Application of Lean to Reduce Operational Wastes in Tiles Manufacturing Process

Abstract. Roofing tile manufacturing is a mass production process with high operational and inventory wastes and costs. Due to huge operational costs, excessive inventory and wastes, and quality problems, roofing tiles manufacturers are trying to implement lean manufacturing practice in their operations in order to remain competitive in an increasingly competitive global market. The aim of this research is to evaluate the possibility of reducing operational and inventory costs of tiles manufacturing process through waste minimization. This paper analyses the current waste situation in a tile manufacturing process and develops current and future value stream mapping for such process with a view to implement lean principles in manufacturing. The focus of the approach is on cost reduction by eliminating nonvalue added activities.

Keywords: Lean Production, waste reduction, production cost

1. Introduction

Roofing tile manufacturing is a mass production process with high operational and inventory wastes and costs. The high operational costs experienced by the roofing tiles manufacturers due to such operational and inventory wastes, inferior quality problems, the recent downturn in the economy, and drop in residential construction activities created an urgent need to reduce costs and to develop sustainable production practices in the tile manufacturing Industries. One of the possible solutions for this problem could be the implementation of most modern production philosophy such as Lean manufacturing.

The concept Lean manufacturing is derived from the Toyota Production System or Just in Time Production, Henry Ford and other Predecessors (Strategos International). The basic idea behind the system is to eliminate waste. Waste is defined as the non-value added items to the end product in terms of customer's perspective. Eiji Toyoda and Taiichi Ohno incorporated Ford production and other techniques into an approach called Toyota Production System or Just in Time, when Japanese manufacturers in the automotive industry were faced with the dilemma of crisis of material, financial and human resources after World War II. The term "lean" as defined by Womack et al [1] is to manufacture only what is needed by the customer, only when it is needed and only in the quantities ordered by the customer. In the lean Philosophy, the whole process of producing and delivering a product should be examined and optimized from customer's Perspective [2].

Based on the overwhelming success of the application of Lean approach observed in many discrete product manufacturing, it was expected that if lean methods were used appropriately, the overall operational cost of tile manufacturing would be reduced as sources of waste were addressed and mitigation measures put in place.

This paper acts as a pre-assessment for the implementation of a full lean production system in roofing tile manufacturing with a view to minimize wastes. The objective of this paper is to use a case-based approach to demonstrate how lean manufacturing tools when used appropriately, can help the tiles industry eliminate waste, maintain better inventory control, improve product quality, and obtain better overall financial and operational control.

The proposed approach is illustrated with a case study for a large roof tiles manufacturer. Due to strict confidentiality of information, the original company is referred to as XY Roofing throughout this paper. XY Roofing is a leading supplier of concrete and terracotta roof tiles, producing up to 250 000 units a day with 40 different color ranges in seven profiles. The manufacturing processes at XY Roofing are characterized by high operational costs which have become unsustainable over the past few years due to operational and inventory wastes. Research into current practices reveals that there are high levels of waste generated during the production.

The outline of this paper is as follows: Section 1 introduces the lean application in mass production process with high operational and inventory wastes and costs such as tiles roofing production. A brief literature review on lean manufacturing is discussed in Section 2. Section 3 describes and analyses the implementation of Lean approach in Roofing tiles manufacturing process to reduce high operational and inventory wastes and costs. Section 4 discusses the analysis of the industry data to develop VSM future state map for Lean implementation purpose. Finally contributions of the paper and future scopes are highlighted in Section 5.

2. Literature review

The logic of lean production, leaving aside for a moment its implications for working practices and social impact, describes value-adding processes unencumbered by non-value adding activities [3]. So the essential focus of Lean manufacturing is the efficient use of scarce resources through the minimization of all forms of waste and other non-value added activities in the organization [4]. Lean production is derived from the need to increase product flow velocity through the elimination of all wastes [5]. Waste is an inevitable by-product of all individual and social activities, and better control of its creation could lead to substantial monetary and resources savings. The challenge is to minimize waste and gain the benefits associated with less waste such as reduced operational and waste removal costs [6]. Wastes are usually grouped into the following categories: overproduction, motion, inventory, defects, waiting, transportation, extra processing, and underutilized people [7]. Keeping parts and products in stock does not add value to them, and should be eliminated [8].

Lean manufacturing has been increasingly adopted as a potential solution for waste elimination for many organizations, particularly within the automotive and aerospace manufacturing industries [9]. Lean is a revolution—it isn't just about using tools, or changing a few steps in our manufacturing processes—it's about the complete change of our businesses—how the supply chain operates, how the directors direct, how the managers manage, how employees—people—go about their daily work [10].

Lean manufacturing pursues the source and root causes of waste. Use of Lean as the root-cause eliminator of waste is based on the fundamental assumptions below [11], [12]:

- Perfect processes have no waste. When every step in the process is fully efficient, right processes perform exactly as needed, the process will produce waste free outcomes.
- Business objective is a customer focussed sell and service. The customer determines ultimate value they are willing to pay for hence everything begins and ends with the customer wants.
- Creating value is a process. The end value of a product is contributed to by various steps such as design, production, marketing, processing and delivery.
- Waste diminishes value. Creation of waste reduces efforts of value-creation.

