Application of lean manufacturing tools and techniques for waste reduction in Nigerian bricks production process

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Abstract

Purpose – Non-value adding activities or wastes in the lean term have been the major challenge of the construction industry. Numerous studies have been conducted to investigate how such wastes can be reduced so as to improve the performance of the construction industry. However, the aspect of bricks production process (BPP) has not been extensively covered. Therefore, the purpose of this paper is to investigate the application of lean manufacturing concepts in BPP with a view to identifying the various wastes in the practice, the causes of these wastes and how such wastes can be reduced.
Design/methodology/approach – Mixed methods research design was adopted by the researchers where literature review was first conducted to establish the fundamental theories and practice standards of lean manufacturing process. Thereafter, a phenomenological study was carried out in a Shelter Clay and Brick Factory located in Minna, Niger State, Nigeria. The data obtained in the phenomenological study were analyzed through content analysis. These data served as the basis for the validation survey that subsequently followed the phenomenological study.
Findings – The findings in the study show that poor or inadequate supervision is the main factor responsible for wastes such as excessive drying of bricks, overheating of bricks and re-glazing of bricks in Nigerian BPP.
Research limitations/implications – The study focused on the various wastes in Nigerian BPP. It also focused on the various lean tools/techniques that can be adopted to reduce the wastes. Aspects such as the percentage of the wastes and their cost implication on the factory were not covered during the study and could be further investigated by prospective researchers.
Practical implications – The study provides knowledge on how lean thinking can be adopted to reduce wastes in BPP. Such knowledge may be beneficial to the present and prospective bricks producers. This implies that the proposed framework in the study allows producers of bricks to identify gaps in their implementation efforts, focus attention on areas that may require improvements, and access the benefits of lean approach in their factory products. The proposed framework may also be beneficial to the academics.
Originality/value – This paper first gain originality in the study context to propose for a lean framework that can be adopted to reduce wastes in BPP. Furthermore, the paper has not been previously published and all the information obtained from other sources are duly referenced.

Keywords Process, Construction, Productivity, Interview, Questionnaire survey
Paper type Research paper

1. Introduction

Blocks are materials used to make walls, pavements and other elements in masonry constructions. They may compose of clay-bearing soil (bricks), sand and lime (sandcrete blocks) or concrete materials. Presently, lack of guidelines to determine qualified producers of blocks in Nigeria has made several manufacturing factories to spring up in the country

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(Oyekan and Kamiyo, 2011; Abdullah *et al.*, 2012). This implies that workers of most blocks producing factories in Nigeria are illiterates or semi-literates that are trained on the job rather than acquiring formal technical training, prior to being employed in the firm. Consequently, the production process of bricks in the study context is characterized by several non-value adding activities (NVAAs) known as wastes in the lean term (Yahia, 2004). These NVAAs have constituted to poor quality of production, material wastage/unbalanced resource allocation, unnecessary delay, reduction in the overall performance and efficiency of production, reduction in the speed of daily production, and increase in the overall cost of production (Hatami *et al.*, 2014; Zahraee, Golroudbary, Hashemi, Afshar and Haghighi, 2014; Zahraee, 2016). It is therefore imperative that bricks production process (BPP) is properly monitored so as to reduce the NVAAs in the production process, enhance value adding activities (VAAs) and the overall production cost.

Waste is any form of unnecessary activity such as excessive waiting and rework in the construction and manufacturing processes that can increase production costs but adds no value to the product itself (Koskela, 1992; Womack and Jones, 2003). According to Shingo (1985) and Ohno (1988), wastes in the manufacturing process can be categorized into seven forms. These include transportation, correction, overproduction, over-processing, motion, waiting time and inventory. It should be noted that the main objective of every manufacturer is to deliver products fast at a low cost without compromising the quality (Holweg, 2007). Therefore, strategies that can be adopted to mitigate the aforementioned wastes and their subsequent impacts in the manufacturing process have been the subject of several studies. Consequently, researchers worldwide have investigated how such wastes can be overcome through the application of lean concepts (Osmani, 2011; Al-Aomar, 2012; Nagapan *et al.*, 2012; Koskela *et al.*, 2013; Ko and Chung, 2014).

The purpose of lean concepts is to eliminate wastes in a manufacturing process. This infers that lean manufacturing is one of the strategies most manufacturers employ in expanding global market to sustain competitiveness (Zahraee, Golroudbary, Hashemi, Afshar and Haghighi, 2014). According to Womack and Jones (2003), lean concepts originate from the production process (lean production (LP)), and can be viewed as a systemic method for the elimination of wastes (Muda) within a manufacturing process. It is worth noting that the main goal of LP in the construction and manufacturing sectors is to generate a rationalized and high-quality system that produces finished products at the leap of customer demand with limited waste (Shah and Ward, 2003). This objective can be achieved through the adoption of diverse tools and techniques such as just-in-time (JIT), Kanban, total productive maintenance (TPM), cellular manufacturing (CM) and 5S to reduce cycle time and remove any form of devastation that could lead to wastes in the production process (Isaksson, 2006; Rother and Shook, 2009; Luna *et al.*, 2013; Zahraee, Hashemi, Abdi, Shahpanah and Rohani, 2014).

The above-mentioned lean tools, techniques and concepts have been extensively adopted in the manufacturing and construction sectors so as to improve the performance of the industry (Nagapan *et al.*, 2012; Koskela *et al.*, 2013; Zahraee, Hashemi, Abdi, Shahpanah and Rohani, 2014; Hatami *et al.*, 2014; Sangwa *et al.*, 2015; Nikakhtar *et al.*, 2015; Suleiman and Luvara, 2016; Yap *et al.*, 2017; Mpofu *et al.*, 2017; Love *et al.*, 2018; Matthews *et al.*, 2018). However, the aspect of bricks manufacturing process where production cost can further be reduced has not been extensively covered. Premised on all these explanations, this study argues that wastes in Nigerian BPP may contribute to poor quality of production, cost and time overruns which may consequently lead to poor performance of the organization. It is obvious that the persistence of these wastes in the BPP will continue to contribute to the poor performance of the firm and construction industry at large. Hence, a comprehensive study on the concepts for wastes reduction in BPP is essential.

Based on this requirement, a mixed methods research design was conducted in a bricks producing factory in Nigeria to investigate the various types of wastes in BPP, and to find out how such wastes can be reduced so as to enhance the performance of the factory and the construction industry at large. The Nigerian shelter and brick factory was selected for the study as it has earlier been stated that block factories in the context are faced with several challenges to include obsolete technology, engagement of workers that are not adequately trained (shortage of skilled labor) and inadequate managerial skills, which have led to several NVAAs in BPP in the context. Therefore, there is need to mitigate the impacts of the challenges of such NVAAs on the factory and the construction industry. Presently, there seems to be scarce literature in the implementation of lean manufacturing in Nigerian BPP. Hence, limited literature on lean application in Nigerian bricks production firms has necessitated this research. Consequently, this study aims to investigate how lean concepts can be used to identify and reduce wastes in Nigerian BPP.

