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A conceptual framework for waste identification and reduction in Nigerian sandcrete blocks production process

Received 21 November 2017
Revised 18 July 2018
13 November 2018
Accepted 8 April 2019

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Abstract

Purpose – Non-value adding activities or waste have been a major challenge for the construction industry. Researchers worldwide have investigated how such activities can be reduced or overcome in the industry. However, much has not been done regarding waste in the production process of building blocks. Therefore, this study aims to investigate the various waste in sandcrete blocks production process (SBPP). The study also aims to find out the causes of the waste and their impacts on the factory performance.

Design/methodology/approach – To achieve the aims of this study, a qualitative study was conducted in five sandcrete blocks firms in Minna. Physical observation and interviews were the main instruments used for data collection. The data obtained were analyzed through content analysis. Samples of blocks (low standard only) were also taken to the laboratory for compressive and porosity tests. Thereafter, questionnaires were administered to other sandcrete blocks producers in six firms. The essence of this was to investigate the applicability of the identified waste in other factories in the study context and for further data analysis.

Findings – Typical forms of waste in SBPP are excessive stocking of sand and cement, long distance covered from the store to the mixing or production location, excessive quantity or over design of materials and over vibration or compaction of the newly produced blocks. It is anticipated that adoption of lean concepts, tools and techniques in the production of sandcrete blocks will help to eradicate the identified waste in the process and stimulate a future state value stream mapping (VSM). The practicality of the expected future state VSM is presently being investigated by one of the five firms in the study context.

Research limitations/implications – The findings of the study mainly provide further insights on the various process waste in Nigerian sandcrete blocks production.

Practical implications – The study provides knowledge on how lean thinking can be adopted to identify and reduce waste in SBPP. Such knowledge may be beneficial to the present and prospective sandcrete blocks producers. The study also provides insight on how the overall cost of production of sandcrete blocks and the quantity of CO_2 that is being released into the atmosphere in the production process can be reduced. The VSM in the proposed framework also serves as a tool that can be globally adopted for waste identification by producers of other forms of blocks such as bricks.

Construction Innovation
Vol. 19 No. 3, 2019
pp. 405-423

1471-4175
DOI 10.1108/CI-11-2017-0091

Originality/value – This paper satisfies all the tenets of originality as it has not been previously published and all the information obtained from other studies have been duly referenced. The study is also original as it is first in the study context to propose for a lean framework that can be used to reduce waste in SBPP.

Keywords Framework, Waste, Industry, Building, Firms, Blocks

Paper type Research paper

1. Introduction

A sandcrete block is a composite material that is made of cement, sand and water and molded into different sizes (Yahia, 2004; Abdullahi, 2005; Banuso and Ejeh, 2008). It is widely used as a walling unit in Nigeria and other developing countries such as Ghana and Togo (Yahia, 2004; Joel and Utyankpan, 2005). This implies that sandcrete blocks are value-adding materials that satisfy clients' needs in construction projects (Feijo, 2001). Despite its importance, its production process is characterized by several non-value adding activities (NVAAs). Such activities include low productivity, defects, poor coordination, bad reputation, high accident rates, insufficient quality and overruns in cost and schedule (Yahia, 2004). Theoretically and from customers' perspective, any activity in the manufacturing/construction process that adds no value to the service or delivery of goods for the organization is waste (Osmani, 2011; Koskela *et al.*, 2013; Ko and Chung, 2014).

This implies that waste is any activity that produces direct or indirect costs and takes time, resources or requires storage, but does not add value or progress to a particular product (Womack and Jones, 2003; Zoya-Kpamma and Adjei-Kumi, 2011; Al-Aomar, 2012; Koskela *et al.*, 2013). Shingo (1985), Ohno (1988), Womack and Jones (2003), Simms (2007) categorized waste in the construction and manufacturing processes into the following seven forms: overproduction, transportation, inventory, defects or corrections, over-processing, waiting time and motion.

Globally, the construction and manufacturing industries are susceptible to the abovementioned waste in practice (Horman and Kenley, 2005; Oyedele and Tham, 2007; Osmani, 2011; Al-Aomar, 2012). Some of the negative impacts of such waste are poor quality of production/projects delivery, rework, erratic decision making by project actors, lack of constructability, unbalanced resource allocation, poor or inadequate communication among the construction specialists, excessive request for information, unnecessary delay, mistakes, dispute, cost overrun and slow progress of projects. (AbdelSalam *et al.*, 2010; Zoya-Kpamma and Adjei-kumi, 2011).

Several advanced technologies such as computer-aided design have been applied to projects to weed out such waste in the process. However, the performance and efficiency of the construction and manufacturing industries have remained low (Sacks and Goldin, 2007; Oyedele and Tham, 2007; Osmani, 2011). To provide the client with the lowest possible cost and high-quality project, actors have to devise both the new technology and contemporary management concepts to reduce the activities that do not add value to projects (Green, 1999; Chase *et al.*, 2006). One of these strategies is the adoption of lean concepts (Green, 1999; Forbes and Ahmed, 2011).