The Lean approach provides methods and tools for continually pursuing the forever elusive perfect process. Waste elimination is the goal of Lean, and Toyota defined three broad types of waste:

Muri (overburden) : Focuses on what work can be avoided through design that addresses all the unreasonable work imposed on workers and machines because of poor organization.

Mura (unevenness): Focuses on how the work design is implemented and smoothens the production process at the scheduling level with regards to things such as quality and volume.

Muda (non-value-adding work): Refer to all the unnecessary non value adding activities which are exposed when a system is in place and deals with them reactively. It can be seen through variation in output and can be controlled through process examination and elimination of the root causes by considering the connections to the mura and muri of the production system. Note that normally muda is the only waste addressed as it is easier to control.

Continuous waste elimination in Lean Manufacturing cycle begins with the identification of the waste area, and then the root causes for the waste are analysed. Improvements are introduced into the system and measured to check the progress. Information is fed back and improvements evaluated, the next waste is identified and the cycle restarts. Figure 1 shows the basic steps of reducing waste in a lean manufacturing system [12].

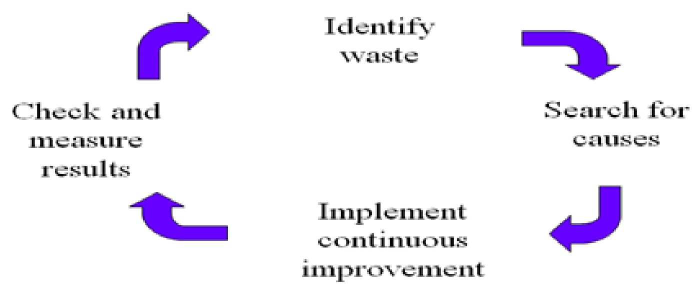

Fig. 1: Waste elimination cycle. Source

Shah and Ward [13] addressed the confusion and inconsistency associated with lean production where they attempted to clarify the semantic confusion surrounding lean production. They mapped the operational space corresponding to conceptual space surrounding lean production. To date numerous books and articles have been published and academic conceptual and empirical articles have been published that highlighted the overarching nature of lean production. Literature review indicates that there exist many descriptions of lean production and its underlying components along with a few conceptual definitions.

The literature reviews also evident that the Lean applications have spanned many discrete and continuous process sectors including automotive, electronics, white goods, consumer products manufacturing, chemical and steel manufacturing where the production processes involved less operational and inventory losses. Roofing tile manufacturing is a mass discrete production process with high operational and inventory wastes. Literatures on effectiveness of lean application in such production process are very limited. This inspires the authors to study and research on implementation of lean in mass production process with high operational and inventory wastes and costs.

3. Lean implementation approach in Roofing Tiles

3.1. Introduction

The methodology used for the project involved the use of literature, possible approaches to address the selected problems and review in detail. The more befitting approach would be selected and it would be used in more detail to map, assess and recommend on the sources of XY Roofing's waste. The study focused on pinpointing the major sources of wastes, and then using tools such as 5s, JIT and others to eliminate the waste. Descriptions of the most common lean tools is addressed by many authors and the interested readers are referred to Monden, [14]; Feld [15]; Nahmias [16].

Value stream mapping is considered as the main tool used to identify the opportunities for various lean techniques. Rahani and Al Ashraf [17] demonstrated the VSM techniques and discussed the application in an LP initiative on a product case study.

3.2. Value stream mapping (VSM)

A value stream mapping is a collection of all actions (flow of both information and materials within the overall supply chain) which are required to bring a product through the main flows, starting with raw material and ending with the customer. The objective is to identify all types of waste in the value stream and to take steps to try and eliminate these [18]. VSM creates a common basis for the production process, thus facilitating more thoughtful decisions to improve the value stream [19]. The Value Stream map development process consists of the following two steps:

- Development of the current state map: capturing a snapshot how things are currently being done. This is accomplished while walking along the actual process, and provides one with a basis for analysing the system and identifying its weaknesses;
- Development of the Future state: a picture of how the system should look after the inefficiencies in it have been removed. Creating a future state map is done by answering a set of questions on issues related to efficiency, and on technical implementation related to the use of lean tools. This map then becomes the basis for making the necessary changes to the system [20].

3.3. Value Stream Mapping (VSM): Current state map

The data for the current state map were collected based on the approach recommended by Rother and Shook (1999)[18] to reveal the amount and type of waste produced at XY Roofing. The data provides a reflection of the lean opportunities available to reduce identified wastes throughout the production line. Tools used in collecting data included a walkthrough observation, a questionnaire sent to different stockholders, financial records, waste mapping and root cause analysis.