2. Literature review

2.1 The lean theory/frameworks in the manufacturing process

The Toyota Production System (TPS) uses lean production principles proposed by Ohno (1988) to eliminate wastes in their production process by creating process "flow" to reveal problems, use pull system to avoid overproduction, level out workload, stop when there is a quality problem, standardize tasks for continuous improvement, use visual control (transparency), and use of reliable and tested technology (Forbes and Ahmed, 2011). Based on the opinions of Ohno (1988) on wastes elimination in the TPS, Melton (2005) developed a conceptual model for wastes reduction in projects (Figure 1).

Further, Zahraee, Golroudbary, Hashemi, Afshar and Haghighi (2014) developed a value stream mapping (VSM) framework for effective production line of a company that produces several components for vehicle assembly line. The purpose of the framework was to enable the factory determine and reduce wastes for any process that does not add value to the final product in the production line. Several other researchers have also come up with different models/frameworks for wastes reduction in the manufacturing processes (Anand and

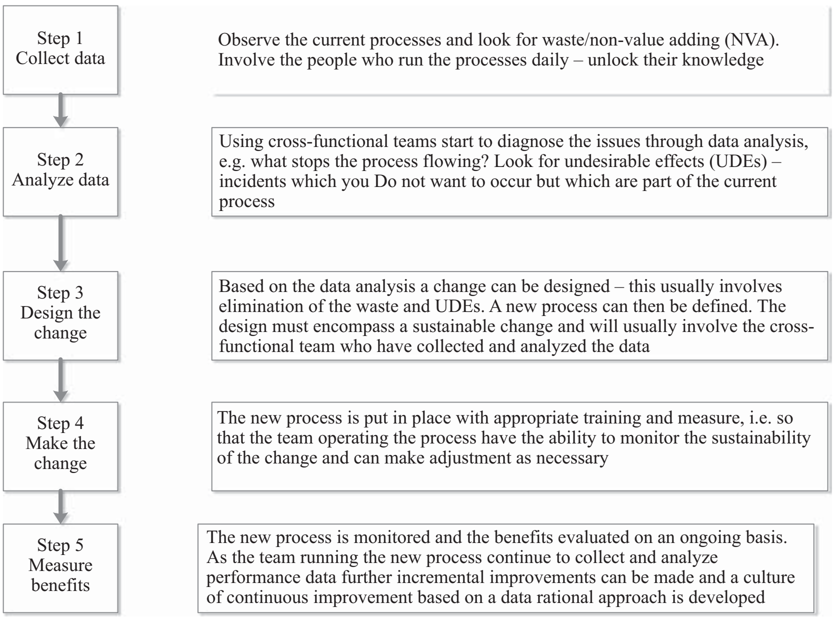


Figure 1.
A Lean conceptual model for wastes reduction in projects

Kodali, 2010; Anvari *et al.*, 2011; Buus, 2011; Cottyn *et al.*, 2011; Nordin *et al.*, 2012; Powell *et al.*, 2013; Mostafa *et al.*, 2013; Ko and Chung, 2014: Hadid and Mansouri, 2014; Wangwe *et al.*, 2014; Sangwa *et al.*, 2015). However, the findings in the reviewed literature indicate that a lean framework in the aspect of BPP has not been marginally explored. Therefore, this study intends to investigate the applicability of lean tools and techniques in the production process of bricks with a view to come up with a new framework that can be adopted to reduce wastes in the system.

2.2 Lean practices and tools in different manufacturing industries

Several lean tools and techniques have been used by many factories and industries to improve performance in the manufacturing process. A brief explanation of the few of these lean tools and techniques are given as follows:

(1) Just-in-time (JIT)

JIT means to produce or provide only what is needed or the quantity that is needed at the right time or when it is needed (Koskela, 1992). The concept has led to inventory control (space) in many organizations (Forbes and Ahmed, 2011). It can be adopted in a manufacturing factory under three conditions, namely, JIT production (JIT-P), JIT distribution (JIT-D) and JIT purchasing (JIT-P) (Koskela, 1992).

(2) Total quality management (TQM) and quality assurance (QA)

TQM and QA enable an organization to develop standard operating procedures (specifications) that the organization staff must abide by during work activities so as to achieve well-defined project outcomes (Isaksson, 2006). It should be noted that QA (a unit in International Organization for Standardization) is the office that is responsible to enforce TQM in an organization (Shah and Ward, 2003).

(3) Total productivity maintenance (TPM)

TPM is a management approach that can be adopted to reduce sudden machine breakdowns during the progress of work (Feld, 2000). This improves equipment reliability and efficiency rates by eliminating unnecessary waiting in a process (Chan, 2005).

(4) Kanban

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 the withdrawal Kanban that specify the quantity that the succeeding process should pull from the preceding process, and the production Kanban, which indicates the quantity to be produced by the preceding process (Monden, 1998).

(5) Value stream mapping (VSM)

VSM is a tool that uses symbols known as "language of lean" to depict and improve the flow of inventory or information. It is much more useful as a layout diagrams that produces a tally of non-value adding steps, lead time (LT), distance traveled and the amount of inventory in a process (Rother and Shook, 2009).

(6) Black belt team (BBT)

For effective lean implementation in any process, a team known as BBT should be formed to coordinate the transition and ensure that there are continuous improvements in a process (Melton, 2005).

(7) Cellular manufacturing (CM)

In CM, the entire process is systematized for a particular product or related products into a set or cell that includes all the needed equipment, machines and operators.

(8) 5S

5s is a device that based emphasis on efficient workplace organization and standardized work events.

The aforementioned lean tools and techniques can also be of great benefits for wastes reduction in BPP but this has to be exploratory investigated.

2.3 Specific terminologies in the manufacturing process

According to Project Management Institute (2008), Cousens *et al.* (2009), Silva (2013), Wangwe *et al.* (2014) and Sangwa *et al.* (2015), certain parameters need to be understood by the manager of any manufacturing company. This will enable the manager to reduce or eliminate NVAAs in the company manufacturing process, and subsequently re-engineered the process for effective production. These parameters include:

(1) Manufacturing cycle time (MCT)

MCT refers to the time required or spent to convert raw materials into finished goods. It is also known as throughput time. Technically, it is the length of time from the start of production to the delivery of the products. It is composed of actual processing time (APT), move time, inspection time and queue time. Therefore, in this study, bricks MCT in each phase of the production process were established through this formula: MCT = bricks APT + move time + inspection time + queue time.

(2) Wait time (WT)

WT refers to the length of time from the receipt of customer order to the start of production.

(3) Actual processing time (APT)

APT refers to the time required to actually procure or manufacture an item or product. It can also be referred to as the time used to actually work on a product.