The idea of lean concepts originated from the production processes (lean production) and can be viewed as a systemic method for the elimination of waste (Muda) within a manufacturing process (Womack and Jones, 2003). Lean production adopts five principles to reduce waste in a process (Womack and Jones, 2003):

(1) precisely specifying value regarding a particular product;

(2) identifying the value stream for each product;

(3) making value flow without interruptions;
(4) let the customers pull value from the producers; and
(5) pursuing perfection.

In 1992, Koskela extended the lean production concept to construction. Thereafter, several lean tools, including value stream mapping (VSM), have been deployed by researchers to clearly identify the activities that add no value to projects (Rother and Shook, 2009; Ko and Chung, 2014).

VSM has been described as a paper-and-pen tool that enables diagrams of a complete process to be drawn with a set of standardized icons. It is a special type of flowchart that uses symbols known as "the language of Lean" to depict and improve the flow of inventory and information (Mossman, 2009). Furthermore, VSM describes in detail how the organization's activities and facilities should flow or operate so as to create opportunities or space for future improvements (Tapping and Shuker, 2003; Rother and Shook, 2009).

Based on the opinions of the abovementioned authors on VSM, researchers have investigated how the tool can be adopted for waste identification and reduction in different projects. However, the aspect of manufacturing such as building blocks, where projects cost can further be effectively reduced, has not been extensively covered. Based on this gap in the literature, this research was conducted in 2017 to investigate how VSM can be adopted for waste identification in sandcrete blocks production process (SBPP).

2. Literature review

2.1 The standard of Nigerian sandcrete blocks

Sandcrete blocks are made in different sizes and shape, but the most common type is rectangular, which may be hollow or solid (Banuso and Ejeh, 2008). The literature reveals that the standard or suitability of sandcrete blocks is often assessed with strength and water durability indices (BS 2028: 1970; Joel and Utyankpan, 2005; Abdullahi, 2005; Sadiku and Aguwa, 2013). The strength is often determined by the compressive strength test, while the durability is assessed through water absorption and porosity tests (Joel and Utyankpan, 2005). This implies that strength, water absorption/porosity are the essential factors that determine the quality/standard of sandcrete blocks.

The literature shows that the Nigerian Industrial Standard (NIS) is a regulatory authority that is responsible for the quality control of sandcrete blocks production. The organization specifies a compressive strength value that ranges from 2.5 to 3.45 N/mm^2 for a load-bearing wall (with a depth of 225–450 mm in length) and from 1.8 to 2.5 N/mm^2 for partitioning or non-load bearing walls (having a depth of 150–225 mm length). Moreover, BS 2028 (1970) specifies the maximum water absorption value of 7 per cent for sandcrete blocks. Based on this specification, Joel and Utyankpan (2005) reveal that sandcrete blocks porosity (υ) can be obtained using the following expression:

$$U = fv/V \times 100\%$$

where U is the porosity of the material (sandcrete block); fv is the volume of the water absorbed (m^3) and V is the volume of the material sample (m^3). Hence, the above expression and compressive strength values specified by NIS were used in this study to ascertain the standard of some blocks that were observed as waste during the physical observation (PO) and interviews exercise in the case study firms.

2.2 Causes of waste in construction and manufacturing processes

The causes of waste in construction and manufacturing processes have been the subject of several studies (Mossman, 2009; Nagapan *et al.*, 2012; Koskela *et al.*, 2013). For instance, Koskela (2004) identifies making-do as a factor that is responsible for most of the NVAAs in the construction process. The author refers making-do as a waste that arises when a contractor starts a task before all the preconditions are ready. This denotes that making-do is the waste that is responsible for most of the NVAAs or lead time (LT) experienced in projects. Similar to making-do, Ohno (1988) identified overproduction as the primary source of waste in the manufacturing process.

2.3 Application of value stream mapping in construction and manufacturing processes

The literature indicates that the concept of VSM enables construction and manufacturing actors to easily identify and analyze any weakness or waste and its source(s) in a process by doing the following:

- setting the scope of the process;
- identifying the current state of the chosen process;
- clearly showing the activities that add no value to the process;
- drawing a future as well as the desired state; and
- making a work plan to ensure the elimination of the NVAAs so as to create a flow that can brings improvement in the process.

3. Research methods

This study aims to identify the various waste that is significant to the production process of sandcrete blocks in Nigerian firms. The research also intends to establish how the identified waste in the process can be reduced or eliminated. To achieve this aim, a qualitative research method was adopted. The qualitative method was adopted as it allows a deeper understanding of holistic interactions among the participants in the case study firms (Saunders *et al.*, 2009). The method was also adopted as it allows for the adoption of certain techniques, such as individual or focus interviews, and physical observation for data collection (Gray, 2014). The qualitative study was conducted with staff of SBP in five firms in Minna Niger State in 2017. The selection of the firms was based on purposive sampling techniques (Ritchie *et al.*, 2003). This implies that only the firms that have been established for not less than 10 years and had profound knowledge in the production of six and nine inches blocks were selected for the study. At the start of the qualitative study, invitations were initially sent to managers of 18 suitable sandcrete blocks firms discovered in the study environment. However, responses were obtained from only five, which represents a response rate of 27.78 per cent of the total 18.