3.3.1. Walk through Scenario

The data A Walk through was conducted to get a picture of the situation at XY Roofing. This simple but effective method allows for the quick identification of waste areas and possible improvement opportunities. Supported by key questions relating to the production and waste, areas of opportunity were identified and mapped out. The system was observed from receiving of raw materials through to dispatch of final product. Supporting data collected from records and field experiments were used to compliment the observations.

After mapping the waste key areas of concern were noted and more focused queries directed towards them. Since there were gaps in the data due to incomplete or unavailable records, the field tests conducted made it possible to acquire more information about the system. The planned tests included weighing the amount of waste thrown out on the wet-side of the plant and observing the downtime during shifts. The data was converted into useful performance information and used as a baseline for performance. Using the "Seven deadly Wastes" to target areas of concern, affected areas were identified and are indicated in the waste map in Figure 2.

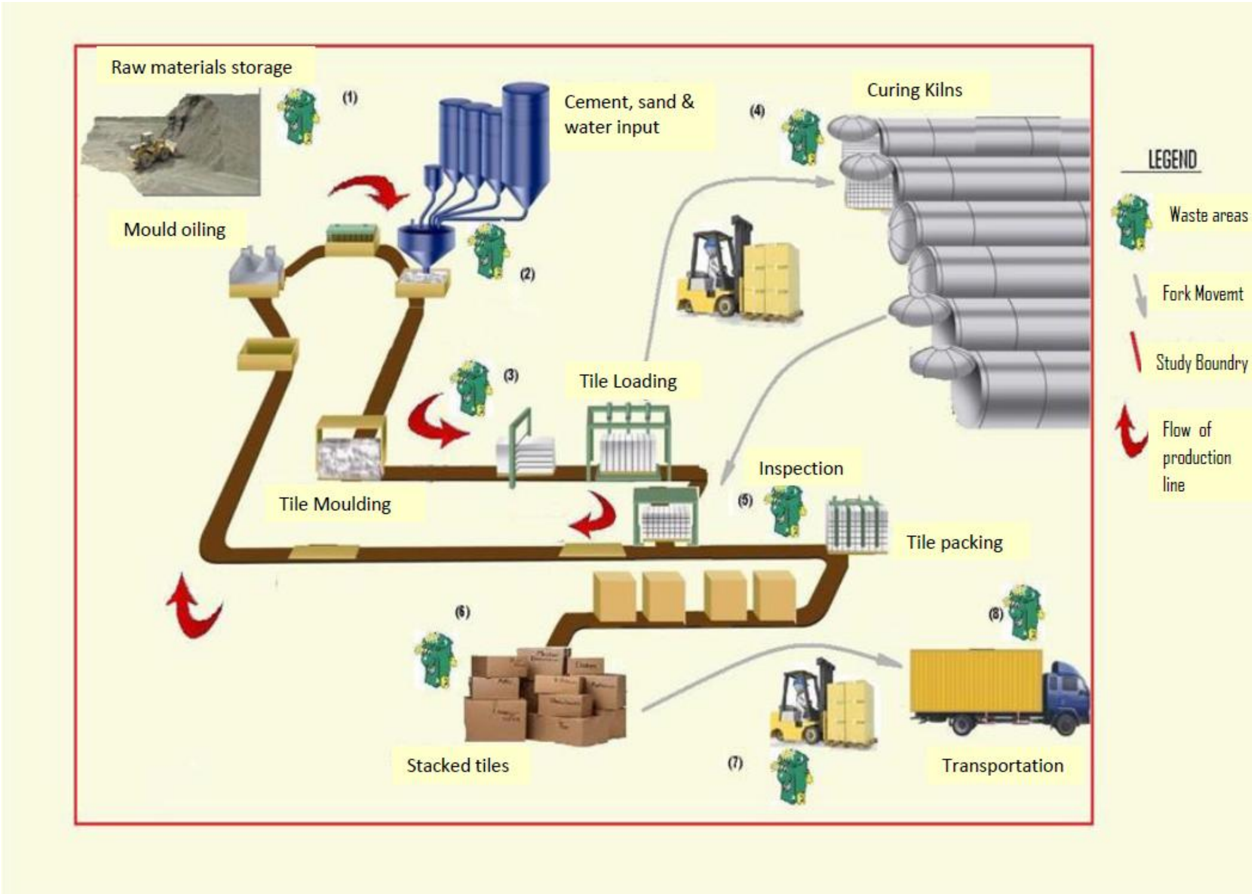

Figure 2: Identified waste areas in XY Roofing

3.3.2. Identified wastes

The numbered areas in the waste map indicate identified areas of waste. Notes taken on the identified areas are shown in table 1. (Note: The wet-side mentioned refers to the area between the mixing of materials and the kiln loading).

3.3.3. Waste scenario from Financial Records

Data relating to the accounting department was used to determine how much was invested and how much went to waste in the past financial year. The actual document is not presented in this document due to confidentiality reasons, however relevant data extracted from the records are utilized in the data analysis stage.