(4) Manufacturing lead time (MLT)

MLT is the total time required to manufacture an item. It composes of several waiting times to include preparation time, queue time, setup time, run time, move time, inspection time and put-away time.

(5) Takt Time (TT)

TT is the average time between the start of production of one unit and the start of production of the next unit. It is a process that enables manufacturers to determine the minimum resource necessary to get a job done (JIT), and a way of continuously comparing what is actually happening with what should be happening in the production process, which enables the manufacturers to immediately act on any variation in the process. This confers that TT reflects the rate of production needed to match the demand (Rother and Shook, 2009). It is essential to know that the brick production firm selected for this study carries out production when the available goods are getting out of stock. Therefore, TT was determined by putting into cognizance the average time taken from one phase of production and the next one.

3. Methodology

This research aims to identify the causes of wastes in BPP, and to establish how the causes can be eliminated. To achieve this aim, mixed methods research design was adopted. The mixed methods were adopted so as to achieve robust findings (Pinto and Patanakul, 2015). In the mixed methods, literature review was first conducted to establish the fundamental theories and practice standards of lean manufacturing process, which enabled the researchers to have insight of the probable wastes in BPP. Published work reviewed at the commencement of the study include Osmani (2011), Zoya-Kpamma and Adjei-Kumi (2011), Nagapan *et al.* (2012), Emuze *et al.* (2014), Hwang and Yang (2014), Oyewobi *et al.* (2016), Suleiman and Luvara (2016), Yap *et al.* (2017), Love *et al.* (2018) and Matthews *et al.* (2018). After the reviewed literature, phenomenological study and validation survey were conducted sequentially for data triangulation toward examining the practical wastes reduction situation in bricks factories in the study context (Saunders *et al.*, 2009).

It is imperative to know that the Phenomenology approach adopted in the study allowed the researchers to use several unstructured procedures for inductive collection of data (Bryman, 2004; Saunders *et al.*, 2009). In the phenomenological study, a single case study was adopted as it assisted the researchers to seek for the in-depth opinions, subjective account and interpretations of the participants (Yin, 2014; Gray, 2014). Hence, Nigerian Shelter Clay and Brick Factory located in Minna, Niger State where the researchers reside was selected for the study. Field trips (FT), unobtrusive observation (UO), personal enquiries (PE), interviews and VSM tool were the instruments used for data collection in the case selected for the study. The FT was used to understand clearly where and how the materials needed for the production of bricks are locally sourced. The UO and PE were adopted to clearly understand the activities in BPP in the factory. The FT, UO and PE were conducted over a period of approximately three months (five hours per day). Two hours were dedicated for the FT, while the remaining three hours were dedicated for UO and PE in the case study firm. During the UO conducted, the researchers observed clearly the activities in BPP and compared each activity with what have been discovered in the reviewed literature. In addition, the researchers ensure that questions such as "why are you doing this," and of "what use is this activity in the production process," were also asked from some of the staff in the production unit of the case study factory.

After the FT, UO and PE exercise, VSM was deployed on the various activities in BPP. The essence of this was to observe clearly the activities that add no value in the process (wastes). This implies that UO and VSM adopted in the study enabled the researchers to clearly identify the various wastes in the factory BPP. After the identification of the wastes, interviews were conducted with some selected participants of the firm. The essence of the interview was to enable the researchers and the study participants agree on the likely causes of the wastes, the impacts of the wastes on production performance, and to suggest possible strategies that can be adopted to eliminate the wastes. Hence, participants were interviewed using interview guide with a total of four structured open-ended questions. Purposive sampling technique was used to select the participants of the interview (Ritchie *et al.*, 2003). Explicitly, to attain an unbiased understanding of the research aim during the interviews, head of the production unit (coordinator), assistant coordinator, 3 quality control managers (QCMs) and 15 other staff of the production unit of the case study firm were selected for the interview exercise. These participants were selected for the interview exercise as the researchers perceived that they have profound knowledge in the production of different building bricks based on their experiences over the years. With the exception of the coordinator and the assistant that were masters' holders when this study was conducted, the academic qualifications of other participants were BTech and Higher National Diploma, which the researchers considered adequate for the case study. In total, 20 participants took part in the interview exercise.

For consistency, the interviews were conducted three times in the factory. Each of the interviews was between 60 to 80 min in duration. All the interviews discussions in the firm were recorded alongside with hand written notes for appropriate transcription (McNamara, 2009). Thereafter, the resultant information was analyzed using content analysis (Bryman, 2004; 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 production coordinator, his assistant and the three QCMs in the case study firm. The phenomenological study identified 16 wastes in BPP, 9 causes of the wastes and 7 impacts of the wastes on production performance. Lean techniques, tools and concepts were suggested to reduce the identified wastes. These findings and suggestions formed the basis for the development of the questionnaire used in the validation survey section of the study. The essence of the survey exercise was to further validate the data obtained in the phenomenological section of the study, and to also increase the reliability of the data (Joslin and Müller, 2016). This implies that the validation survey conducted after the case study helps to overcome all forms of complications associated with bias and validity in a phenomenological study (Love *et al.*, 2018).

In the survey section, questionnaires were administered to staff of other bricks manufacturing companies within the study context. The questionnaires were distributed and collected back from the selected staff of each factory hand to hand by the researchers. At the start of the survey study, invitations were sent to all the production coordinators of the Nigerian bricks producing factories that their e-mail addresses were sourced on the net. Out of the 23 companies discovered which invitations were initially sent, responses were obtained from only 15 which represent a total of 65.22 percent of the 23 companies. Therefore, a pilot study was first conducted by sending the questionnaires to the coordinators of the production unit of the 15 companies through their respective e-mails. The essence of the pilot study was to test the likely response rate, the clarity and aptness of the survey questionnaire. After the pilot study, another invitation was sent to all the head of the production unit of the 15 companies so as to agree on the date of visitation for the main survey.

