A Study to Reduce the Lead Time of a Bakery Factory by Using Lean Tools: A Case Study

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Abstract- This study was carried out in a Bread production floor of Z Bakery factory in Bangladesh. The basic target of this study was to reduce the lead time of the observed Bread production floor. The lean tools like Value Stream Map (VSM), Process Cycle Efficiency (PCE) and Pareto Analysis were used to reduce the lead time. Lead time is the summation of value added (VD) time and non value added (NVD) time. It was observed a number of causes that were responsible for long lead time. Pareto principles were used to find out, quantified and also to reduce the causes prior to short lead time. Takt time and PCE of the Bread production floor were also evaluated which are considered as the process capability factors. At present state, lead time PCE and Takt time were observed consecutively 32605 sec, 12.86% and 19.94 sec/Bread. Eventually, after the proper implementation of lean tools, at future state, the lead time, PCE and Takt time would be 18742 sec, 29.98% and 10.69 sec/Bread.

Index Terms- Bread production floor, Lean tools, PCE, Takt time, Value Stream Map

I. INTRODUCTION

World is very competitive where the basic concern of a manufacturing company is to incase their customers' satisfaction by constantly improving their delivery yet, to keep quality at its best level. At the same time, the companies need to keep their costs and prices as low as possible to be able to compete with others by keeping their profitability. In order to achieve this, a company should have a very good control on its production system. A company should have a strong vision and clear idea of its future goals to establish the most effective production system.Today the use of lean tools in the manufacturing world has been remarkably increased because of its impressive power in manufacturing waste and lead time reduction. However, this study was conducted in a Bread production floor of Z Bakery Company in Sylhet, Bangladesh. The stated bakery company was endeavored to reduce its long lead time, but they were not able to reduce it even though by taking big capital investment. In this circumstance, the author was convinced to implement the lean tools towards reducing the unwanted long lead time. It was also attempted to reduce the Takt time and improve the Process Cycle Efficiency (PCE) along with the reduced long lead time.

II. HISTORY OF LEAN TOOLS

Many companies are now facing very strong competitors; therefore, it is very emergence to eliminate any actions that do not produce any value. It is very true for companies to survive; they must be able to maximize their outputs by using minimal inputs. Lean tools have been defined as the means of maximizing output by the reduction of waste in all forms [1]. According to Dennis [2] lean tools were first used in Toyota Production System (TPS) that brought the revolutionary change in the mindset of manufacturers in the search of quite perfection with its effects to the actions as well as to the visions. According to Lathin [3] lean manufacturing is an approach that can be used to maximize the use of resources while keeping processes simple. It achieves this by using less of everything like human effort, manufacturing space, tooling investment, and engineering hours spent in designing new products, a reduction in inventory and a number of defects can also be reduced. In the last century the main focus of any company was the customers. Gaither [4] stated due to global competitive business, customer's satisfaction has become more and more competitive to manufacturers. Consequently, to execute the business in a global market short lead times become the essential key to provide customer satisfaction. Organizations that have on cycle time as a productivity measure can reduce delivery time and improve quality, thereby creating more satisfied customer. Harrington [5] reported by eliminating the NVD activities from the processes and streamlining the flow of value towards the finished products and services significant lead time reduction can be achieved. Womack & Jones [6] mentioned that lean tools as dynamic wheel for NVD times and manufacturing waste reduction towards lead time reduction. Lean is a unique approach to eliminate the excess production and inventory, redundant movement of material, waiting and delays, over processing, excess worker motion, and the need for rework and corrections. Wilson [7] defined the lean as a comprehensive set of techniques which in combined allows to reduce the wastes that makes the company more flexible and more responsive to customers. Nash, et al. [8] defined the lean as the systematic approach to identifying and eliminating NVD activities through continuous improvement by flowing the product or service at the pull of your customer in pursuit of perfection. Womack and Jones [6] considered the lean as a set of tools to create the value to the customer with little or no waste existing in operation. According to Holweg [9] the implementation of lean toots is focused on getting the right things to the right place at the right time in the right quantity to achieve perfect work flow, while minimizing the waste. Fled [10] defined the lean as an approach that is used in order to develop the highest quality of products, at the lowest cost, with the shortest lead time by systematically and continuously eliminating waste, while

respecting people and the environment. Different organizations and different researchers are given the lean principles at different ways, keeping the same focus on process improvement. Mintz [11] reported the lean principles which were given by the Lean Enterprise Memory Jogger as- improving quality, eliminating waste, reducing lead time and reducing total cost of a process. Today the use of lean tools in the manufacturing world has been lucratively increased because of its impressive power in manufacturing waste and lead time reduction.