3.3.4 Data from personnel interview

Informal interviews were carried out with different personnel at XY Roofing and questions related to the problem were asked to the relevant people.

The intention of the interviews were to elicit straight forward response from the people who were closest to the production line and clearly had an in depth knowledge of the problems. The instrumentation process involved 10 questions which were expected to enlighten on the subject. The questions were designed to give an insight as to what could have been missed during the walk through and to identify opportunities and viewpoints of those closer to the plant.

Table 1: Description of identified waste areas

Lean deadly waste	Waste areas	Description
Operator motion	2	• It was noted that during a changeover one operator seemed to be strained by the die changeover as he had to go back and forth several times before the die was ready for production. However things seemed to be done a lot quicker when a colleague assisted him as he did not have to go back and forth.
Lost resources	1 & 2	• Losses occurring throughout the line which were not recorded included the sand lost in the drain or washed away during a storm. • As no accurate data was available as to how much sand was lost or in the sand bunker at any given time, these losses would remain hidden. • Losses in raw materials on the wet-side also contributed as they were significant amounts of wet waste thrown out, but were not recorded or accounted for.
Over production	6	• Large stocks, held for months, stacked out in yard resulting in tied up money (shown in figure 2). • Packaging deterioration on stocks held for too long resulting in plastic waste all over the factory. • Breakages are occurring out in the yard on stock tiles, resulting in waste and loss of products which might go unaccounted. • Over producing leads to other types of waste. It will lead to excess inventory, which will result in increased material handling and increased labor. Extra equipment will be required to move this material
inventory	1	• Although keeping some stock may make good business sense, there are hidden losses incurred. Losses are occurring with the large stocks of sand. As some is lost through the storm drain located in front of the sand bunker, some is simply blowing away from its stored place out in the open. • Large amounts of oxide spilt on floor and unaccounted for in oxide storage • Oil spills in oil shed, unaccounted for (and potential environmental hazard)
Idle time	1 & 6	• Changeover time, stoppages usually long, resulting in loss of production time. Observation on two shifts reviled that changeovers could be as long as an hour.
Quality issues	2 & 5	• Rejects on the dry side were thrown out during the inspection, but because of the high speed of the process some defective tiles were undetected and were stacked. • On the wet-side the rejects were thrown out before they went to the kilns, but all the necessary materials would already be consumed by the tile. These rejects where not accounted for in any way or the material that went to waste. • Accumulating costs of rejects can easily climb into the millions of unaccountable dollars over time.
transportation	7	• Transportation of materials between stations resulted in losses. As sand was transported from the bunker to the hopper it was noted that a significant amount of sand was lost either during the transportation or from an over filled hopper. • Other losses occurred during the transportation of tiles either to or from the kilns. Information gathered from the questionnaire suggests it was a result of the water on the floor which caused the forklift to slip and slide hence resulting in a bumpy transportation causing damage to the tiles.

3.3.5. Field tests Scenario

Three field tests were carried out to collect data. The tests involved sampling products to determine changeover times, wet-waste generated, how long they spent out in the yard, determining how many products had damaged packaging from the sample and how many pallets contained damaged stock.

Test 1: Changeover times: a sample of the changeover times was taken to determine how much time was lost on average. The data collected over 15 observations is presented below in table 2 below. The data was collected over random visits made into the plant. The target changeover time set for changeovers was set at 15 minutes.

Test 2: Yard experiments: The yard experiments would be conducted to determine several parameters namely, the average duration products spent out in the yard, average amount of products with damaged packaging leading to waste generation and the average amount of product orders with damaged products. The data collected could be further improved on through the use of larger sample size and more rigorous statistical methods but due to limited resources basic statistical methods were be used to give an estimate of the results.

Table 2: Observed changeover times

Observations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Changeover times (minutes)	38	49	78	64	40	80	45	53	44	58	47	45	53	45	34

Test 3: Wet-side rejects: To determine just how much waste was lost and unaccounted for on the wet-side of the line, experiments were carried out to determine average losses incurred that were not recorded. The questionnaire and frequency observations were used to estimate how much waste was lost in the wet-side of the plant as there were no scales available at the time of experimentation to weigh the actual weight as initially intended. Figure 3 summarizes the current state at XY Roofing in the form of a current Value Stream Map (VSM).