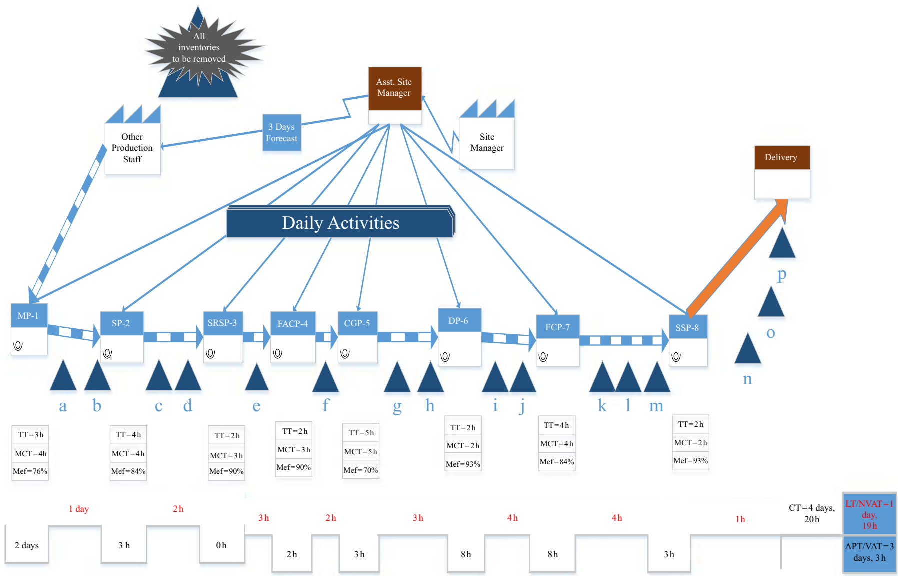
The researchers visited each of the company one after the other based on the agreed date of the study. In each factory, questionnaires were administered to some selected participants in the production unit. The participants were selected based on their availability and wiliness to participate in the study. The academic qualifications of all the respondents in the survey study ranged from secondary school certificate to masters' holders which the researchers considered adequate for the survey study. Out of the 408 questionnaires that were administered in the main survey, 372 were returned which represent a total of 91.18 percent response rate. This response rate is considered very adequate for a survey study (Lucko and Rojas, 2010).

In the survey study, the coordinators, the assistant coordinators, the QCMs and those that have been working in each firm for not less than 10 years were assumed to be highly experienced (Lee and Rojas, 2013), and were categorized as group A. While other participants with less than 10 years' experience, and were not holding any managerial position in the respective firms were purported to be less experienced and classified as group B. In the questionnaires distributed in each factory, the participants were asked to rate the 16 wastes in BPP based on a five-point Likert scale so as to measure the extent of their agreement for each waste. The nine significant causes of the wastes and their seven impacts on production performance were also rated by the participant through the five-point Likert scale. In the five-point Likert scale, 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree and 5 = strongly agree were adopted for guiding the participants to provide their objective responses to the various questions (Gravetter and Wallnau, 2008; Doloi *et al.*, 2012). The reliability and analysis of the outcomes of the five-point Likert scale in the pilot study and the main survey were determined through Cronbach's α test and quantitative descriptive statistics analysis (Gliem and Gliem, 2003). After the validation survey, the findings of the study were adopted to develop a new lean framework for wastes reduction in BPP. Thereafter, the proposed framework was evaluated by the participants of the case study firm.

4. Results and analysis

4.1 The various wastes in bricks production process

The 16 wastes identified through UO and VSM in BPP in Minna Shelter Clay and Bricks Company are clearly marked out with a VSM icon known as kaizen burst (Figure 2).



Source: Minna Shelter Clay and Bricks Company

Figure 2. The current state value stream mapping in the production process of bricks

For adequate understanding, details of the wastes in each phase of the bricks production are presented in Table I.

Table II shows the number of the questionnaires distributed and those that were returned in the validation survey conducted after the phenomenological phase of the study, while Table III presents the extent of agreement of the respondents on the various wastes discovered in BPP. The high Cronbach's α values obtained for the respondents in groups A and B (0.991 and 0.977 = excellent) in the validation survey show the reliability and acceptability of the data (Agresti and Franklin, 2007). The standard deviations (SD) obtained in the two groups are also within the acceptable range, as they indicate that there were low variations on the responses among the respondents (Sabine and Braine, 2004).

Further, Kendall's correlation Coefficient of concordance (W) was calculated in order to measure the degree of agreements of all the respondents in the two groups (Digital Bridge Institute, 2018). Literature shows that either Spearman Rank correlation (SRC) or W can be adopted to determine the degree or strength of agreement of two or more ordinal variables. However, W is preferable if there are tied ranks among the variables (DBIA, 2018). W ranges from $0 \leqslant 1$, where 0 (H_2) implies that there is no agreement among the respondents, while 1 (H_1) indicates complete agreement among the respondents of the survey study (Siegel and Castellant, 1988). In this study, W in the two groups' ranges from 0.627 to 0.747 at two-tailed significant level of 0.000 ($p < 0.05$) which is satisfactory (Siegel and Castellant, 1988). This implies that there was a significant correlation or general agreement on the ranking of the respondents across the cases irrespective of the respondents' portfolio or years of experience.

In Table III, it is clear that wastes with mean item score (MIS) ranges from 4.5937 to 3.1796 were rated high by the respondents and can be classified as the significant or generally experienced wastes in BPP (Sakaram and Bougie, 2010). It is essential to know that MIS is an alternative procedure for calculating a composite score for each individual or variable in an observation (DBIA, 2018). Further, it can be contended that wastes with MIS above the midpoint of 3.00 occur not only in Nigerian BPP but possibly in the global bricks

Phases in the production of Nigerian building bricks	Various waste	Causes
The mining phase (MP)	Several sample tests before mining (a)	The need to be sure of the properties of the materials used for production
	Excessive waiting before transporting the excavated or mined materials (clay or shale admixtures) from the mining site to the factory (b)	Several sample tests
The storing phase (SP)	Stocking of the mined materials regardless of when they will be needed for production (c)	Sudden needs specifically in poor weather conditions
	Long distance covered from the store where the production materials are temporarily kept to the production machine (d)	Poor factory design
The size reduction/ screening phase (SRSP)	Waiting for the repair of production machine while the work is in progress (e)	Poor maintenance culture
The forming and cutting phase (FACP)	Delay during forming and cutting activities (f)	Unnecessary conversation or arguments among the workers
The coating or glazing phase (CGP)	Over glazing of some bricks (g)	Poor or inadequate supervisions
	Re-glazing of bricks that are not uniform in color (h)	Poor or inadequate supervisions
The drying phase (DP)	Excessive drying of some bricks (i)	Poor or inadequate supervision
	Long distance covered from the production machine to the drying equipment (j)	Poor factory design
The firing and cooling phase (FCP)	Excessive energy consumption (k)	Poor or inadequate supervisions
	Overheating or firing of the bricks (l)	Poor or inadequate supervisions
	Breaking and deformation in shape/size of some bricks in uncontrolled heat in the production kiln (m)	Poor or inadequate supervisions
Storage and shipping (SSP)	Long distance covered from the production machine to the storing location (n)	Poor factory design
	Breaking of some bricks during transportation from the production machine to the storing location (o)	Workers fatigue
	Stocking of the newly produced bricks before delivery to customers (p)	Lack of immediate patronages

Table I. Waste in the production process of bricks

Phases of the study	No. distributed	No. returned
Pilot study	23	15
Main survey (Group A)	99	87
Main survey (Group B)	309	285
Total	431	387

Table II. Details of the questionnaires distributed and returned in the survey exercise

factory (Emuze *et al.*, 2014). Further, wastes with MIS of 2.0090 and 1.7441 were rated very low by the respondents and may be experienced in few bricks producing factories in the study context. In the table, it can also be observed that the perceptions of the respondents in all the factories covered were similar with no significant deviation across cases. The reason for this similarity may be that related procedures are being adopted in all the factories during bricks production, which makes the factories to experience related wastes. Another possible explanation for likely responses in all the factories is that most of the wastes such as stocking of the newly produced bricks and re-glazing of bricks are seen as norms over the years in the production process due to the absence of lean practitioners in the various factories (Ohno, 1988; Simms, 2007).

