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Lead Time Reduction and Process Cycle Improvement of an Ice-cream Manufacturing Factory in Bangladesh by Using Value Stream Map and Kanban Board: A Case Study

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ABSTRACT

Background: This study was conducted in an ice-cream factory in Bangladesh in order to improve its production efficiency by reducing long lead time and non-value added activities. **Objectives:** To identify the causes of non-value added times and manufacturing waste, to reduce the lead time and to improve the process cycle efficiency. **Results:** Throughout this study the existing manufacturing line was assayed by using Value Stream Mapping, where current cycle time, lead time, and non-value added time were found to be 521 min, 665 min, and 190 min accordingly; thereby the present process cycle efficiency was calculated at 11.58% that should be improved to be globally competitive. In order to do this; it was proposed to use the just in time and Kanban production philosophy. It was enumerated that after the lean tool implementation the lead time, cycle time, and non-value added time would be reduced to 366 min, 396 min, and 99 min respectively and consequently, the process cycle efficiency would be improved to 21.04%. **Conclusion:** There is a significant effect of lean tools in shortening the lead time and non-value added time and in improving the process cycle efficiency.

INTRODUCTION

Nowadays, in this fast modern global life, customers' aptitudes are changing more frequently compared to in the past, therefore, manufacturing companies need to be dynamic in order to formulate a novel controlled manufacturing strategy which meets customer demand (Zahraee *et al*., 2014). Today, customers want to receive their order within a very short time and they also demand that products should be flawless. As a result, manufacturing companies started to look at how to be more competitive by considering customer satisfaction (Rad, 2008). For more than two decades most of the manufacturers have been faced a critical situation in delivering their goods to customers promptly whilst keeping quality at high levels with minimum costs (Holweg, 2007). To overcome this problem, most of the organizations are attempting to implement the applications of lean principles in order to sustain in the competitive market (Eng Lim Ang, 2015). The concept

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of the lean approach was first developed by Toyota during the 1950s (Srinivasaraghavan and Allada, 2006; Womack, 2006) where the basic principles of lean was to reduce cost of production by the elimination of non-value added (NVD) activities (Wai Seng Foo *et al*., 2015). However, the implementation of the lean principles is still in the rudimentary stage in Bangladesh, with only a limited number of applications in the garment sector. This study was conducted in the KY ice-cream manufacturing factory which is one of the most competitive ice-cream companies in Bangladesh. It should be noted that the real name of the company is not mentioned throughout this study due to confidentiality. The objectives of this study were to evaluate the present state value stream, to propose an improved future state value stream by using a Value Stream Map (VSM), to find out and to reduce the NVD time by carrying out Pareto analysis, to use the Kanban philosophy to reduce the work in process(WIP) inventory, and to improve the process cycle efficiency (PCE).

Literature Review of Lean Production:

