are used only during operational hours, which leads to the longer dwell time of 14 hours per day in each terminal, or both. These results are in line with the findings of Rahman *et al.* (2013: 171). They confirmed that long-haul trucks were idle for between six and 16 hours per day. This is also supported by Andrejić *et al.* (2013: 3926) that inefficiency is measured in terms of the amount of time spent waiting on-site. The longer waiting time increases the inefficiency of vehicles' output in terms of time consumption. However, a shorter time increases the efficiency of the transportation processes (Drozd & Kisielewski, 2017: 32).

However, the findings are contrary to the fact that transport efficiency is achieved by full loads and utilising the transport for as long as possible each day (Vogt, 2016: 342). In addition, flexibility of loading and offloading times can significantly improve productivity and increase the vehicles' efficiency. Therefore, it can be deduced that underutilisation of vehicles during operational hours is due to the longer dwell time of 14 hours per day in each terminal, or both. This was due to restrictions and the inflexibility of loading and offloading periods.

5.2 Number of vehicles loading at a time

The study found that most of the manufacturer loading bays had the capacity to load four vehicles at a time. No traffic congestion was observed at the manufacturing companies' dispatch bays. This contradicts the submission that vehicles waste time, due to congestion at the docks of plants, or at the distribution centres/warehouses and retailer stores (Eskigun *et al.*, 2005: 181; Gwynne, 2014: 73). The waiting time could be due to administrative issues or inefficiencies in the system that are unrelated to the volume of vehicles passing through these locations (Eskigun *et al.*, 2005: 181). On this premise, it can be inferred that vehicle waiting time at the terminals was not related to the congestion at the loading bay. This long waiting time may be as a result of other adminstrative issues or inefficiencies in the system.

5.3 Loading and offloading equipment

The study revealed that two-thirds of the manufacturers' warehouses used equipment such as automatic loaders for loading cement, high-level cranes for loading reinforcement bars, pay loaders for loading crushed stones/sand, and forklift trucks for loading ceramic tiles. These findings are supported by Bouh & Riopel (2015: 468) that the operations should be mechanised and/or automated, where feasible, in order to improve operational efficiency, reduce operating costs, and eliminate repetitive manual handling of material. However, the remaining companies used manual labour in the loading of ceramic tiles (semi-mechanised), blocks, crushed stones, and sand.

Furthermore, the 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, in order to save time and cost. More so, it also contradicted the view that block manufacturers normally use self-loading vehicles with cranes mounted on the edge or on a removable mounting (Vidalakis & Sommerville, 2013: 478). This truck equipment allows for extra grades of movement for handling unit loads (Hannan, 2011: 36).

It can now be deduced that the use of loading equipment at the manufacturers' warehouses was minimal, while there was no offloading equipment at the distribution centres/warehouses, retailer stores, and construction sites. Hence, loading processes at the manufacturers' plant/warehouses, and offloading of vehicle processes at the distribution centres/warehouses, retailer stores and construction sites were inefficient.

5.4 Loading and offloading time

The study sought to confirm the average time taken per ton for loading and offloading each material. The results revealed much disparity in the average time taken per ton for loading and offloading each material. It took much less time per ton to load at the manufacturers' 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 of the offloading was done manually. These processes combined used fewer machines, but more manual labour that involved multiple handling.

These findings contradict Pienaar's (2016: 380) assertion that using high-capacity technology to carry and handle large bulk loads can help minimise loading and offloading times. Therefore, the efficiency of loading and offloading time per ton is sub-optimal.

5.5 Loading and offloading costs

The study also revealed a great deal of 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 is done mechanically at the manufacturers' warehouses, as against most 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: 468).

The findings corroborate Michael's (2015: 16) submission that the more the 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 made out for the load (Niggi, 2017: 52). Thus, for construction material handling, the efficiency of loading and offloading cost per ton was sub-optimal and inefficient.

5.6 Vehicle technology

The study sought to find the level of utilisation of technology to integrate the transport system with the other subsystems. The finding revealed that most of the vehicles used for the delivery of material do not have any transport system software installed in them. A few vehicles owned by the cement companies did have tracker and speed limits installed in them to enable their head office to monitor and track their vehicles. This did not link them to other subsystems and customers.

Andrejić and Kilibarda (2016: 143) found that it was necessary to integrate the transport management system, warehouse management system and other systems. Most importantly, the utilisation of TMS software can provide effective and efficient management of the transportation fleet used in the distribution network (Apte & Viswanathan, 2000: 291). This study found that there was minimal use of transport management system software in vehicles. It can thus be inferred that the transport management system was sub-optimal and inefficient.

6. CONCLUSION

This article assessed transport efficiency for the delivery of construction materials. Fundamentally, any inefficiency in the delivery of construction materials will result in higher material prices, thereby increasing construction costs. This assumption is well founded on the concept of TAC and strongly connected with the general perception that poor cost performance of construction material manufacturers can add significantly to the TAC of construction materials, which, by increasing material purchase price, results in higher construction costs.

Using the dynamics of transport operations as guidance for data collection, the evidence provided in the case study establishes significant inefficiency in construction material manufacturers' transport system. The main problems observed on-site were low efficiency in vehicle dwell time, loading and off-loading vehicles at the warehouses, retailer stores, and construction sites. The study also revealed that there was no utilisation of technology in the transport system to integrate the manufacturers' warehouses with the other logistics partners in the supply chain. The implication of the findings is high prices of materials and delay in delivery. Furthermore, transportation inefficiency became increasingly clearer.

This article concludes by providing the construction material manufacturers with areas that require addressing, in order to improve transportation operations along the nodes (terminals) to help ensure that the construction material arrives at its final destination at optimal quality, time and cost. 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. However, it is believed that the dynamics and capacity of the manufacturing company to provide a cost-effective service to the construction industry revealed by this research will be applicable to similar typical manufacturing firms. This study was conducted using observations, which is one of the limitations of this study. Another limitation of this study is the geographical aspect. Since this study covered only one out of the six geopolitical zones of the country, other zones should be studied and the results compared.

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