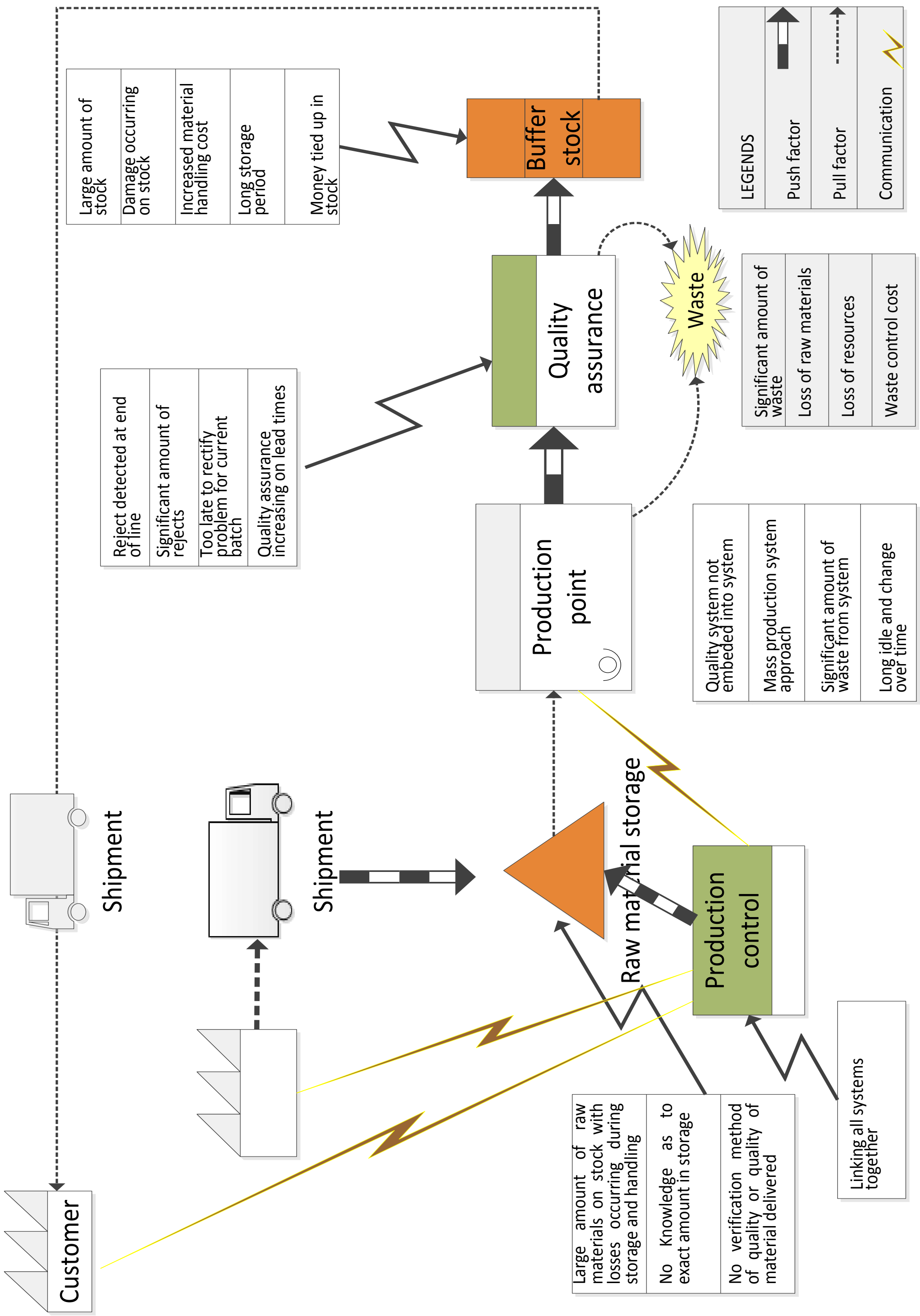

Fig. 3: Current Value Stream Map for XY Roofing

4. Data Analysis

4.1. Root Cause Analysis

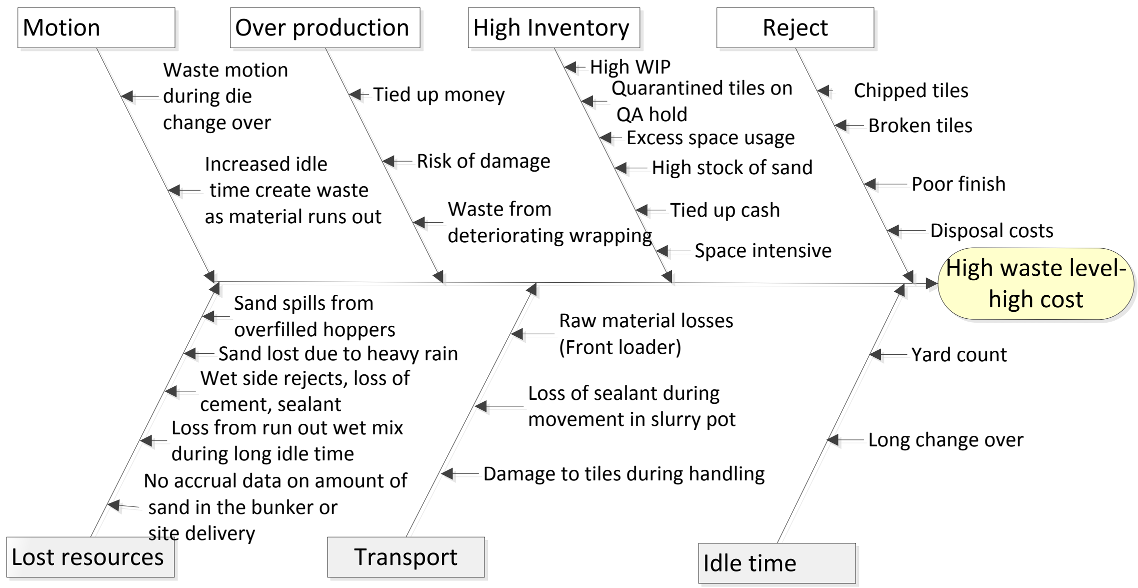

Fig. 4: Cause and effect diagram for XY Roofing

The Ishikawa diagram was developed using the "5 why" method to examine the root causes for the identified wastes along the line. The possible remedies suggested for the identified wastes to be incorporated into the recommendations for the reduction waste at XY Roofing. The root cause analysis identifies the root causes of the wastes and isolates the individual symptoms, by breaking them down into smaller segments making them easier to tackle and working backward to find the causes. The analysis is presented below in Table 3.

Table 3: Analysis of root cause using '5 Why' method

3.1	***Lost resources***	**Explanation**
3.1.1	*Why?*	i. Because wet mix is run out when there are long idle times ii. Because it will not bond properly iii. Because it will have started to dry up iv. Because water was added to the sand-cement upstream and the reaction has started
	Possible Remedy	So adding water to the sand-cement mix further downstream could improve on the reject rate for run out waste as it eliminates the possibility of drying during machine stoppage.
3.2	***No accurate data on amount of sand in the bunker***	
3.2.1	*Why?*	i. Because there are losses incurred through the storm drain located in-front of the bunker and losses cannot be measured ii. Because there is no measure in place to weigh the sand iii. Because the system relies on data collected at the end of the line (difference between extruded tiles and stacked tiles) iv. Because there is no Kanban in place
	Possible Remedy	So implementing a system to weigh the actual sand in the bunker could show how much sand was lost to the drain and in general. Other solutions could include relocating the bunker or shifting the storm drain

3.3	***Wet-side rejects (unaccounted)***	
3.3.1	*Why?*	i. Because defects occur on the wet-side of the plant ii. Various reasons including poor form, poor mix or machine malfunction iii. Because the waste is not weighed or measured in any way losses in the form of cement, sand, machine hours, and other inputs are unaccounted for leading to hidden losses in the line.
	Possible Remedy	Keeping track of the wet-side losses could give a more accurate picture of how effectively resources are utilized
3.4	***High inventory***	
3.4.1	*Why?1*	i. Because there is buffer stock ii. Because of anticipated demand, the buffer is made ahead of orders iii. To avoid a stock out and meet urgent orders
3.4.2	*Why? 2*	i. Because there is stock held for quality inspections ii. To ensure that defective products are not passed onto customers