After the World War II, the world was facing an economic recession, material resources were very limited everywhere, and in the case of Japan it was very hard to run manufacturing companies, because a significant portion of their resources was destroyed by the War (Askin and Goldberg, 2002). Therefore, it was difficult for Japan to sustain itself in the global competitive market. The country was searching for a way to elate them from this adversity, and they were wondering how to develop a device in order to utilize limited resources at maximum level. As a consequence, while American manufacturers Ford and General Motors (GM) producing mass production, Toyota realized that investing in people was more important than investing in larger machinery. Toyota's basic philosophy was to reduce unexpected manufacturing waste and NVD activities, which was initially known as the Toyota Production System (TPS), and later was modified as lean manufacturing. In 1950, Toyota produced 2,685 vehicles, whilst American manufacturer Ford was producing at around 7,000 cars per day; however, after 40 years, Toyota was producing 4 million cars per year which was double that of Ford, using less labor and making less investment; moreover, the average number of assembly defects per 1000 cars at Toyota was 45 whilst it was 130 at GM (Womack *et al*., 1991) where the noteworthy difference was the lean approach. The lean approach consists of a set of tools; nevertheless, the most frequently used lean tools are the VSM, PCE, 5S, Kaizen, Poka-yoke, Key Performance Indicators, Overall Equipment Effectiveness (OEE), the Ishikawa diagram, Kanban, and the Spaghetti diagram (Bisgaard and Freiesleben, 2004). The VSM has been used since the initiation of lean tools for the identification and constant elimination of manufacturing waste to improve quality, and to reduce production costs and production lead time. A case study was conducted by Grewal (2008) in a bicycle manufacturing company where they endeavored to implement lean manufacturing by using VSM. Seth and Gupta (2005) carried out a study to use the VSM in an auto industry where they suggested that after the implementation of VSM the production lead time could be reduced significantly from 3.215 to 0.54 days. Sahoo *et al* (2008) reported that by using VSM in a forging company the forging defects could be reduced significantly. Sultana and Islam (2011) launched a study in a garment factory of Bangladesh to implement the VSM and they reported that after the implementation of VSM the lead time would be reduced by 65.40% and labor utilization would be improved from 45% to 64%. Samad *et al*. (2013) reported that if the VSM is implemented in a semi-automated garment factory the lead time could be reduced from 9.12 days to 2.04 days. Hossain and Uddin (2015) estimated that with the proper implementation of VSM the PCE could be improve to 24.45% from 10.68% of a mango juice manufacturing plant in Bangladesh. It was estimated by Young and Frank (2006) that by adopting lean tools in the pharmaceutical industry a cost of up to $90 per year could be saved throughout the world. Several hospitals in different countries across the world have started to work with lean tools and the savings obtained for these projects ranges from $57,000 to $229,000 annually (De Knoning etal., 2006; Chalice, 2005; George, 2003). In the USA, it was reported that a food manufacturing industry gained $2 million per year by adopting lean tools (Carlos, 2006).From previous study it was found that there is no preceding experience of lean tools implementation in the ice-cream industry of Bangladesh, although, there are some lucid and hidden causes beyond mass manufacturing waste, and long lead time which could be a large barrier in coming days to contending in both in the regional and global market.

Methodology:

At first, the product family was selected to implement the lean tools. After that primary data were collected for the calculation of cycle time, uptime, batch size, PCE, lead time, and to quantify the NVD time, while secondary data were collected for the evaluation of findings with other regarding studies. In addition, the Kanban or pull system was proposed for future VSM in order to reduce the WIP inventory and achieve a shorter lead time and improved PCE. The whole research work was conducted by using following steps-

Step-1: Product Family Selection:

The current layout of the ice-cream processing line was observed and the product family was selected. Different types of ice-cream are processed within the same factory and each type is different from the others, with little differences. The most similar production stations were followed by a number of products which in together are known as the product family.

Step-2: Data Collection:

The primary data were collected throughout the intense investigation by the authors on the ice-cream processing line and by the review of recorded documents. The secondary data were collected by regarding journals, books, archives, and internet browsing. The cycle time, lead time, VD, and NVD time were recorded by using a stopwatch.

Step-3: Construction of Current State VSM:

The current state VSM was constructed using the overview of the present state production phenomenon as well as the product family value stream. The current state value added time, NVD time, cycle time, uptime, lead time, and PCE were estimated by using the data from the current state VSM.

Step-4: Identification of Causes for Lower Efficiencies:

The causes that were responsible for manufacturing waste, NVD time, lower PCE, and long lead time were identified and quantified in terms of time.

Step-5: Pareto Analysis:

The Pareto chart was constructed where different causes of NVD time were arranged against the cumulative occurrence that was considered in terms of time, in order to find out the 20% causes that are responsible for 80% of manufacturing wastes.

Step-6: Construction of Future State VSM:

A future state VSM was constructed where the Kanban or pull production system was incorporated in order to reduce the WIP inventory, and longer lead time.

Step-7: Cost-Benefit Analysis and Recommendation:

A cost-benefit estimation was formulated to find out the effect of lean tools implementation. Eventually, some recommendations were suggested to implement the lean tools as well as to complete this study.

RESULTS AND DISCUSSION

Case Study:

Bangladesh is suitable for the ice-cream business because of its warm weather and large market, and as a consequence, a number of ice-cream businesses have been emerged in Bangladesh. However, in this study, the elimination of NVD activities and reducing the lead time in order to improve the PCE were the pivotal points of concern rather than the formulation of ice-cream. The studied ice-cream company has been facing a number of hurdles in meeting customer demand due to its long lead time and lower PCE. As the company was headstrong to overcome these hurdles, the authors were invited to formulate a promising value stream by using the lean concept; eventually, this study was conducted during the time period October 2015 to January 2016.