Physical observation (PO), the VSM tool and interviews served as the instruments for data collection in the qualitative study. The PO was first conducted so as to understand the phases and activities in SBP. It was conducted over a period of a month (six hours per day). During the PO exercise, the researchers clearly observed the activities in each phase of the production of sandcrete blocks and compared each activity with the various waste that has been observed in the literature. In addition, the researchers ensures that questions, such as "why are you doing this," or "what use is this activity in the production process," "does it mean it cannot be done this way" and "what if this is not done what will happen," were also asked from some of the staff of the case study firms during the PO exercise. After the PO study, a funnel shape VSM (FS-VSM) was deployed on the activities in SBP so as to clearly identify where waste is present in the process. This implies that the VSM was adopted to bring out the diagram (summary) of all the values and NVAAs in SBPP. Hence, the tool enabled the researchers and the participants in the case study firms to observe the activities that constitute lead time (LT) in the production process. This denotes that the VSM tool was used to analyze and design the flow of information in SBPP in the case study factories. After the depiction of the FS-VSM, interviews were conducted with each firm.

Explicitly, for the interview study in each firm, the manager, assistant manager and four laborers were selected. With the exception of the managers that were higher national diploma holders in all the firms, the academic qualifications of other participants (laborers) were national diploma and secondary school certificate. These levels of educations indicate that all the study participants had the required knowledge to provide answers to the interview questions. At the start of each interview, the researchers sought the permission of the participants to audio record the interview (Saunders *et al.*, 2009). Thereafter, the participants were reminded of the research aim and objectives and asked to answer the questions based on their experience in the previous work. Participants were interviewed using an interview guide with a total of four main structured open-ended questions. The questions that were asked during the interviews were intended to produce in-depth understanding on waste in SBPP such as the causes of the waste, the impacts of the waste on production performance and the strategies that can be adopted to reduce the waste. To keep the interviews opened, questions were asked using phrases such as "can you describe with examples," "please explain further." In total, 30 participants took part in the interview exercise because, at each firm, six staff constituted a group for the interviews.

For consistency, the interviews were conducted three times in each firm (Stringer, 2014). Each interview in all the firms was between 60 and 80 min in duration. All the interviews discussions in each firm were accordingly transcribed (Saunders *et al.*, 2009). After transcription, the resultant information was analyzed using the content analysis method (Krippendorff, 2012). The themes that were extracted within and across each interview were then validated through a follow-up interview, which was conducted by the researchers with the manager and the assistant manager of each firm during the study. The qualitative study enabled the researchers to identify 13 waste in SBPP, seven likely causes of the waste and six impacts of the waste on production or factory performance. As there was no reasonable suggestion on the strategies that can be adopted to overcome the identified waste in SBPP, the researchers suggested a lean framework for all the case study firms. The samples of blocks observed to be of a low standard from the case study firms were also taken to the laboratory for compressive and porosity tests. These were done to corroborate the information obtained from the PO and interviews exercise regarding the low standard of some blocks in all the case study firms. The findings of the qualitative study formed the basis for the development of the questionnaire that was adopted in the survey section.

The survey study was conducted to investigate the applicability of the identified waste in other sandcrete blocks producing factories in the study context (Yin, 2014). It was also conducted so as to complement for the weaknesses of the qualitative study and allow for further analysis (Hesse-Biber and Leavy, 2011). In the survey exercise, questionnaires were distributed to managers, assistant managers and laborers of sandcrete blocks factories. To be precise, six sandcrete blocks firms in different locations, i.e. FCT, Kaduna, Suleja, Zuba, Kwankwalada and Kothangora, were identified for the survey study. The selection of the firms was based on their proximity to the study area. With the exclusion of the manager and assistant manager, the number of laborers in each firm ranges from 25 to 27. Therefore, the researchers administered the questionnaires to the manager, assistant manager and 23 randomly selected laborers at each firm. This indicates that 25 participants took part in the survey exercise in each firm. Out of the 150 questionnaires distributed, only 121 were returned, which represents a response rate of 80.67 per cent. This response rate is considered very adequate for a survey study that intends to obtain information from industry practitioners (Lucko and Rojas, 2010).

In the questionnaires distributed in each factory, the participants were asked to rate the 13 discovered waste in SBPP based on a five-point Likert scale to measure the extent of their agreement for each waste. The significant causes of the waste and their impacts were also rated by the participant through the five-point Likert scale. Likert scale scrutiny has frequently been utilized in the field of social sciences and management to get the view of the respondent to each of the statements relatives to numerous degrees. It ranges from 3 to 7 degrees of agreement/disagreement depending on the opinions of the respondents. In this study, the five-point Likert scale was adopted for the analysis of the data obtained in the survey exercise (Diker *et al.*, 2011; Elizer, 2011). In the five-point Likert scale, 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree and 5 = strongly agree (Doloi *et al.*, 2012; Gravetter and Wallnau, 2008). The reliability and analysis of the outcomes of the five-point Likert scale in the survey exercise were determined through Cronbach's α test along with quantitative descriptive statistics analysis (Gliem and Gliem, 2003). Hence, variables with mean item score (MIS) 3.0 and above were considered to be more significant, while those with less than 3.0 were rated as less important (Sakaram and Bougie, 2010).