	Possible Remedy	Producing to order might solve the high inventory levels issue. A smaller stock could be held
3.5	***Rejects***	
3.5.1	*Why? 1*	i. Because some are damaged during handling ii. Tiles are damaged during kiln loading and unloading iii. Forklift transfers not smooth as forklift sometimes slips and slides iv. Water on floors coming from kilns v. Leaks from pipes and condensing steam produce the water that leaks onto the floors vi. Aging equipment with several inefficiencies
3.5.2	*Why? 2*	i. Because of accidents out in the yard ii. Limited space to maneuver forklifts iii. Large amounts of stock out in yard iv. Refer back to question 4.
	Possible remedy 1	So eliminating the water from the floors and keeping them dry could smoothen the ride and thus reduce the number of breakages and rejects
	Possible remedy 2	Reducing stock out in yard free up space and thus making folk maneuvering easier and reduces accidents as there is open space to see
3.6	***Long non-productive breaks***	
3.6.1	*Why? 1*	i. Because the is a long changeover period ii. Because cleaning has to be thorough iii. Because color is changing from dark to clear sealant iv. Because a darker product was scheduled before a lighter one
3.6.2	*Why? 2*	i. Because there is a long break during changeover ii. Because there is a lot of cleaning iii. Because there is a lot of waste on the floor and on equipment iv. Because waste accumulated during production v. Because there is waste coming from the production line
3.6.3	*Why? 3*	i. Long die set up time during changeovers ii. Because operator kept walking back and forth to set up the machine iii. Because one operator was performing the operation iv. Because the changeover is not standardized
	Possible Remedy 1	scheduling of lighter colors ahead of darker could resolve the issue as most of the darker colors can easily absorb the lighter colors without
	Possible Remedy 2	Reducing the amount of waste produced during production or avoiding its accumulation could result in less cleaning time as there is less waste to clear. This could be an

		improvement of the material recovery system already in place as it was noted that significant amounts of material is still lost during production.
3.7	***Transportation***	
3.7.1	*Why? 1*	There are losses due to tile damage during transportation Refer to question 5
3.7.2	*Why? 2*	• There are losses due to spills and drops during transportation • Because a front loader is used to load the hopper because the system is designed that way
	Possible Remedy 1	Refer to possible remedy in question 5
	Possible Remedy 2	Eliminating the front loader through a process redesign could cut down on front loader transportation losses. Having eliminated the loader also means there is fuel savings.