III. RESEARCH METHODOLOGY

In this study, Z Bakery factory was the population and its Bread production floor was the sample. The primary data were collected and documented by the direct observation of set up time, machine function, material and labor flow at each and every processing stages of the production line. The observed time was recorded by a stopwatch. The secondary data were collected through the internet, books, journals, related studies and other sources of information. To find out and to eliminate the manufacturing wastes and unwanted non value adding activities lean tools like VSM, PCE and Pareto analysis were used.

Value Stream Map (VSM)

According to Rother and Shook [12] VSM is a lean manufacturing technique used to analyze and design the flow of materials and information required to bring a product or service to a consumer. At Toyota, where the technique originated, it is known as "material and information flow mapping". Murman [13] mentioned that the lean Aerospace Initiative at MIT describes the objective of VSM as an important lean practice to eliminate waste and make the VD steps 'flow' in meeting customer requirements. The value stream is further described by Womack and Jones [6] in lean thinking: "A VSM identifies every action required to design, order, and make a specific product. The actions are sorted into three categories: (1) those that actually create value as perceived by the customer; (2) those which create no value but are currently required by the product development, order filling, or production systems; and (3) those actions which don't create value as perceived by the customer and can be eliminated immediately".

Process Cycle Efficiency (PCE)

PCE is one of the most useful lean tools that are widely using to evaluate the efficiency of an organization or a project or a process. According to Zhen [14] PCE is the percentage of ratio of value added and lead time.

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

Where, lead time = VD time +NVD time.

Pareto Analysis

It is a statistical technique in decision making that is used for selection of a limited number of tasks that produce significant overall effect. It uses the Pareto principle. The Pareto principle also known as the "80/20 Rule" – which is the idea that 20% of causes generate 80% of results. With this tool, we're trying to find the 20% of work that will generate 80% of the results that doing all of the work would deliver. Under this assumption that, in all situations, it is convinced that 20% of causes responsible for 80% of problems creation. Indeed, this ratio is simply a convenient rule of thumb and it should not be considered immutable law of nature. David [15] stated the application of the Pareto analysis in risk management allows management to focus on those risks that have the most impact on the project. The steps to identify the important causes using 80/20 rule are as follows-

Step 1: Form an explicit table listing the causes and their frequency as a percentage.
Step 2: Arrange the rows in the decreasing order of importance of the causes (i.e., the most important cause first)
Step 3: Add a cumulative percentage column to the table
Step 4: Plot with causes on x-and cumulative percentage on y-axis
Step 5: Join the above points to form a curve
Step 6: Plot (on the same graph) a bar graph with causes on x-and percentage frequency on y-axis
Step 7: Draw line at 80% y-axis parallel to x-axis. Then drop the line at the point of intersection with the curve on x-axis. This point on the x-axis separates the important causes (on the left) and trivial causes(on the right)
Step 8: Explicitly review the chart to ensure that at least 80% of the causes are captured [16]

Takt Time

Takt time can be defined as the time required producing one unit of daily salable quantity [17]. The purpose of takt time is to precisely match production with demand. It provides the heartbeat of a lean production system. At first, Takt time was used as a production management tool in the German aircraft industry in the 1930s.Takt time can be first determined with the formula:

$$T = \frac{T_a}{T_d}$$

Where

T = Takt time, e.g. [work time between two consecutive units]

T_a = Net time available to work, e.g. [work time per period]
T_d = Time demand (customer demand), e.g. [units required per period]
Net available time is the amount of time available for work to be done. This excludes break times and any expected stoppage time (for example scheduled maintenance, team briefings, lunch time etc.).