Product Family Selection:

A family of products is a group of products with similar manufacturing or processing routings, and with similar customers with similar needs and demand rates (Neilson, 2008), and it is recognized that all members of the group have a core set of operations that are the same. Duggan (2002) reported that a product family shares at least 80% of the processing steps of the whole production line, but according to Neilson (2008) each member of the product family should be within 30% of the entire production line of a plant. Typically, a group of products is considered as a product family that share a common processing method and are made with the same type of machinery. The KY ice-cream manufacturing company has seven products which are segregated into two parts; product family-1, and product family-2. These two product families followed an almost similar process line except for the freezing of product family-1 (Table-1). However, in this study, the product family-1 was considered to implement the lean tools.

Table 1: Product family matrix

Customer	Name of product	Product Code No	Mixing	Pasteurizing & Homogenizing	Aging	Coloring&Flavoring	Freezing	Hardening	Packaging	Product family
1	Vanilla	5331	1	1	1	1	1	1	1	1
2	Dudemalai	2397	2	2	2	2		2	2	2
3	Lasse	5332	1	1	1	1	1	1	1	1
4	Stick shell	2398	2	2	2	2		2	2	2

5	Mega	5333	1	1	1	1	1	1	1	1
6	Stickchocbar	2399	2	2	2	2		2	2	2
7	Macho	5334	1	1	1	1	1	1	1	1

Implementation of VSM as a Lean Tool:

VSM is the overview of the whole manufacturing floor that contains all materials and information that are required to produce the finished goods from the raw materials. It is a visual representation that facilitates the process of lean implementation by eliminating the NVD steps, identifying manufacturing waste and noticing the location where improvement is necessary. Russel and Taylor (1999) mentioned that if any enterprise wants to become lean, VSM is an excellent tool to execute this. According to Rother and Shook (1999), VSM is a powerful tool that not only discovers process inefficiencies and transactional and communicational mismatch but also advises on improvements. Hines and Rich (1997) reported that VSM is a collection of all VA and NVA activities or times. Jones and Womack (2000) delineated VSM as a process of visually mapping the flow of information and materials, as they are preparing a future state map with a better method and performance. Rother and Shook (1999) have discussed that VSM is used to define and analyse the current state for a product value stream and design a future state focused on reducing waste and lead time and improving workflow. In order to attain noteworthy improvements, Zayko et.al (1997) used VSM as a lean tool to visualize the entire flow that yielded maximum benefits. After all, it can be assumed that VSM is an effective lean tool that can be used to analyze the present conditions of any manufacturing floor in order to find out its NVD activities, and to indicate the focus points where the necessary improvements should be made.

Construction of Current VSM:

The current VSM of ice-cream manufacturing line was depicted as shown in figure-1with the present flow of materials and information throughout its different processing stations. The required data for the construction of current state VSM were documented in Table 2. A timeline is added at the bottom of the VSM recording VD and NVD time prior to the completion of the current state VSM, which helps to see the present state cycle time (C/T), uptime (U/T), changeover (C/O) time, batch size, labor movement, loading and unloading pattern of every processing station from beginning to end.