4. Findings and discussions

4.1 Phases in the production of sandcrete blocks

Based on the PO conducted by researchers in all the selected firms in this study, it is palpable that SBP encompasses the following eight distinct phases:

(1) The materials off-loading phase where the required sand and cement that are required for the production of the blocks are procured and transported to the site.

(2) The materials design phase where the strength and the quantity of the materials that are required for the production of a number of blocks are computed by the site engineer/manager.

(3) The materials mixing phase where the required sand, cement and water are adequately mixed in a calculated proportion.

(4) The materials filling phase where the mixture of the aforementioned materials are filled into the molding machine.

(5) The materials compacting phase where the materials are compacted in the machine for adequate/required strength.

(6) The transportation phase where the newly produced block is transported to an environment for adequate drying.

(7) The uplifting phase where the blocks are raised or positioned for appropriate curing/drying.

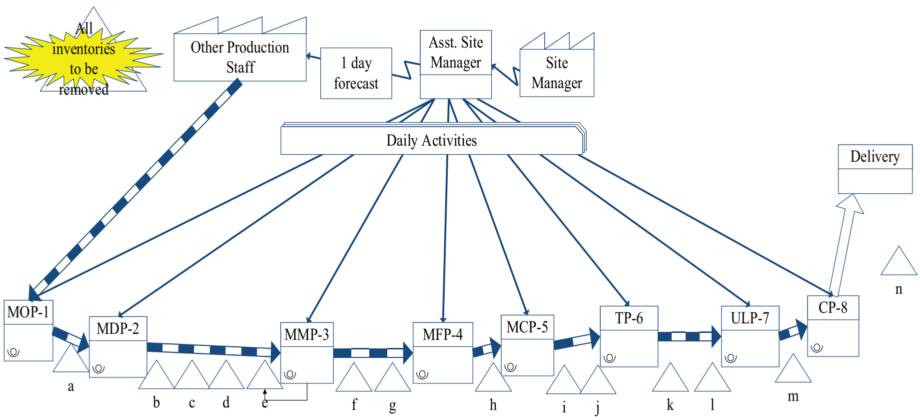
(8) The curing phase where the products are adequately cured with water for certain days before it can be supplied to the customers.

4.2 The various activities in each phase of the production of sandcrete blocks

As stated earlier in the methodological section of this study, the second phase of the study is the depiction of a FS-VSM tool for the identified activities in each phase of hollow sandcrete block production. It is essential to know that before the adoption of the FS-VSM, the flow of activities in all the phases of the production of hollow sandcrete blocks (HSB) appeared flawless to the managers in all the firms covered. However, after the espousal of the FS-VSM, the managers in all the firms realized that several NVAA (waste) occur in each phase. These waste are clearly marked out with a VSM icon known as kaizen burst in each phase, as shown in Figure 1. For adequate understanding, Figure 2 provides the predefined VSM icons that are used in the figure. While details of the waste in each phase are represented in Table I, the discovered waste in each phase of SBP is peculiar to the production of both six- and nine-inch sandcrete blocks.

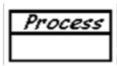
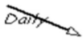
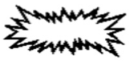
4.3 The categories of waste in sandcrete block production process and their impacts on the firm
Alarcon (1997) and Koskela (1992) emphasize that waste in the production environment can be grouped into two categories: waste in manufacturing and waste in construction. Typical examples of waste in manufacturing are waste because of defective products, wait periods, overproduction, over-processing and motion. Some of the examples of waste in construction are rework, error, clarification, excessive vigilance and incomplete work. In this study, it was discovered that the various forms of waste in SBP are excessive stocking of sand and cements, long or excessive distance from the store to the mixing or production location, excessive quantity or over design of materials, poor materials design, delay in designing and redesigning of materials, delay in every new mix, unnecessary waiting while filling the molding machine with the mixed materials, over vibration or compaction of newly produced blocks, poor vibration or compaction of blocks, breakages in the process of conveying the newly produced block from the molding machine to the curing position, long or excessive distance covered from the molding machine to the drying position, breakages while raising (positioning) the newly produced blocks for curing and breakages while curing the newly produced blocks. These waste and their impacts on the factory performance are listed in Table II.

4.4 Porosity and compressive strength of the low standard sandcrete blocks in the studied firms
The results of the compressive strength and porosity tests of certain HSB observed in all the case study firms to be of a low standard are abridged in Tables III and IV.



Note: Details of letter a to n are presented in Table I

Figure 1. The current state value stream mapping in sandcrete block production process

Symbols	Description
	Customer/Supplier Icon (C/SI): represents the Supplier when in the upper left, customer when in the upper right, the usual endpoint for material
	Dedicated Process Flow Icon (DPFI): a process, operation, machine or department, through which material flows. It represents one department with a continuous, internal fixed flow
	Inventory Icons (II): show inventory between two processes
	Push Arrow Icon (PAI): represents the 'pushing' of material from one process to the next process
	Production Control Icon (PCI): This box represents a central production scheduling or control department, person or operation
	Manual Info Icon (MII): A straight, thin arrow shows the general flow of information from memos, reports, or conversation. Frequency and other notes may be relevant
	Electronic Info Icon (EII): This wiggle arrow represents electronic flow such as electronic data interchange (EDI), the Internet, Intranets, LANs (local area network), WANs (wide area network).
	Kaizen Burst Icon (KBI): used to highlight improvement needs and plan kaizen workshops for specific processes that are critical to achieving the Future State Map of the value stream