IV. RESULTS AND DISCUSSIONS

As earlier it is mentioned that this study was conducted in a Bread production floor. The ingredients come from different sources which are mixed together that are termed as dough that is finally formulated into Bread through a number of processing stages. The basic stages of Bread processing line are shown in figure 1.

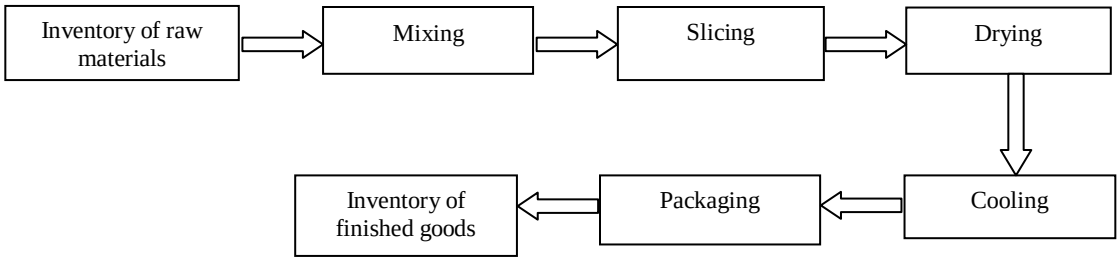


Figure1: Basic stages of Z Bread production floor

Present VSM of Z Bread production floor

The VSM was used to evaluate the VD and NVD time of studied Bread production floor. Cycle time, uptime, changeover time and lead time are very important to build the VSM. Cycle time is the time that elapses between one parts coming off the process to the next part coming off. Uptime is the time when the equipment system is in a condition to perform its intended function. It includes productive, standby, and engineering time, and does not include any portion of downtime or nonscheduled time [18]. Manufacturing lead time can be defined as total time it takes to manufacture an item, including order preparation time, queue time, setup time, run time, move time, inspection time, and put away time. It is the time interval between the initiation and the completion of a production process. For make-to-stock products, it is the time taken from the release of an order to production and receipt into finished goods inventory. The required data for the construction of present VSM were collected and in Table 1.

Table 1: Required data for present VSM

Processing stage	VD time (sec)	NVD time (sec)	Cycle time (sec)	Mean down time (sec)	Up time (%)	Change over time (sec)	Number of labor
Receiving inventory	00	12600	-	-	-	-	3
Mixing	483	787	590	107	82	15	8
Slicing	832	558	1110	278	75	10	6
Drying	1077	1098	1475	398	73	15	2
Cooling	912	1348	1600	688	57	10	4
Packaging	877	433	1310	433	67	10	8
Shipping inventory	00	11600	-	-	-	-	3
Total	**4181**	**28424**					**34**

Note: **VD time-** that is desired which add the value to goods or service; **NVD time-** that is not desired or that does not add any value to goods or service