Changeover times observations

The sample data from observations on changeover times was collected for 15 observed changeovers. Through informal interviews it was found that the target time for changeovers was aimed to be close to 15 minutes, but from the observations it was noted that the current times were nowhere close to the target time. The average time observed was approximately 52 minutes, with the highest being 80 minutes and shortest 34 minutes. Several reasons contributed to the high changeover times, which meant a lot of takt time was lost. Cumulatively that would lead to large amounts of lost production and machine time. The long changeovers resulted in further material losses as materials run out after long idle times.

Yard experiments

Data collected from the yard experiments revealed that some orders had a large holding period. The sample data revealed holding periods of more than a year on some products. The sampled products also indicated that approximately 47% of the sampled products had damaged packaging which normally would lead to generation of plastic waste. The observed deteriorating state of some of the products indicated that further losses were imminent as some pallets with products held for too long heavily weathered hence the product was at risk of damage if the stocks collapsed. The collected data also revealed that several of the sampled batches had pallets containing damaged stock. In the event that the damaged sample batches were rectified, handling and packaging costs would be incurred in addition to the replacement costs and if not rectified these could be passed onto the customers resulting in a loss of customer goodwill.

Wet-side rejects

The design for experiments had already been done but delays in equipment led to the use of alternative methods being employed to retrieve required data. The alternative method used was based on a questionnaire and frequency observations.

4.2. Development of VSM Future State Map

The process of defining and describing the future state map starts while developing the current state map, where target areas for improvement start to show up. The need for reduced manufacturing costs at XY Roofing is to be dedicated in identifying the best approach and possible ways to mitigate waste. The current state map clearly shows large inventories, significant amount of wastes and damaged stock due to quality control problems, long production lead time and storage period are the major problem in the system. Inventory including finished products, raw materials, and lead time may be viewed as two related issues since the more the inventory, the longer any item must wait for its turn and thus, the longer the lead time [20]. In creating the ideal future VSM, lean manufacturing tools need to be utilized to bring down the Inventory and production lead time while looking at the schedule across the entire value stream. This study followed a systematic procedure where answer to a series of structured questions are addressed; this allows to come up with an ideal future state map that might help in eliminating or at least reducing different types of waste in the current system.

What is the Takt time? Does the production rate consistent with the customer demand (TAKT time, a benchmark for process pace)? The answer to this question will set the frequency by which the product has to be released by the manufacturer to meet customer demands. It is calculated by dividing the total available time per day by the daily customer demand. The higher inventory or buffer stock at XY roofing indicate an over production rate and uncontrolled overtime. The XY Roofing needs to use flexible resources to react quickly, control process through Visual Management i.e. each process knows what is the next needs, in the correct order & amount,

Do the products directly to deliver to the customer or stock as finished goods in the Buffer? Products directly deliver to the customer means only the units that are ready to be delivered are produced, no extra production. Large amount of stocks at XY Roofing implies the inconsistency of production with the customer. That is the products are produced without the concern of customer demand. However, this is done based on a push system, and tiles can wait a long time in this area before being shipped. It is therefore recommended that XY Roofing should produce to a supermarket (warehouse) and move the tiles based on a Kanban system. Whenever, the supermarket inventory is below a certain level this would trigger for further production. Where will XY Roofing need to use pull system supermarkets inside the value stream? Identify processes that control production of upstream processes. While addressing this question DM should evaluate the factors such as Cycle time compatibility, equipment uptime/downtime, equipment investment and flexibility.

Where can continuous flow be used? The Company needs supermarket pull systems to be used to control production of upstream processes. Where flow is not possible it should use inventory to buffer the problem to stabilize supply to the next process. Visual quantity control is needed without physically counting parts and scheduling machine.

What single point in the production chain (the ‘‘pacemaker’’ process) should XY Roofing schedule? To stop overproduction at any workstation in the value stream, the XY needs pace maker process (only one point in the supplier-to customer value stream) to be scheduled. This point sets the pace of production for all the upstream processes and ties the downstream and upstream processes together. Every workstation upstream produces by a pull signal from the next downstream process and flows downstream from the pacemaker must occur in a continuous manner.

What process improvements should the XY Roofing need to achieve their future state design? This step is key to any successful value stream improvement activities. Data should be analyzed to determine waste (inhibitors to flow). It should Identify kaizen bursts necessary to achieve the desired performance in the future state plans should be developed to reduce or eliminate waste. The results from the analyzed data revealed that the existence of opportunities for Lean Production implementation and improvements. The long changeovers and long stock holding periods observed meant that unnecessary costs were being incurred. The changeover times were observed to be approximately an hour, which meant that each time a changeover occurred valuable production time was lost. More losses were observed in areas such as the sand storage where resources were lost into the storm drain, but there was no equipment or measure set in place to know how much was in storage in the first place or lost. The quality of the data available was thus greatly affected as some assumptions had to be made. Data analyzed from records also revealed that over the past four years rejects cost the company more than $214 807.46, with approximately 9.27 tons of material lost on a daily basis. After addressing all the above question accurately and implementing necessary Lean manufacturing tools, an overall ideal value stream map for XY Roofing can be drawn as exhibited in Figure 5. The depicted system is idealistic with no losses occurring at any point and no storage of goods occurring at any point.