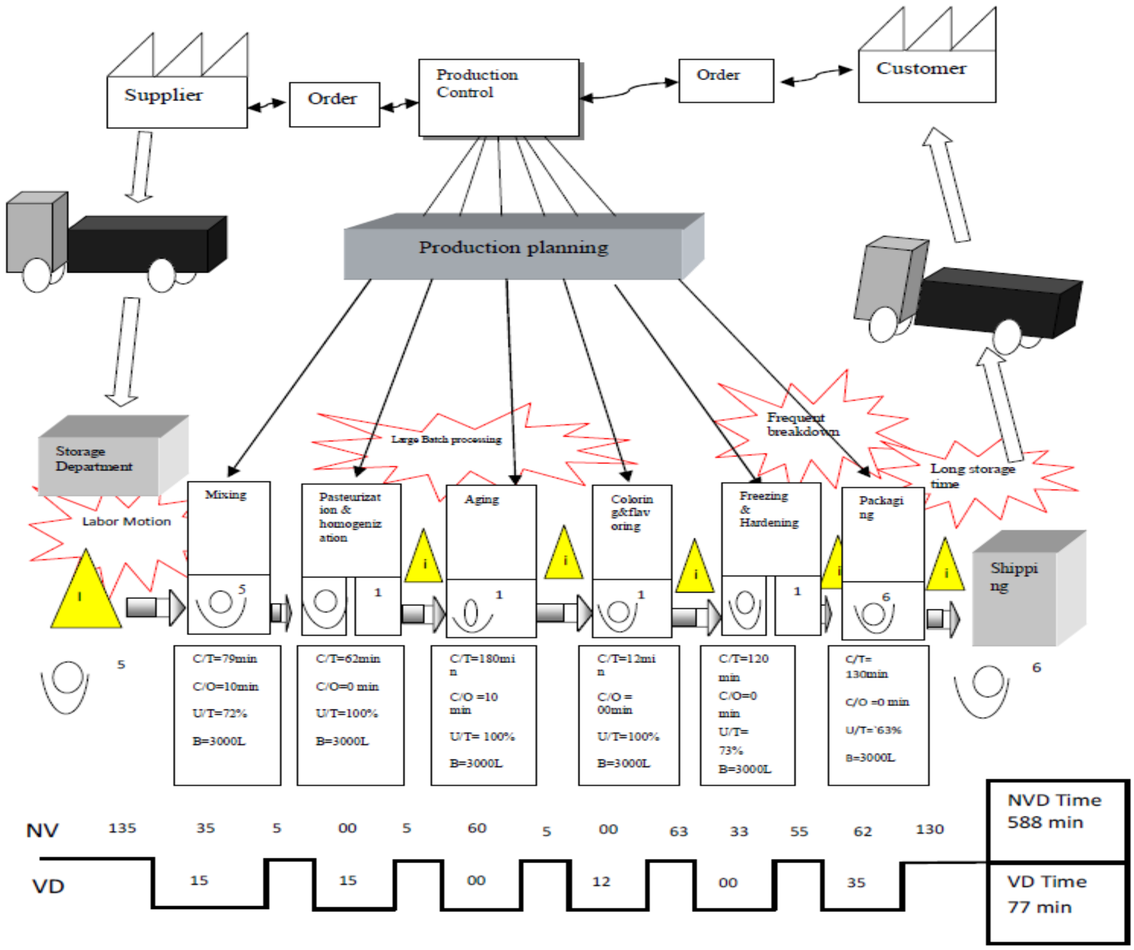

Fig. 1: Current VSM of ice-cream manufacturing line of KY company

Table 2: Required data for current VSM

Process Name	Machine cycle time (C/T) (Min)	Machine idle time (Min)	Uptime (%)	NVD time (Min)	VD time (Min)	WIP (Min)	Loading	Unloading
Mixing	79	21	72	35	15	135	Manual	Auto
Pasteurization & Homogenization	62	00	100	00	15	5	Auto	Auto
Aging	180	00	100	60	00	5	Auto	Auto
Color & flavor adding	12	00	100	00	12	5	Auto	Auto
Freezing and Hardening	120	33	73	33	00	63	Auto	Auto
Packaging	130	48	63	62	35	55	Auto	Manual
Shipping	-	-	-	-	-	130	Manual	Manual
Total	521	102		190	77	398	-	-

The cycle time is the time required to produce a single batch production from a machine, while uptime is the available time for the machine's production, and change over time is the necessary time to make the machine suitable for further uses. As seen from the current state VSM, the VD time, NVD time, WIP inventory, cycle time, machine idle time, total number of labor engagements, present state PCE, and lead time can be estimated. It helps to formulate an action plan to eliminate the NVD activities and longer lead time. It also helps to identify the causes of unexpected NVD time and the large WIP inventory that results in the long lead time and lower PCE. Moreover, it helps to find out which production station has the higher machine idle time and lower uptime so that it can be incorporated in the action plan in order to reduce these times in the future state VSM.

Current State Lead Time:

Lead time is the total time required to complete an order after receiving it from the customer (Cuatrecasas-Arbós *et al*., 2015). Lawson and Porteus (2000) considered the lead time as the time it takes for a unit to go through all the stages in a serial system. Lead time is the sum of the set up time, processing time, move time and waiting time (Alad and Deshpande, 2014). According to the Business Dictionary, a lead time can be defined as the number of minutes, hours, or days that must be allowed for the completion of an operation or process, or must elapse before a desired action takes place. In this study, the manufacturing lead time was considered for analysis. The manufacturing lead time is the summation of VD and NVD time. The present state VD and NVD times were documented as 77 minutes and 588 minutes accordingly, which yields a total lead time of 665 minutes or 11 hours and 5minutes.