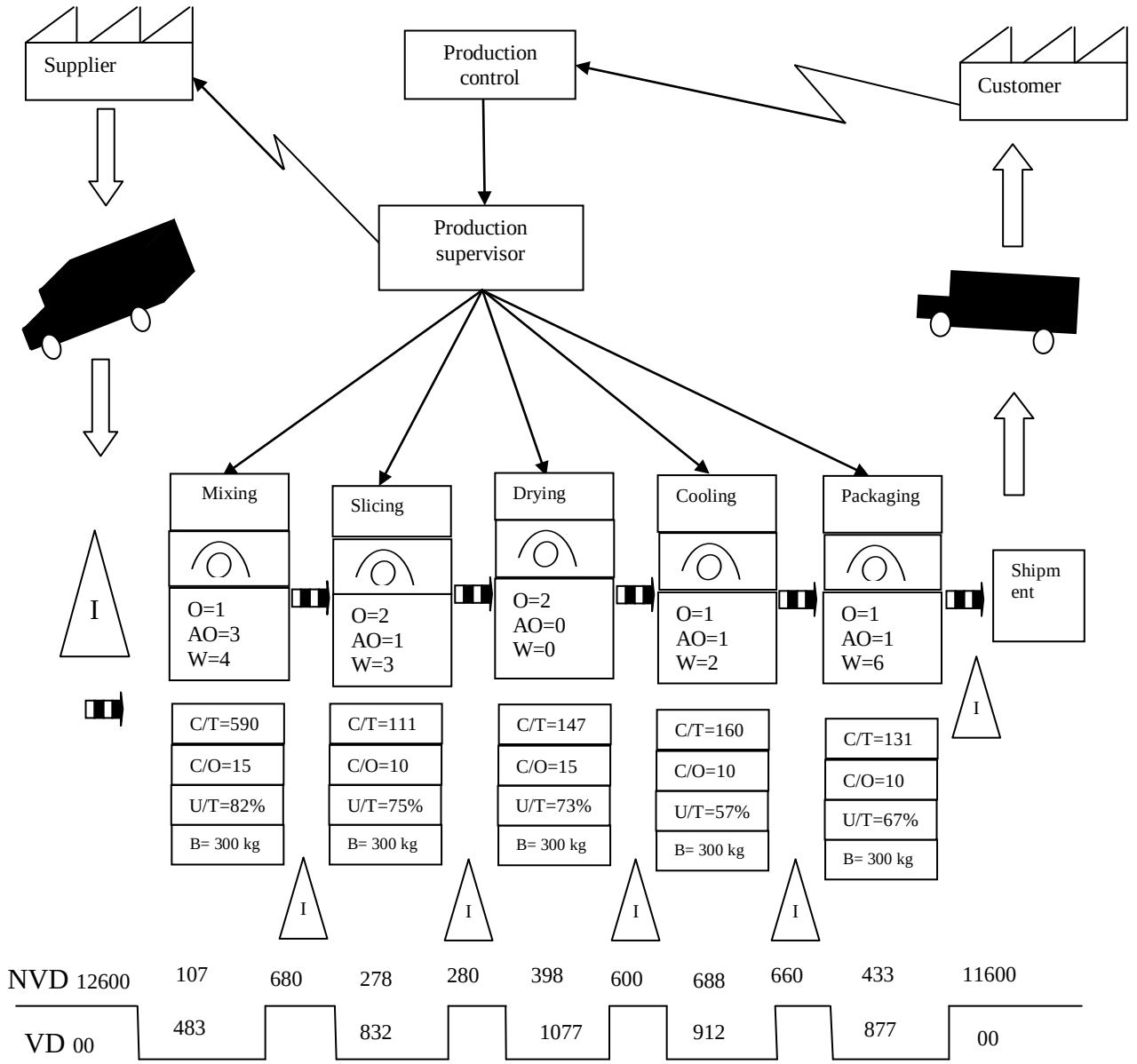


Figure 2: Present VSM of Z Bread production floor

From the present VSM, total VD & NVD time were observed respectively 4181 sec and 28424 sec from the bottom line of the figure 2. The up time of mixing, slicing, drying, cooling and packaging were observed 82%, 75%, 73%, 57% and 67% respectively. It is expected that after the implementation of lean tools up time would be improved. Likewise, the changes over time, cycle time, labor engagement were also be assumed from present VSM. The batch size was 300 kg; single Bread weight was 200g; each batch produces 1500 Bread. The in process inventory was observed between each two processing stages at high that could be reduce by using lean tools.

Present PCE of Z Bread production floor

At present state, VD and NVD time was calculated consecutively 4181 sec and 28424 sec, so the lead time was 32605 sec. As earlier, it was mentioned that-

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

$$\text{PCE} = \frac{4181 \times 100\ \%}{32605} = 12.82\%$$

It seems that at present state, the PCE was 12.82%. But according to Zhen [14] a productive floor PCE is need to be more than 25% to be globally competitive. In this study it was endeavored to increase the present PCE by using lean tools.