Table III.
The various wastes in bricks production process

Forms of wastes in bricks production process	Group A MIS	Group A SD	Group A Ranks	Group B MIS	Group B SD	Group B Ranks	Aggregate MIS	Aggregate SD	Overall ranks
Stocking of the mined materials regardless of when they will be needed for production	4.6961	0.83000	1st	4.4912	0.64793	1st	4.5937	0.73897	1st
Stocking of the newly produced bricks before delivery to customers	4.5588	0.73893	2nd	4.4772	0.63107	2nd	4.5180	0.68500	2nd
Breaking and deformation in shape/size of some bricks in the uncontrolled heat in the production kiln	4.4020	0.93618	3rd	4.4140	0.80304	4th	4.4080	0.86961	4rd
Excessive drying of bricks	4.3725	0.93260	4th	4.4435	0.72687	3rd	4.4080	0.82974	3th
Excessive energy consumption	4.3627	0.95222	5th	4.2947	0.91012	5th	4.3287	0.93117	5th
Overheating or firing of the bricks	4.2941	1.01072	6th	4.2246	1.01681	6th	4.2594	1.01377	6th
Re-glazing of bricks that are not uniform in color	4.1961	1.07205	7th	4.1649	1.11211	9th	4.1805	1.09208	8th
Over glazing of some bricks	4.1765	1.12937	8th	4.2246	1.04415	6th	4.2006	2.17352	7th
Long distance covered from the store where the production materials are temporarily kept to the production machine	4.1078	1.15961	9th	4.0246	1.21729	10th	4.0662	1.18845	9th
Long distance covered from the production machine to the storing location	3.9314	1.29935	10th	3.9334	1.32385	11th	3.9324	1.31160	11th
Breaking of some bricks during transportation from the production machine to the storing location	3.8235	1,28519	11th	4.1895	1.08083	8th	4.0065	1.18301	10th
Waiting for the repair of production machine while the work is in progress	3.7059	1.30185	12th	4.1589	1.36710	12th	3.9324	1.33448	12th
Long distance covered from the production machine to the drying equipment	3.0784	1.55866	13th	3.2807	1.47221	13th	3.1796	1.51544	13th
Excessive waiting before transporting the excavated materials (clay or shale admixtures) from the mining site to the factory	2.1275	1.41191	14th	1.8905	1.27260	14th	2.0090	1.34226	15th
Several sample test before mining	2.0882	1.11784	15th	1.9298	1.15154	15th	2.0090	1.13469	14th
Unnecessary conversation or arguments among the workers in the cutting and forming phase	1.7549	1.06647	16th	1.7333	0.92259	16th	1.7441	0.99453	16th

Note: In the table, variables with tied ranks (similar MIS), the one with lower SD was ranked higher (Ye *et al.*, 2014)

4.2 Causes of wastes in bricks production process

The nine causes of wastes identified in the UO and interviews conducted in Minna Shelter Clay and Bricks Company are indicated in Table IV. The participants of the interview strongly specified that some of the identified factors in the table such as poor or inadequate supervision, work fatigue and poor maintenance culture are the main causes of wastes in BPP. These are consistent with the findings of the validation survey presented in the same table. It is essential to note that the high Cronbach's α values for the two groups (0.771 and 0.708 = good) in the validation survey show the reliability and acceptability of the data (George and Mallery, 2003). The SDs obtained are also within the acceptable range. As there are no tied MIS in this question, SRC was used to determine the strength of agreement of the respondents in the two groups. SRC in the two groups ranges from 0.663 to 0.754 at two-tailed significant level of 0.000 which is satisfactory.

In the table, it can be observed that poor or inadequate supervision and workers fatigue with MIS of 4.3051 and 4.0231 were ranked higher by the respondents. This implies that these variables are the two significant factors influencing wastes in BPP. It can also be said that the two factors contribute extensively to the poor production performance in the factory. Causes of wastes with MIS ranges from 2.4431 to 1.8061were rated very low by the respondents and may not be grouped among the factors responsible for wastes in BPP. Therefore, such factors may be ignored by the managers of the bricks producing firms while immediate actions are needed to overcome the significant causes (Emuze *et al.*, 2014). With only two cause factors in the MIS test, the researchers found it necessary to conduct one sample *t*-test so as to further discover more factors in the study (Kanji, 2005) (see Tables V and VI).

Based on the five-point Likert scale adopted in this study, the one sample *t*-test indicates that variables with 2.5 mean difference and above are satisfactory at two-tailed 95% significant level (Sabine and Braine, 2004). This implies that variables with aggregate mean differences (AMD) above 2.5 are the significant causes of wastes in BPP.

4.3 Impacts of wastes in bricks production process on production performance

The seven impacts of wastes in BPP which were identified through the UO and interviews conducted in Minna Shelter Clay and Bricks Company are indicated in Table VII.

Factors responsible for wastes in bricks production process	Group A			Group B			Aggregate MIS	Aggregate SD	Overall ranks
	MIS	SD	Ranks	MIS	SD	Ranks			
Sudden needs of production materials specifically in poor weather conditions	1.8824	0.93654	6th	1.7298	0.83539	6th	1.8061	0.88597	6th
Lack of immediate patronages	1.9804	1.09888	5th	1.7509	0.91796	5th	1.8657	1.00842	5th
Workers fatigue	4.0882	0.99606	2nd	3.9579	1.21536	2nd	4.0231	1.10571	2nd
Poor maintenance culture	2.4020	1.28402	4th	2.8561	1.85106	3rd	2.62905	1.56754	3rd
Poor factory design	2.4118	1.35962	3rd	2.4561	1.68329	4th	2.43395	1.52146	4th
Poor or inadequate supervision	4.3824	0.94444	1st	4.2281	0.97174	1st	4.3051	0.95809	1st
The need to be sure of the properties of the materials used for production	1.5825	1.23654	7th	1.6123	1.22417	7th	1.5974	1.230355	7th

Table IV. Factors responsible for wastes in bricks production process

The participants of the interviews were of the opinions that wastes such as excessive glazing of bricks, excessive drying, breaking and deformation in shape/size of bricks in uncontrolled heat in the production kiln and excessive heating of bricks normally lead to extension in production completion time, and consequently affect the overall cost of production. These are in agreement with the findings of the validation survey presented in the same table. Again, the high Cronbach's α values obtained in the two groups (0.945 and 0.899) in the validation survey indicate the reliability and acceptability of the data. The SDs obtained are also within the acceptable range. The SRC conducted in the two groups ranges from 0.653 to 0.734 at two-tailed significant level of 0.000 which is satisfactory.