Source: Adapted from Rother and Shook (2009)

Figure 2.
The predefined icons for the value stream mapping process

4.5 The strategy that can be adopted to eliminate the identified waste in sandcrete blocks production process

Although the producers of sandcrete blocks in the study context were aware of some of the waste in the process, the PO and interviews conducted in this study show that there was no practical measure that has been or intends to be put in place by the management of the case studied firms to overcome or reduce the waste experienced in the system. However, the literature shows that lean principles/techniques can be applied to projects so as to weed out waste in the process (Womack and Jones, 2003; Ko and Chung, 2014). Based on the categories of waste discovered in this study, just in time (JIT), the total quality control (TQC), quality assurance (QA), Kanban and the five lean principles (5LPs) proposed by Koskela (1992), Liker and Morgan (2006) for waste reduction in projects were suggested to overcome the identified NVAAs in SBPP.

QA and TQC were first adopted for waste reduction in material and component manufacturing, and later in the design and the construction phases of projects. JIT concept has also found a great application by component manufacturers, specifically for window fabrication and prefabricated housing (Koskela, 1992). Furthermore, Kanban is a lean tool and an information system used to control the number of parts to be produced in every process. The most common types are withdrawal Kanban that specifies the quantity that the succeeding process should pull from the preceding process, and production Kanban, which indicates the quantity to be produced by the preceding process (Liker and Morgan, 2006).

Phases in the production of sandcrete blocks	The various NVAAs in each phase and their causes
MOP	Excessive stocking of sand and cement because of sudden or unexpected needs of the materials (a)
MDP	Long or excessive distance covered from the store to the mixing or production location because of poor factory design (b), excessive quantity or over design of materials because pf poor supervision (c), poor materials design because of poor supervision or non-compliance with the standard (d), delay in designing and redesigning of materials because of unnecessary conversation or arguments among the workers during the activity (e),
MMP	Delay in every new mix because of the need to clear the site of debris (f)
MFP	Unnecessary waiting while filling the molding machine with the mixed materials because of the sudden breakdown and repair of the machine while production is already in progress (g)
MCP	Over vibration or compaction of newly produced blocks because of poor supervision (h), low standard of some blocks because of the lack of compliance with the standard specifications (i)
TP	Breakages in the process of conveying the newly produced block from the molding machine to the curing position due to low standard of the blocks (j), long or excessive distance covered from the molding machine to the drying position due to poor factory design (k)
ULP	Breakages while raising or positioning the newly produced blocks for curing because of the low standard of the blocks (l)
CP	Breakages while curing the newly produced blocks because of the low standard of the blocks (m)

Table I. Non-value adding activities in the production of sandcrete blocks and their plausible causes

Subject to these views/suggestions, the practicality of the expected future state VSM in SBPP wherein all the identified waste will be adequately trimmed is presently being examined by one of the case study firms. For instance, the concept of Kanban, JIT production and the apply pull principle are presently being used to investigate how waste because of inventory can be overcome in the firm. The manager of the firm has been advised by the researchers to procure the required quantities of materials (cement and sand) only when they are required. This will save the firm from the cost of construction of a store or warehouse for the upkeep of materials such as cement that may not be immediately needed. The idea will also increase land mass and reduce waste because of the long or excessive distance covered from the store to the mixing or production location.

Furthermore, the idea of QA and TQC are presently being adopted by the firm to overcome waste because of the low standard of blocks, over or excessive quantity of materials, inadequate/ poor materials design or non-compliance with standards. Based on all these suggestions and the opinions of Womack and Jones (2003) and Melton (2005) on lean production concepts/principles, a lean framework for waste reduction in SBPP is hereby presented (Figure 3).

In the framework, the first aspect is to identify the various activities in SBPP. This can be achieved through PO and interviews. The next phase is to create a process flows in each phase so as to clearly identify the various waste in the system. This can be achieved through the adoption of a lean tool known as VSM. The third phase is to develop certain strategies that can be adopted to eliminate some of the identified waste in each phase to enable value to flow in the system. This can be achieved through the adoption of lean tools such as TQC/ QA, JIT, Kanban and the 5LPs. The fourth stage is the evaluation process where the factory verifies to observe any form of improvement or qualitative problem because of the newly implemented strategies. With any positive improvement, phases three, four and five are to be repeated until no further improvement is realized in the flow.