Current State PCE:

The PCE can be defined as the percentage ratio of VD time and lead time (Zhen, 2011; Rajenthirakumar *et al*., 2011). Mathematically it is denoted as following –

$$\text{PCE} = \frac{\textbf{Value added time}\times\textbf{100\%}}{\textbf{Lead time}}$$

$$= \frac{\textbf{77}\times\textbf{100\%}}{\textbf{665}} = 11.58\%$$

According to Zhen (2011), the PCE should be more than 25% to be globally competitive. However, to improve the PCE, the NVD time should be reduced and the VD time needs to be increased, which was the objective of this study.

Elimination of Causes of NVD Time by Pareto Analysis:

Different causes of NVD activities at different stages were discovered, quantified in time, and documented in Table 3.The causes were arranged in downward movements in terms of their happening frequency. Now, it is big question how these causes could be removed? What could be the effective tools to remove these causes? The 80/20 Pareto analysis ratio could be the effective answer. According to Hart and Hart (1989), the Pareto chart is one of the seven basic tools of quality control. The Pareto principle is that by doing 20% of work 80% of the advantage of doing the entire job can be generated. Or, 80% problems generated from 20% causes. According to Juran (1998) the Pareto principle is a rule of Thumb which states that 20% of the problems have 80% of the impact. Litten (2010) stated that the application of the Pareto analysis in risk management allows management to focus on those risks that have the most impact on the project. In this study, by using this tool the authors endeavored to find out and to remove the major 20% of causes that are responsible for 80% of NVD activities. The major 20% causes of NVD activities were identified and quantified in terms of time (Table 3).The Pareto chart was constructed by aligning the causes of the NVD activities along the x-axis whilst cumulative percentage of frequencies of these causes was aligned along the y-axis. From the Pareto chart (Figure 2), it seems that if the machine breakdown/idle time, wrapping changes in packaging, unwanted labor motion, and waiting for materials could be reduced, 80% NVD time could be removed from the manufacturing plant. Rajenthirakumar *et al*. (2011) and Idrissi *et al*. (2015) showed that by eliminating the basic three causes (20%) approximately 80% manufacturing wastes could be reduced according to the 80/20 rules.

Table 3: Reasons for NVD time with percentage and cumulative percentages

SL No	Causes of NVD activities	Percentage of NVD time	Cumulative percentage of NVD time
1	Machine breakdown/idle time	29.31	29.31
2	Wrapping changes in packaging	28.45	57.76
3	Unwanted labor motion	21.54	79.30
4	Waiting for materials	5.24	84.54
5	Labour queue	4.11	88.65
6	Incorrect materials supply	3.22	91.87
7	Packaged products queue	2.41	94.28
8	Inadequate labor skills	2.25	96.53
9	Wrong use of tools and materials	1.78	98.31
10	Missing sequences	1.69	100

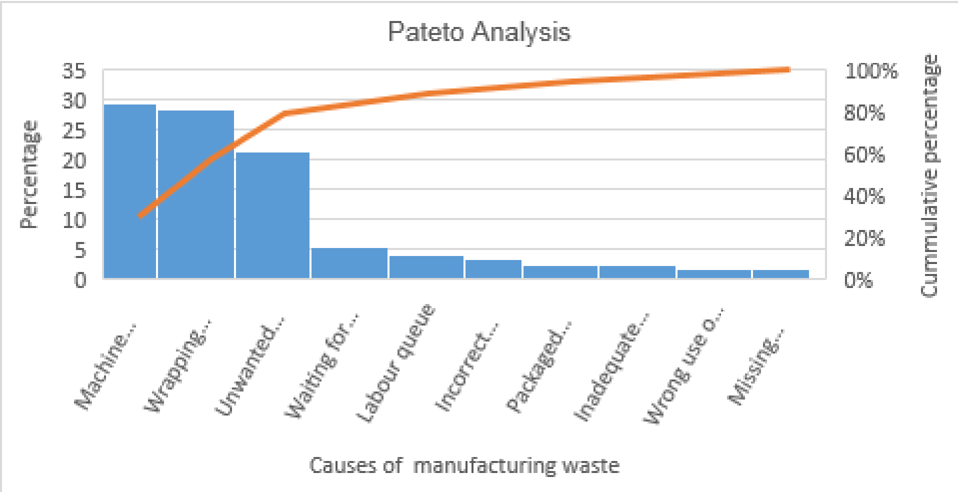

Fig. 2: Pareto chart

Just in Time (JIT) Manufacturing Using Pull System and Kanban:

JIT is one of the most effective lean tools which depict a management strategy that improves the production strategy by inventory reduction. It helps to ensure the sufficient production of output from the limited available input in order to mitigate the market demand (Hemendra Lal Gunasekaran *et al*., 2015).JIT was first introduced in Toyota by Taiichi Onho in the early 1970s and they found it as one of the most effective strategies of production management in order to produce the right quantity of parts at the right location and at the right time within the minimum production costs (Savsar,1997). A few promising advantages such as reduced inventories, shortened lead time, and maximum utilization of equipment and workers have been achieved in a number of organizations after the successful JIT implementation (Dorion *et al*., 2015).Nevertheless, the successful implementation of JIT cannot be considered without Kanban which is considered as a basic tool to establish JIT manufacturing (Chan, 2001).Etymologically, Kanban is a Japanese word meaning signboard or billboard where "Kan" means visual, and "Ban" means card or board. According to Singh (1995), the Kanban system was developed by Mr. TaiichiOhno who was a vice president of Toyota. Sharma and Agrawal (2009) considered Kanban as the most preferable WIP inventory control policy. The Kanban production system is controlled by using cards known as Kanban containing production information which is rectangular in shape. There are two types of card: one is the Withdrawal Kanban (WK) and the other is the Production Ordering Kanban (POK). Both of two Kanban contain specific information such as product or parts, part names, quantity per Kanban container or unit, production order, consumer order etc. A WK determines the quantity that needs to be removed from the following working station while a POK determines the quantity that needs to be replenished in the subsequent production station in order to maintain a balanced inventory between two production stations. Actually, no production is allowed without the POK which permits the processing of parts. On the other hand, without the WK no container can be moved from an outbound buffer towards the downstream. Every Kanban card is attached to each Kanban container, where the quantity and container number is determined based on the customer order and production batch size (Apreutesei *et al*., 2010). Batch production is known as pull system production which is important for maintaining the continuous WIP inventory on the production floor which is the basic objective of JIT; therefore, Ou and Jiang (1997) considered the pull system as one of the crucial elements in JIT manufacturing. Pull production is conducted by taking the order from the customer and the production is carried out considering the demands of the customer. On the other hand, without considering the customer demand and the customer order, mass production is considered by the push system production which creates a common WIP inventory in the production line. According to Spearman *et al*. (1990), the loading schedule is not important in a pull system because the initiation of the production of any parts is actuated by the accomplishment of another stations' production at the downstream. The pull system is effectively performed by visual management where Kanban is one of the basic tools that help with the quick detection of operation problems such as machine failure, unwanted labor motion, and WIP inventory. It seems that in order to satiate customer demand JIT manufacturing is very important, to use the JIT manufacturing pull system production is very crucial, and for the successful completion of pull system production Kanban is necessary. Consequently, it seems that JIT, pull system production, and Kanban are complementary components for the reduction of WIP inventory and the reduction of lead time.

The Operation of Kanban:

The total quantity of a single batch is divided into a number of identical units which is known as a Kanban unit or card. Every Kanban unit corresponds to one container of parts. The number of Kanban card depends on the quantity of the customer demand and size of Kanban unit. After receiving the customer order, the production controller authorized the Kanban card that carried the signals throughout the different work stations and after reaching the end station this card was flowed backward (Spearman *et al*., 1990; Chan, 2001). After that, the first workstation again received a container tagged with a Kanban to produce a new batch of goods upon the completion of single batch production. Moreover, if a breakdown occurred in the downstream station no Kanban should be issued by the production supervisor; therefore, WIP inventory can be tightly controlled (Marek *et al*., 2001). It is important to control the order number of the container in order to maintain the balanced inventory at every production station. It seems that upon getting a sanction of Kanban a pre-determined production sequence need to be formulated in order to replenish the input inventory of the downstream production station up to a marked level (Seidman and Holloway, 2002). If once the production with controlled WIP inventory takes place the Kanban system is confined and cannot be changed except with the special authorization of the production controller (Cao and Chen, 2005). The date when it should be turned in, or dropped is written on the card, and the second date is calculated by adding the lead time of the relevant production line. Now the questions can be raised: how is the number of the Kanban or container determined? By using the following formula, the number of Kanban was calculated (Chan, 2001; Co and Sharafali, 1997).