The outcomes of one-sample *t*-test and the results presented in Table VII show that the significant effects of wastes in BPP are extension in the production completion time, increase in the estimated cost of production, reduction in productivity, increase in the estimated quantity of production materials and interruption in activities sequence, while inefficiency or poor quality of production with MIS 1.8429 and AMD of 1.6761 was not perceived by the respondents as a significant effect on production performance. This perception had been earlier noted in the interview section when the participants declared that their organization has never had problem with any of their customers based on the quality of their products.

With the exception of extension in production completion time that has a distinguished MIS and AMD, other aforementioned effects have close MIS and AMD values. Therefore, the researchers further conducted Wilcoxon Signed Ranks Tests (WSRTs) so as to fully

Table V. One-sample *t*-test on the significance causes of non-value adding activities in bricks production process (Group A)

	One-sample test Test value = 0					
					95% confidence Interval of the difference	
	t	df	Sig. (2-tailed)	Mean difference	Lower	Upper
A	20.299	101	0.000	1.88235	1.6984	2.0663
B	18.201	101	0.000	1.98039	1.7646	2.1962
C	41.452	101	0.000	4.08824	3.8926	4.2839
D	18.893	101	0.000	2.40196	2.1498	2.6542
E	17.915	101	0.000	2.41176	2.1447	2.6788
F	46.863	101	0.000	4.38235	4.1968	4.5679
G	16.231	101	0.000	1.50711	1.8532	2.2871

Note: A–G are the causes of non-value adding activities shown in Table IV

Table VI. One-sample *t*-test on the significance of non-value adding activities causes in bricks production process (Group B)

	One-sample test Test value = 0					
					95% Confidence Interval of the difference	
	t	df	Sig. (2-tailed)	Mean difference	Lower	Upper
a	34.957	284	0.000	1.72982	1.6324	1.8272
b	32.200	284	0.000	1.75088	1.6438	1.8579
c	54.977	284	0.000	3.95789	3.8162	4.0996
d	26.048	284	0.000	2.85614	2.6403	3.0720
e	24.633	284	0.000	2.45614	2.2599	2.6524
f	73.454	284	0.000	4.22807	4.1148	4.3414
g	22.721	284	0.000	1.61012	1.5102	1.7215

Note: a–g are the causes of non-value adding activities shown in Table IV

Parameters	Group A MIS	Group A SD	Group A Ranks	Group B MIS	Group B SD	Group B Ranks	Aggregate MIS	Aggregate SD	Overall ranks
Increase in the estimated cost of production (A = a)	3.7647	1.29107	2nd	3.7088	1.45451	2nd	3.7368	1.37279	2nd
Increase in the estimated quantity of production materials (B = b)	3.5000	1.36976	4th	3.5719	1.46770	4th	3.5360	1.41873	4th
Extension in the production completion time (C = c)	4.1471	1.21376	1st	4.1368	1.28871	1st	4.1420	1.25124	1st
Interruption in activities sequence (D = d)	3.4804	1.37683	5th	3.3158	1.58067	5th	3.3981	1.47875	5th
Reduction in productivity (E = e)	3.5392	1.39072	3rd	3.6456	1.46221	3rd	3.5924	1.42647	3rd
Inefficiency or poor quality of production (F = f)	1.8922	0.96372	6th	1.8035	1.32287	6th	1.8479	1.14330	6th

Table VII. Impacts of the identified wastes in bricks production process on organization performance

understand the statistical divergence of the variables (Cox, 2006). According to DBIA (2018), WSRTs is a non-parametric test that can be used to determine the difference between several groups of measurements specifically when they are closed in ranks. In the WSRTs, two related samples were adopted in which extension in the production completion time with clear differences of MIS and AMD was compared with the other variables with close MIS and AMD (see Tables VIII and IX).

Variables	n	Descriptions	Asymp. Sig. (2 tailed)
A–C	Negative ranks = 32[a]	a. A < C	0.000
	Positive Ranks = 0[b]	b. A > C	
	Ties = 70[c]	c. A = C	
	Total = 102		
B–C	Negative ranks = 52[a]	a. B < C	0.000
	Positive Ranks = 0[b]	b. B > C	
	Ties = 50[c]	c. B = C	
	Total = 102		
D–C	Negative ranks = 53[a]	a. D < C	0.000
	Positive Ranks = 0[b]	b. D > C	
	Ties = 49[c]	c. D = C	
	Total = 102		
E–C	Negative ranks = 43[a]	a. E < C	0.000
	Positive Ranks = 0[b]	b. E > C	
	Ties = 59[c]	c. E = C	
	Total = 102		
F–C	Negative ranks = 91[a]	a. F < C	0.000
	Positive Ranks = 0[b]	b. F > C	
	Ties = 11[c]	c. F = C	
	Total = 102		

Note: A, B, C, D, E and F are the variables indicate in Table VII

Table VIII. Wilcoxon signed rank test on the significance effects of non-value adding activities in bricks production process on the factory performance (Group A)

Table IX. Wilcoxon signed rank test on the significance effects of non-value adding activities in bricks production process on the factory performance (Group B)

Variables	*n*	Descriptions	Asymp. Sig. (2 tailed)
a–c	Negative ranks = 44[a] Positive Ranks = 0[b] Ties = 241[c] Total = 285	a. a < c b. a > c c. a = c	0.000
b–c	Negative ranks = 57[a] Positive Ranks = 0[b] Ties = 228[c] Total = 285	a. b < c b. b > c c. b = c	0.000
d–c	Negative ranks = 75[a] Positive Ranks = 0[b] Ties = 210[c] Total = 285	a. d < c b. d > c c. d = c	0.000
e–c	Negative ranks = 50[a] Positive Ranks = 0[b] Ties = 235[c] Total = 285	a. e < c b. e > c c. e = c	0.000
f–c	Negative ranks = 197[a] Positive Ranks = 0[b] Ties = 88[c] Total = 285	a. f < c b. f > c c. f = c	0.000