Table II.
The categories of waste in sandcrete blocks production process and their impacts on the factory's performance

Category of waste	Waste types	Impacts on the industry
Transportation	Long or excessive distance covered from the store to the mixing or production location, and long or excessive distance covered from the molding machine to the drying position	Delay in the completion of work as scheduled
Waiting time	Delay in every new mix, delay in designing/redesigning of materials, and unnecessary waiting while filling the molding machine with the mixed materials	Delay in the start and completion of work, disruption in the schedule of work, extending the production completion time and increasing the overall cost of production. These are consistent with the results of Horman and Kenley (2005), Sunjka and Jacob (2013) for the impact of waste on project costs
Overproduction	Over design or excessive quantity of materials and over vibration or compaction of newly produced blocks	It leads to the wastage of production materials. This is similar to the opinion of Ohno (1988), Formoso *et al.* (2002) regarding the impacts of overproduction waste on projects. Also, it concurs with the findings of Nazech *et al.* (2008) concerning waste when resources are procured more than the required quantity in a project
Inventory	Excessive stocking of sand and cement	It leads to a significant reduction in an organization workspace. It also constitutes unnecessary stock of capital. This is synonymous with the opinions of Ohno (1988) on the effect of inventory in an organization
Rework	Breakages in the process of conveying the newly produced block from the molding machine to the curing position, breaking of blocks while positioning it for curing and breaking of blocks during curing	These are the main causes of the reversion of blocks which is responsible for delays in the completion of tasks. They can also lead to poor quality product, additional materials procurement, with a consequent increase in the overall cost of production. This is similar with the findings of Osmani (2011) regarding the impacts of rework in projects
Defect	Poor materials design and low standard of some blocks	It makes workers perform an activity more than once, which leads to delay in the completion of daily tasks. This is tantamount to the findings of Li *et al.* (2008), AbdelSalam *et al.* (2010), and Gatlin (2013) concerning the impacts of defects in projects

4.6 The quantitative section

The essence of this phase is to complement the qualitative phase for some of its weaknesses and for further analysis of data. The summary of the questionnaires distributed and returned is listed in Table V.

4.6.1 Analysis and discussions on waste in sandcrete blocks production process. Table VI indicates the opinions of the respondents on the possible forms of NVAAs in SBPP.

The high Cronbach's α value (0.93) shows the reliability and acceptability of the data (Akintoye, 2000; George and Mallery, 2003; Agresti and Franklin, 2007). The standard deviations (SD) are also within the acceptable range, which implies that there were low variations in the responses among the respondents. Hence, the results obtained can be used for further analysis (Landau and Everitt, 2004).

From Table VI, it can be deduced that poor materials design, excessive quantity or over design of materials, long or excessive distance covered from the molding machine to the drying position, over vibration or compaction of the newly produced block, low standards of some blocks, breakages while raising (positioning) the newly produced blocks for curing, long or excessive distance from the store to the mixing or production location, delay in designing and redesigning of materials, excessive stocking of sand and cements and unnecessary delay in every new mix and breakages while curing the newly produced blocks were ranked higher by the respondents and classified as NVAAs that are frequently experienced in SBPP (Sakaram and Bougie, 2010). It can also be inferred in the results presented in Table VI that waste with MIS above the midpoint of 3.00 occurs not only in Nigerian SBPP but possibly in the global blocks factory (Emuze *et al.*, 2014).

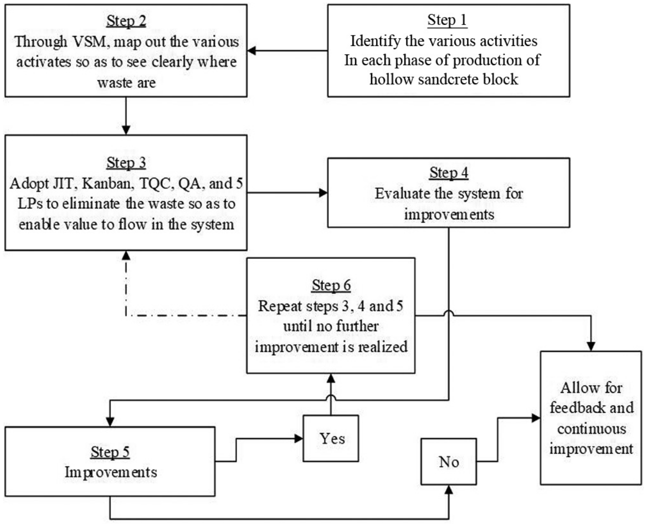
NVAAs, such as breakages in the process of conveying the newly produced blocks from the molding machine to the curing location and unnecessary waiting while filling the molding machine with the mixed materials, were ranked lower by the respondents and may not occur or are not frequently experienced in SBPP. However, the one sample t-Test that

Industries	No. of blocks	Average porosity (water absorption in %)	Remarks	Average compressive strength (N/mm^2)	Remarks
A	3	8.7	More than the standard	2.1	Lower than the standard
B	3	9.2	More than the maximum standard	2.1	Lower than the standard
C	3	8.8	More than the maximum standard	2.2	Lower than the standard
D	3	9.4	More than the maximum standard	2.1	Lower than the standard
E	3	9.6	More than the maximum standard	2.2	Lower than the standard

Table III. Porosity and compressive strength tests of samples of sandcrete blocks in the study firms (load bearing)

Industries	No. of blocks	Average porosity (water absorption in %)	Remarks	Average compressive strength (N/mm^2)	Remarks
A	3	9.7	More than the maximum standard	1.4	Lower than the standard
B	3	9.2	More than the maximum standard	1.4	Lower than the standard
C	3	8.8	More than the maximum standard	1.5	Lower than the standard
D	3	8.6	More than the maximum standard	1.2	Lower than the standard
E	3	9.6	More than the maximum standard	1.3	Lower than the standard

Table IV. Porosity and compressive strength tests of samples of sandcrete blocks in the study firms (non-load bearing)



Source: Adapted from Womack and Jones (2003) and Melton (2005)

Figure 3. A lean framework for waste reduction in the production of sandcrete blocks

Table V. Number of questionnaires administered and returned in the survey study

Location of the firms	Questionnaires administered	Questionnaires returned
FCT	25	22
Kaduna	25	22
Suleja	25	21
Zuba	25	18
Kwankwalada	25	23
Kothangora	25	15
Total	150	121

was later conducted shows that breakages in the process of conveying the newly produced blocks from the molding machine to the curing location with MIS 2.71 is also a significant NVAA in SBPP. For this test, the variable was observed to have a mean difference of 2.6612 at 0.000 significant level ($p < 0.05$), which is satisfactory (Kanji, 2005).