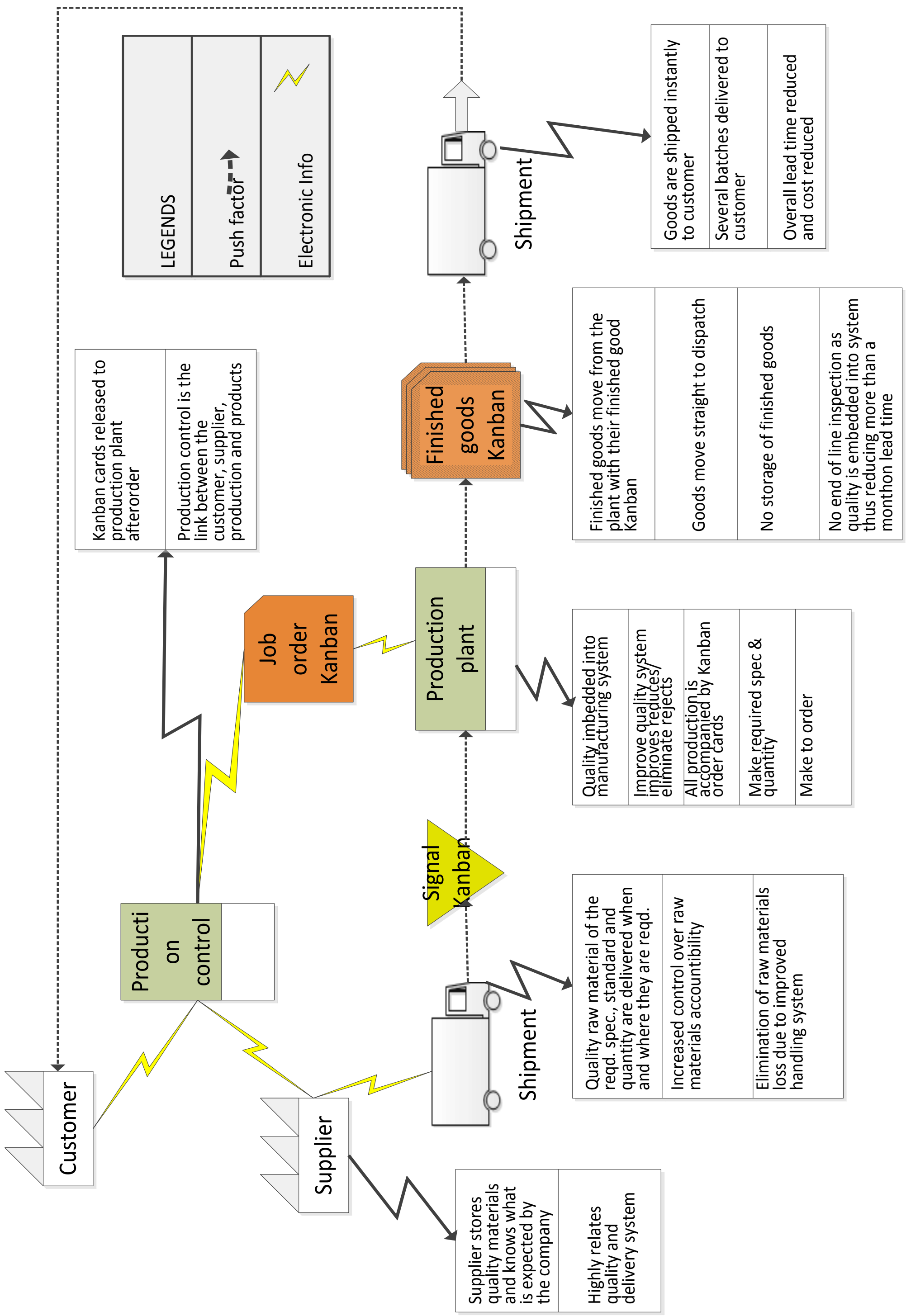

Fig. 5: Future Value Stream map for XY Roofing

5. Conclusions

The need for reduced manufacturing costs for Roofing tiles led to the development of this research, dedicated to identifying the best approach and possible ways to mitigate waste. This paper investigated and analysed the root causes of all wastes and developed current value stream maps for tile manufacturing process and developed a future state map for tile manufacturing to identify improvement to be made to the value stream that would shorten the overall lead time and minimise wastes through the application various lean techniques.

The work presented in this paper has set a base for future work which can be used to develop the lean production system and possibly steps into higher techniques such as Six-Sigma.

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