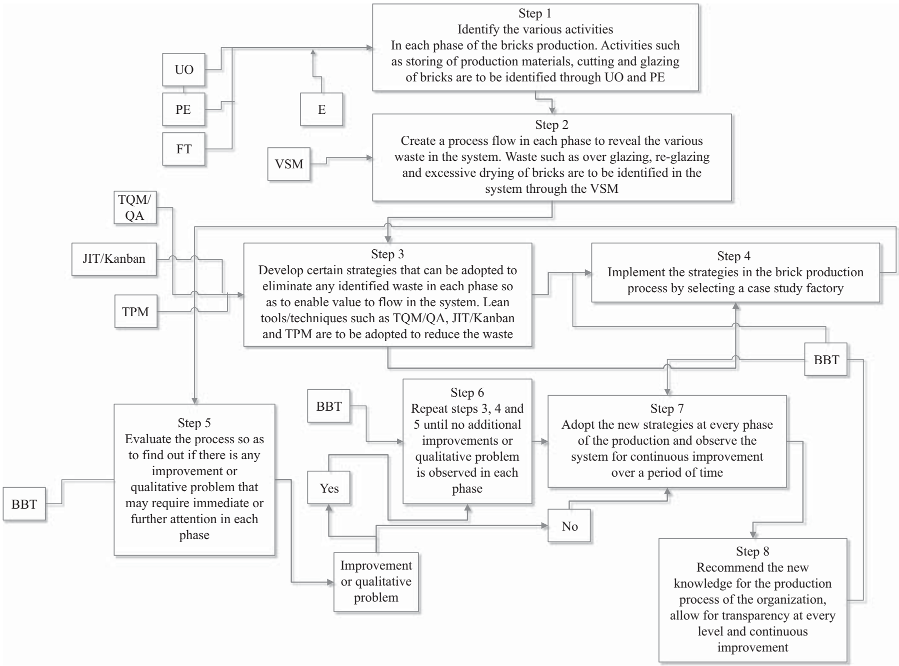
Note: a, b, c, d, e and f are the variables indicate in Table VII

Based on the WSRTs conducted in the two groups, increase in the estimated cost of production with the least negative ranks and highest ties also shows a level of significant effect while compared with extension in the production completion time.

4.4 Strategies that can be adopted to eliminate wastes in Nigerian bricks production process

Based on the categories of wastes discovered in this study, JIT (production, distribution and purchasing), Kanban, TQM, QA, TPM and proper supervisions at every level of activities proposed by Womack and Jones (2003), Holweg (2007) for wastes reduction in projects were suggested by the researchers to the participants of the phenomenological study in the case selected. The researchers made it clear to the participants that the above stated strategies if properly adopted can be used to overcome the discovered wastes in BPP. Based on these suggestions, Kanban and JIT-production are presently being applied in the case study firm to determine the exact quantity of materials required for a specific set of production. This will save prospective bricks factories from the cost of construction of warehouse for up keep of production materials pending the time they will be needed. The idea also increases land mass for future uses, and consequently reduces waste due to long distance covered from the store where the production materials are temporarily kept to the production machine. To reduce inventory due to stocking of the newly produced bricks before delivery to customers, the staff of the factory has also been advised to adopt JIT-distribution and JIT-purchasing concepts. Which consequently eliminates wastes due to long distance covered from the production machine to the storing location and breaking of bricks during transportation from the production machine to the storing location.

Further, TQM, QA and proper supervision are also being used by the factory to overcome wastes such as over glazing, excessive drying, breaking and deformation in shape/size of bricks in uncontrolled heat in the production kiln. Premised on these suggestions and the findings of this study, a lean framework for wastes reduction in BPP is hereby present (Figure 3).



Source: Adapted from Melton (2005)

Figure 3. A lean framework for waste reduction in bricks production process

4.4.1 The proposed framework. In the proposed framework, the first aspect is to identify the various activities in BPP. This can be achieved through UO and PE. The next phase is to create one-piece or a process flow in each phase so as to identify clearly the various wastes in the system. This phase can be achieved through the adoption of a lean tool known as VSM. The third phase in the proposed framework is to introduce the strategies that can be adopted to eliminate the identified wastes so as to enable value to flow in the system. This can be attained through the adoption of lean tools and techniques such as TQM/QA, JIT/Kanban and TPM observed in the literature. In the fourth phase of the proposed framework, the various lean tools and techniques can be deployed on the various activities. This implies that in the proposed framework, lean thinking can be adopted to eliminate wastes due to several sample tests. It should be reminded that the production manager of the case study factory has been advised to make use of one or two sample tests for a new site, and to avoid sample tests if resources are to be sourced from an existing site or location. This has been able to reduce the TT in the mining phase from 3 to 2 h, and MCT from 4 to roughly 2 h as can be observed in the future state value stream mapping (Figure 4).

Similarly, the production manager of the case study firm was advised to source for materials based on the number of bricks to be produced per production. This has enabled the TT and MCT in the storing phase of the production to be reduced from 4 to 1 h, and from 4 to 2 h, respectively. With proper adoption of TPM at SRSP and FACP, unnecessary waiting due to sudden breakdown of machine while production is already in progress has been completely eliminated to a large extend in the production process. Presently, the TT and MCT due to excessive distance covered from the production machine to the drying equipment have been temporarily reduced by advising the production manager of the case study factory to reposition the drying equipment close to the production machine. Therefore, with adequate

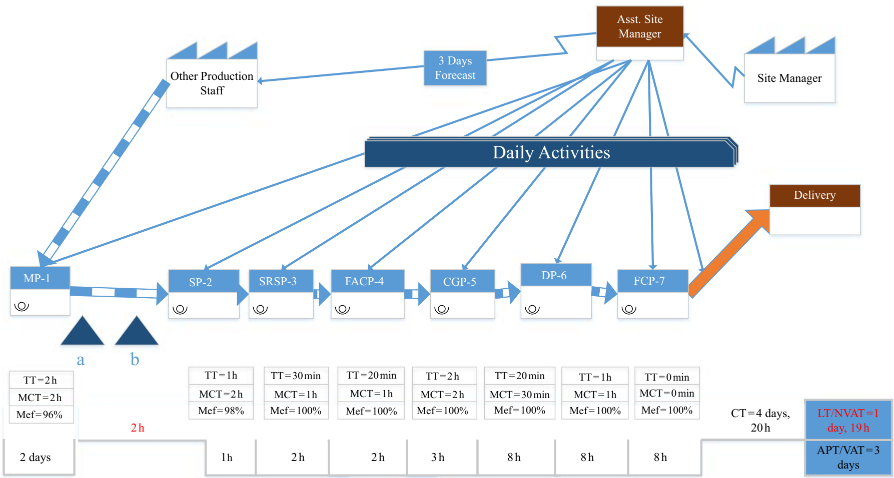


Figure 4.
The Future State value stream mapping in the production process of bricks

Source: Minna Shelter Clay and Bricks Company

supervision, TT and MCT associated with wastes such as excessive drying of bricks and overheating of bricks have been greatly reduced in the production process, while that of the stocking of the newly produced bricks before delivery to customers have been overcome through JIT-distribution and JIT-Purchasing concepts. Therefore, the overall TT and MCT in BPP in the case study factory was realized to have been reduced from 24 h to approximately 7 h (29 percent reduction), and from 27 h to roughly 9 h (33 percent reduction).