4.6.2 Analysis and discussions on the significant causes of waste in sandcrete blocks production process. Table VII shows the ranking of the respondents' opinions concerning the significant factors influencing NVAAs in SBPP. According to (George and Mallery, 2003), the high Cronbach's α value obtained (0.871 = good) also shows the reliability and acceptability of the data. The standard deviation obtained are also within the acceptable range.

In the table, causes of waste such as poor supervision, noncompliance with the standard specifications, poor factory design, sudden breakdown and repair of machine while production is already in progress, clearing of site from the broken pieces of blocks and site debris, and low standard of blocks, were ranked higher by the respondents and can be classified as the significant causes of waste in SBPP. This implies that such variables are

Table VI. Waste in the production process of sandcrete blocks

The following are the frequent waste experienced in sandcrete blocks production process	Mean item score	SD	Cronbach' α	Ranking
Poor materials design	4.38	0.84	0.93	1st
Excessive quantity or over design of materials	4.25	0.83		2nd
Long or excessive distance covered from the molding machine to the drying position	4.27	0.77		3rd
Over vibration or compaction of the newly produced block	4.22	0.81		4th
Low standard of some blocks	4.17	0.89		5th
Breakages while raising or positioning the newly produced blocks for curing	4.15	0.91		6th
Long or excessive distance covered from the store to the mixing or production location	4.14	0.87		7th
Delay in designing and redesigning of materials	4.11	0.72		8th
Excessive stocking of sand and cement	4.07	0.73		9th
Delay in every new mix	3.60	0.85		10th
Breakages while curing the newly produced blocks	3.36	0.91		11th
Breakages in the process of conveying the newly produced blocks from the molding machine to the curing location	2.71	1.02		12th
Unnecessary waiting while filling the molding machine with the mixed materials	2.31	1.04		13th

Table VII. Factors responsible for waste in sandcrete blocks production process

The following are the causes of non-value adding activities in the production process of sandcrete blocks	Mean item score	SD	Cronbach' α	Ranking
Sudden or unexpected needs of materials such as sand and cement	1.98	1.21	0.871	7th
Poor factory design	4.11	0.86		3rd
Poor supervision	4.21	0.89		1st
Noncompliance with the standard specifications	4.17	0.85		2nd
Unnecessary conversation or argument among the workers during materials design	1.76	1.25		8th
Sudden breakdown and repair of the machine while production is in progress	3.94	0.79		4th
Clearing of the site from all forms of debris before every new mix	3.91	1.23		5th
Low standard blocks	3.71	1.27		6th

the responsible factors that contribute extensively to the poor performance of the factory (Al-Aomar, 2012). Other causes, such as sudden or unexpected needs of materials such as sand and cement and unnecessary conversation or argument among the workers during materials design, were ranked very low by the respondents. Hence, managers of the SBP firms may be less perturbed over such factors. In other words, such waste causes may be neglected by the managers of the factories while immediate actions may be needed to overcome the identified significant causes to improve the performance of the factory and the construction industry at large (Emuze *et al.*, 2014).

4.6.3 Analysis and discussions on the impacts of waste in sandcrete blocks production process on the factory performance. Table VIII indicates the respondents' perceptions of the extent to which the discovered waste in SBPP affects factory performance in the study context. All the six parameters identified in the qualitative phase of the study were used to measure the performance level in the quantitative section. The high Cronbach's α value (0.899) indicates the reliability and acceptability of the data. The SD obtained are also within the acceptable range.

Based on the outcomes of the results presented in Table VIII, it can be emphasized that the significant effects of waste in SPBB on the factory performance are an extension of production completion time, increase of the overall cost of production and poor quality of products and materials waste. These variables were ranked higher by the respondents. While variables, such as disruptions in the scheduled of daily activities and unnecessary stock of capital, were ranked lower by the respondents. This implies that such parameters are not perceived by the respondents as significant effects of the identified waste in SBPP on the factory performance.

It is worth noting that the researchers also conducted a correlation test so as to further understand the strength of relationships between the parameters (Nagapan *et al.*, 2012). Literature shows that either the Spearman's rank correlation (SRC) or Kendall's correlation coefficient of concordance (W) can be adopted to determine the degree or strength of agreement of two or more ordinal variables. However, SRC is preferable if there are no tied (similar) ranks among the variables. SRC ranges from $0 \leq 1$, where 0 implies that there is no tendency of an agreement, while 1 indicates complete agreement between two or more variables (Siegel and Castellant, 1988; Field, 2013).