Kanban card, N= $\frac{D\times(1+SF)\times LT}{K}$

Where, D is the average daily consumer demand, S is the safety factor, LT is the average lead time, and K is the Kanban unit or container size. The safety factor was considered as 10-20% (QAD Inc., 2001) and in this study, it was determined as 15%. The Kanban unit was determined as 320 liters of ice-cream.

In this study, D=6000 liters of ice-cream (the customer's daily demand), SF=15%, LT=665 min or 11.08 h (per single batch), and K=320

So, the number of Kanban, N= $\frac{6000\times(1+0.15)\times\frac{11.08}{24}day}{320}$
$= 9.95 \approx 10$ (for two batch per day)

It seems that in order to control the right quantity of WIP inventory, 10 Kanban cards (either WK or POK or both) should be allowed for two shift productions per day.

Future VSM of Ice-Cream Processing Line:

A future VSM was constructed by considering a value stream design by using lean philosophy throughout the reduction of the root causes of NVD activities in order to establish the continuous and smooth flow of production as shown in figure-3. The required data to construct the future VSM is summarized in Table 4. It was estimated that the cycle time, up time, and lead time would be reduced and the PCE would be improved after the implementation of lean tools. It can be seen from figure 3 and Table 4 that if the proposed lean tools could be adopted the cycle time, lead time, NVD, machine idle time, labor involvement and WIP inventory could be reduced; on the other hand, the PCE would be improved. Kanban tool was proposed to involve in the production management strategy to eliminate the WIP inventory that heads to the reduction of lead time (Alad and Deshpande, 2014). The WK and POK were used interchangeably according to the requirement at future VSM. It was estimated that after the lean tools implementation the uptime of mixing, freezing and hardening, and packaging could be improved to 75%, 92%, and 67% respectively at future state which were estimated 72%, 73%, and 63% accordingly at present state.

Table 4: Required data for future VSM

Process Name	Machine cycle time (C/T) (Min)	Machine idle time (Min)	Uptime (%)	NVD time (Min)	VD time (Min)	WIP (Min)	Loading	Unloading
Mixing	55	14	75	18	15	62	Manual	Auto
Pasteurization and Homogenization	62	00	100	00	15	5	Auto	Auto
Aging with Coloring&Flavoring	90	00	100	30	12	5	Auto	Auto
Freezing and Hardening	95	8	92	8	00	27	Auto	Auto
Packaging	94	31	67	43	35	33	Auto	Manual
Shipping	-	-	-	-	-	58	Manual	Manual
Total	396	53	-	99	77	187	-	-