4.4.2 The evaluation process. The evaluation process is the fifth stage of the proposed framework where the BBT of the case study factory were consulted on a weekly basis to verify any form of improvement in the factory BPP. According to Abbasian-Hosseini *et al.* (2014), one of the appropriate factors that can be adopted to compare the traditional and modern methods of production is the manufacturing time. This implies that time is useful and universal metric for comparison, as it can be used to generate improvements in cost and quality of a product (Krupka *et al.*, 1992). Therefore, at the end of the first, second and third months of adoption of the lean framework, the BBT of the case study factory emphasized that LT has been greatly reduced while compared to the traditional or former method of production. The BBT of the factory further declared that the adopted lean framework has led to a significant reduction in wastes or NVAAs such as over glazing of bricks, several sample test, excessive heating of the bricks and unnecessary delay in the factory BPP, which have led to significant reduction in TT and MCT in the production process, and have consequently resulted to great reduction in production completion time. The BBT emphases in the case study firm are consistent with the findings of Anand and Kodali (2010), Anvari *et al.* (2011), Buus (2011), Cottyn *et al.* (2011), Nordin *et al.* (2012), Powell *et al.* (2013), Hadid and Mansouri (2014), Zahraee, Golroudbary, Hashemi, Afshar and Haghighi (2014) and Sangwa *et al.* (2015) on lean frameworks for wastes reduction in the manufacturing process.

5. Discussion and managerial implications

5.1 Discussion

The study conducted on the various forms of wastes in the BPP reveals that wastes such as stocking of the mined materials regardless of when they will be needed for production, stocking of the newly produced bricks before delivery to customers and breaking and excessive drying of bricks with MIS above 3.0 may not only occur in the study context factories, but possibly in the global bricks factory. While wastes such as several samples test before mining and delay to transport the excavated materials from the mining site to the factory have MIS less than 3.0 and may not be experienced in the global brick factory. This concurs with the findings of Emuze *et al.* (2014) on factors contributing to NVAAs in South African construction.

Further, the significant factors responsible for wastes in BPP are poor supervision, workers fatigue and poor maintenance culture. These discoveries concurred with the findings in the literature. For instance, Nagapan *et al.* (2012) acknowledged supervision delay as one of the main factors influencing productivity in construction industry. Lopez *et al.* (2010) reveal that overtime policy in organizations may introduce workers fatigue that may influence more wastes and productivity loss. If fatigue is not tackled immediately by reducing workers overtime, it may decrease their morale and attitude to work. Consequently, low productivity may set in (Lyneis and Ford, 2007; Emuze *et al.*, 2014), whilst Al-Aomar (2012) identified lack of proper maintenance procedures as the main causes of equipment breakdown during the progress of work.

The study conducted also reveals that extension in production completion time is the major effects of the discovered wastes in BPP on production performance. In addition, increase in the estimated cost of production was observed to exhibits strong relationship with extension in production completion time. Therefore, it can be deduced that wastes in BPP will lead to time overrun which will consequently lead to increase in production cost. It is worth mentioning that cost increment has been observed as one of the major effects of rework and delay (waste) in building production (Khurshid and Nauman, 2016; Yap *et al.*, 2017; Mpofu *et al.*, 2017). This implies that wastes in BPP are frequently associated with high cost of production.

The study conducted also shows that lean thinking is not being adopted in all the bricks factories covered in the study context. However, based on literature the discovered wastes in BPP can be reduced through the adoption of lean principles, tools/techniques and concepts. Hence, VSM, TQM, QA, JIT, Kanban, TPM, proper supervisions at all levels and BBT can be adopted to reduce virtually all the wastes in BPP. These compared favorably with lean implementation in other countries/industries such as UK and USA. For instance, the literature indicates that several manufacturing industries/factories in the aforementioned advanced countries have successfully made used of lean tools and techniques in their production process. QA, TQC and Kanban were first adopted in material and component manufacturing process (Koskela, 1992). JIT concept has also found a great application by component manufacturers, specifically in window fabrication and prefabricated housing (Koskela, 1992). Further, Hook and Stehn (2008) studied the organizational culture of the industrialized housing industry and realized that after the depiction of lean principles and techniques to the work floor order and visibility, workers' attitude and cultures completely changed, whilst VSM was successfully adopted by Zahraee, Hashemi, Abdi, Shahpanah and Rohani (2014) to provide visibility in companies' production system so that the companies can choose improvement activities to achieve the maximum benefit.

5.2 Managerial implications

This study provides information on the various wastes in BPP. Such information may be useful to bricks factory prospective and managers of the existing ones. It also provides knowledge on how lean thinking can be adopted to reduce the identified wastes in BPP. Therefore, the study allows prospective and present bricks producers to identify gaps in their implementation efforts, focus attention on areas for improvements, and assess the benefits of lean approach in their organization products. The study also enables bricks manufacturers to effectively reduce TT, MCT and LT in the BPP with the consequent reduction in the overall cost of production. In addition, the VSM adopted in the study can serve as a tool for wastes identification by the producers of other forms of building blocks such as concrete blocks.

6. Conclusions

Based on the findings of this study, it can be concluded that wastes such as stocking of the mined materials regardless of when they will be needed for production, stocking of the newly produced bricks before delivery to customers, excessive drying of bricks, excessive energy consumption and excessive glazing of bricks are the significant wastes in BPP. This is similar to the finding of Simms (2007) on the seven forms of wastes that are often overlooked in the manufacturing design process. Hence, eliminating these wastes in BPP will enable manufacturers to focus attentions on quality improvement, reduction in production time and cost.

It can also be concluded that the above-mentioned waste in BPP occur not only in Nigerian BPP but possibly in the global bricks factory. The study further concludes that poor supervision, workers fatigue and poor maintenance culture are the significant causes of wastes in BPP, while extension in production completion time can be emphasized as the major effect of the identified wastes in BPP on the factory performance. This concurred with the findings of Nagapan *et al.* (2012) on the main impact of wastes on projects performance. It can also be affirmed that wastes in BPP will lead to time overrun which will consequently lead to increase in the estimated cost of production. This is similar to the opinion of Osmani (2011) on the impact of NVAAs on the completion time of construction projects.

Finally, the study concludes that TT, MCT, LT and other forms of wastes in BPP can be reduced or overcome through the adoption of lean tools, techniques and concepts. Typical examples of these tools, techniques and concepts are VSM, TQM, QA, JIT, Kanban, TPM, proper supervisions at all levels and BBT. This agrees with the view of Koskela (1992) and Zahraee, Golroudbary, Hashemi, Afshar and Haghighi (2014) on the various lean tools/techniques that can be adopted to eliminate wastes such as overproduction, over-processing and unnecessary delays in the manufacturing process. One main limitation of this study is the inability of the researchers to investigate the percentage of the discovered wastes in BPP. Therefore, further studies should be conducted on the level of wastes in BPP so as to establish it extent on the overall cost of production.

This study recommends the framework developed with VSM, TQM, QA, JIT, Kanban, TPM and BBT for wastes reduction in BPP. The BBT of the bricks factories needs to set up a production standard through the application of the framework, and link the standard with the identified wastes in the study. This standard should be benched marked against the traditional methods of production and should be monitored and updated yearly or from time to time depending on the achievement of the factory.

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