From the SRC that was conducted, four parameters (extend the production completion time, increase the overall cost of production, materials wastage and poor quality of production) were identified with a correlation coefficient of >0.76 at a significant level of 0.000 ($p < 0.05$). The highest strong bond was observed between extending the production completion time and increasing the overall cost of production with an SRC of 0.91. This implies that waste in SBPP will lead to time overrun in the production process, which will consequently increase the production cost. This is similar to the findings of Al-Aomar (2012) regarding the impact of NVAAs on the completion time and cost of construction projects. The other two variables (disruption in the scheduled of daily activities and unnecessary stocks of capital) were observed with a weak correlation coefficient (<0.5).

5. Research implications, conclusions and recommendations

5.1 Research implications

The developed framework is explicit and easy to understand by all levels of producers of sandcrete blocks in the study context. It offers a guiding information on how lean thinking can be adopted to reduce waste in the SBPP. Hence, the proposed framework allows

Table VIII. The impacts of waste in sandcrete blocks production process on the firm's performance

The following are the plausible impacts of non-value adding activities in sandcrete blocks production process on the factory performance	MIS	SD	Cronbach 'α	Ranking
Extend the production completion time	4.29	0.87	0.899	1st
Disruption in the scheduled of daily activities	2.31	1.27		5th
Increase the overall cost of production	4.25	0.91		2nd
Materials waste	3.51	0.73		4th
Constitutes unnecessary stock of capital	2.13	1.69		6th
Poor quality of production	3.76	0.71		3rd

producers of sandcrete blocks to identify gaps in their implementation efforts, focus attention on areas for improvements and assess the benefits of a lean approach in their organization product. In other words, the framework provides producers of sandcrete block in Nigeria with a tool that can be used to reduce waste such as excessive stocking of sand and cement, long or excessive distance from the store to the mixing or production location and excessive quantity or over design of materials during SBPP.

Furthermore, Yuan (2013) suggests that the major indicators for measuring the cost-benefit or economic performance of waste management in the construction process are as follows:

- cost of waste collection;
- re-use and recycling of waste;
- transportation of the waste from site to landfills;
- revenue from the sale of waste; and
- transportation costs from construction sites to landfills.

Therefore, adequate reduction in NVAAs in SBPP will reduce the following costs:

- overtime payments because of delay or excessive waiting;
- procuring for additional materials such as sand and cement because of overdesigning of materials and poor materials design;
- electricity (energy) required for over vibration or compaction of the newly produced blocks; and
- re-work in the reproduction of the broken blocks.

Furthermore, the literature indicates that construction industry has long been globally criticized in term of environmental degradation, particularly for carbon dioxide (CO_2) emissions (Poon *et al.*, 2004). NVAAs, such as over vibration and compaction of the newly produced blocks, increase the degradation by releasing more of CO_2 into the atmosphere. Reduction of such waste in SBPP will minimize the quantity of CO_2 that is being released into the atmosphere and consequently reduce any environmental damage because of the greenhouse effect.

In addition, the VSM in the proposed framework may also serve as a tool that can be adopted for waste identification by producers of other forms of blocks such as bricks, particularly in other contexts outside Nigeria.

6. Conclusions

Based on this study, it can be concluded that waste exists in every phase of SBP. The waste can be identified through the application of PO and the adoption of a lean tool known as VSM. The typical examples of waste in SBPP are stocking of sand and cement; long or excessive distance from the store to the mixing or production location; excessive quantity or over design of materials; poor materials design or not compliance with the standard; delay in designing/redesigning of materials; delay while mixing materials and waiting for the vibration or compaction of the newly produced block. These discoveries are consistent with the findings of Yahia (2004), Mossman (2009), Nagapan *et al.* (2012) and Gatlin (2013) regarding waste in construction projects. In all the waste, excessive stocking of sand and cement, long or excessive distance covered from the store to the production location/excessive distance covered from the molding machine to the curing position, and waiting for compaction are the prevalent waste in the SBP process. Based on the MIS calculated, it can also be concluded that wastes in SBPP do not only occur in the study context factories but possibly in the global HSB factory too.

The significant causes of waste in SBPP are poor factory design, poor supervision, non-compliance with the specification standards, sudden breakdown and repair of the machine while production is in progress and low standard blocks. The significant impacts of waste in SBP on the factory performance are wastage of materials, poor quality of production (which consequently leads to low product demand), production time overrun, disruption in the schedule of work and increase in the overall cost of production. In all the impacts, production time overrun and increase in the overall cost of production exhibit a strong relationship. Moreover, it can be contended that waste in SBPP will increase production time, which will consequently lead to increase in the overall production cost.

6.1 Recommendations

Based on the above conclusions, this study recommends that VSM, the 5LPs, and some basic lean techniques such as Kanban, JIT, TQC and QA should be adopted by the producers of sandcrete blocks for waste reduction. The effectiveness of these techniques and principles as a waste reduction in SBP are presently being examined by one of the studied factories. For effective implementation of the tools and techniques, this study also recommends that all the staff of sandcrete blocks firms in the study context should be properly trained on the application and benefits of lean concepts. In addition, the percentage of the discovered waste in SBPP and their energy implication in the society should be investigated by prospective researchers.

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