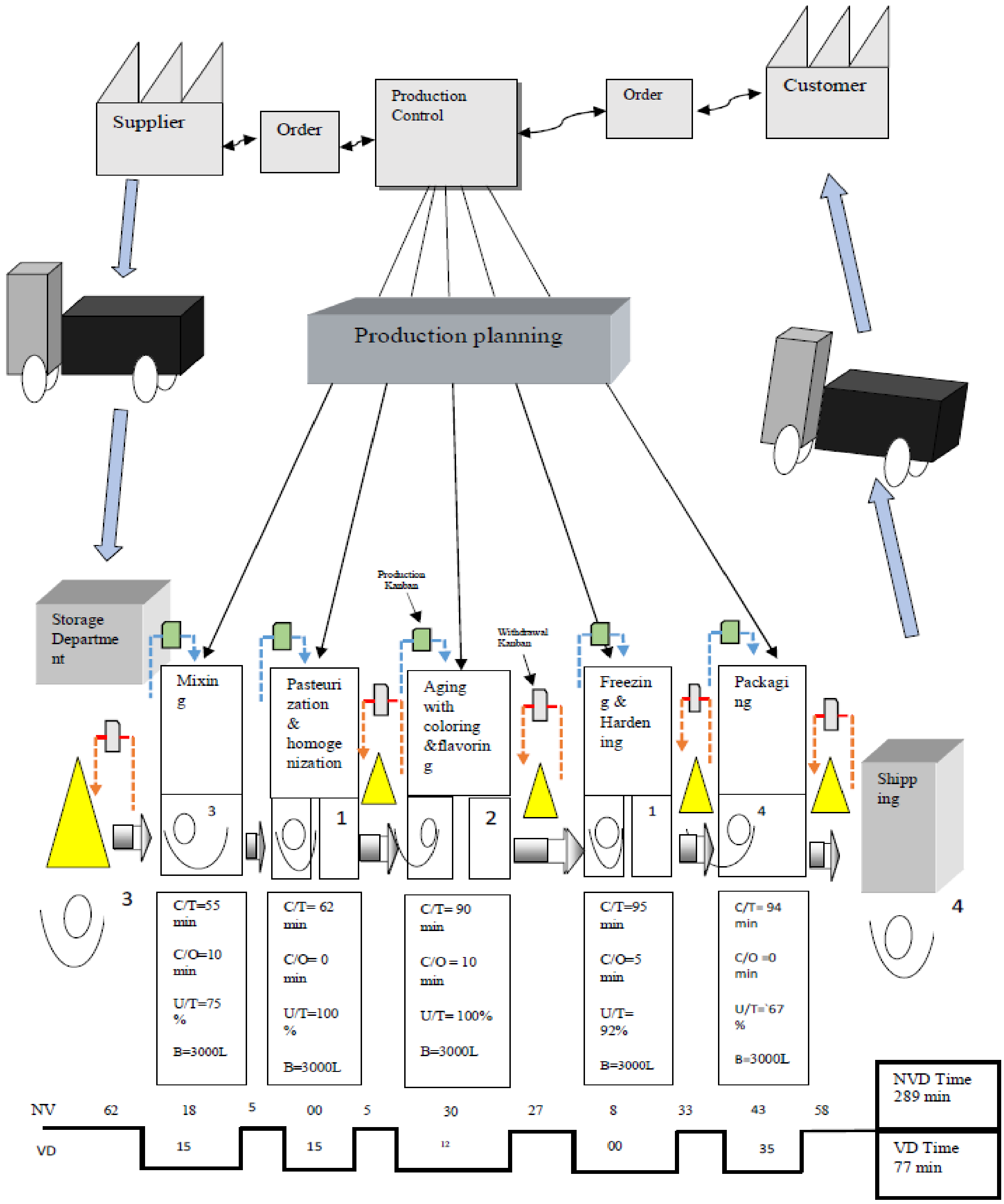

Fig. 3: Proposed future VSM of ice-cream manufacturing line of KY company

Future State PCE:

As earlier it is mentioned that according to Zhen (2011) and Rajenthirakumar *et al.* (2011) PCE is the percentage ratio of VD time and lead time which can be denoted as following –

$$\text{PCE} = \frac{\textbf{Value added time} \times \textbf{100\%}}{\textbf{Lead time}}$$

$$= \frac{\textbf{77} \times \textbf{100\%}}{\textbf{366}} = 21.04\%$$

It is clearly apparent that the expected PCE would be more competitive after the involvement of lean philosophy in the production management strategy.

Cost-Benefit Analysis:

A cost-benefit analysis was conducted and is summarized in Table 5. The substantial cost savings were unveiled by this analysis. It was estimated that with the proper implementation of proposed lean tools the cycle time, machine idle time, NVD time, WIP inventory, lead time, and labor engagement would be reduced by 24%, 48.03%, 47.89%, 34.42%, 53.02% and 30.78% respectively (Table 5) whilst PCE would be improved by 52.16%; moreover, a cost of $1063 per month could also be saved.

Table 5: Cost benefit analysis after lean tools implementation

SL No	Considered points	Before improvement at present state	After Kaizen at future state	Improvement
1	Cycle time (in minutes)	521	396	24% reduction
2	Machine idle time (in minutes)	102	53	48.03% reduction
3	NVD time (in minutes)	190	99	47.89% reduction
4	WIP inventory (in minutes)	398	187	34.42% reduction
5	Lead time (in minutes)	665	366	44.96% reduction
	PCE	11.58%	21.04%	81.69% improved
6	Labor engagement	26	18	8 Labor or 30.78% reduction
8	Total cost per labor per month	12000 Taka		
9	Cost saving per month by labor reduction	84000 Taka= $1063		

Conclusion:

This research paper depicts a systematic approach about how to use the lean tools in an ice-cream manufacturing plant in order to reduce the lead time and to improve the PCE. The different causes of longer lead time, and WIP inventories were identified and suggested to reduce the most frequently occurring incidents (20%) to save the maximum loss (80%). In addition, a cost-benefit analysis was conducted which unveiled that the lean tools implementation has a significant influence in profit maximization by reducing the production cost. Finally, it was recommended to follow this study for the lean tools implementation in the studied ice-cream manufacturing plant.

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