Present Takt time of Z Bread production floor

Working shift per day	=2 shift
One shift time	=9 hours and 4 minutes or 32605 sec
Two shift time	=18 hours and 8 minutes or 65210 sec
Total change over time	=1 hour or 3600 sec
Lunch time	=30 minutes or 1800 sec
Net available time per day	=Two shift time – (Total change over time + Lunch time)
	= 65210 sec – 5400 sec
	= 59810 sec
Daily saleable demand	=300 kg or 3000 Bread (each brad is 200 g)

$$\text{Takt time} = \frac{59810}{3000} = 19.94 \text{ sec/Bread}$$

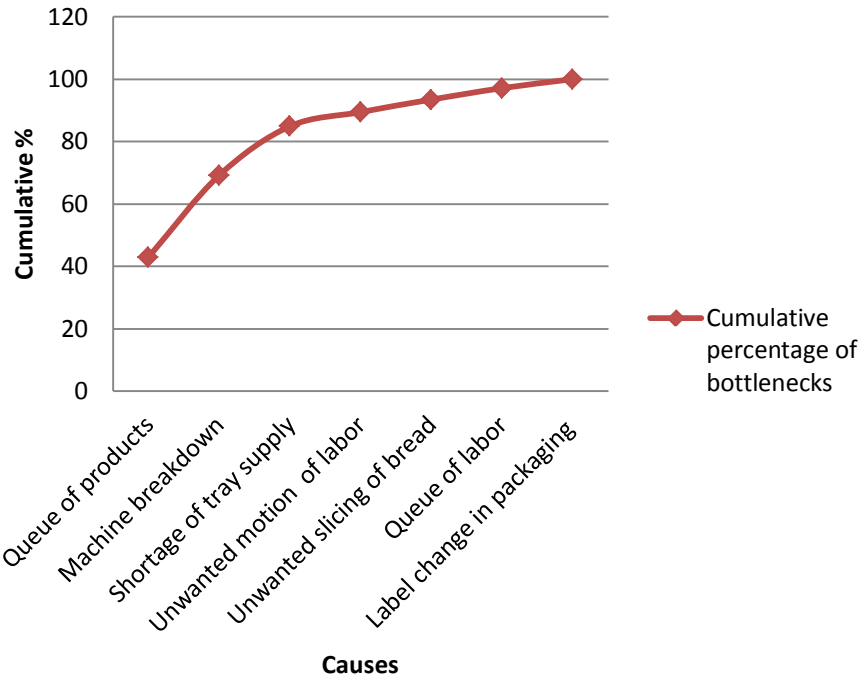
Causes for NVD time/ activities or bottlenecks

Different types of causes were observed for different types of bottlenecks like- defect product production, machine breakdowns, overproduction, waiting or queuing, unnecessary processing, unnecessary inventory, unnecessary transportation between work sites, and unnecessary motion of labor in the work place. These causes were identified, quantified and arranged in descending order in Table 2, prior to apply the Pareto analysis. Pareto chart was depicted by using data from Table 2 in figure 3. It is clearly observed from Pareto chart that the cause's like- queue of products in production floor and machine breakdown are responsible for the creation of 80% bottlenecks. As a result, by considering this philosophy the regarding production management can take the initiatives in order to remove these basic causes; eventually the company can get the speed up production towards the competitive lead time.

Table 2: Percentage and cumulative percentage of different types of causes that are responsible for bottlenecks

Causes of bottlenecks	Percentage of bottlenecks	Cumulative percentage of bottlenecks
Queue of products in production floor	42.97	42.97
Machine breakdown	26.22	69.19
Shortage of tray supply	15.71	84.90
Unwanted motion of labor	4.55	89.45
Unwanted slicing of Bread	4.01	93.46
Queue of labor	3.67	97.13
Label change in packaging	2.87	100.00

Figure 3: Pareto chart



Future VSM of Z Bread production floor

In order to draw the VSM, it is needed to know the clear information of some factors like VD & NVD time, cycle time, mean down time of machine, machine up time, change over time and total number of labor engaged in the production floor. All required data for the construction of future VSM were observed and documented in Table 3.

Table 3: Required data for future VSM

Processing stage	VD time (sec)	NVD time in sec (% of reduction of present state)	Cycle time (sec)	Mean down time in sec (% of reduction of present state)	Up time (%)	Change over time (sec)	Number of labor
Receiving inventory	00	6300 (50%)	-	-	-	-	2
Mixing	558	236 (70%)	590	32 (70%)	94.58	15	5
Slicing	1024	167(70%)	1110	83 (70%)	92.52	10	3
Drying	1395	220 (80%)	1475	80 (80%)	94.57	15	2
Cooling	1462	270 (80%)	1600	138 (80%)	91.37	10	3
Packaging	1180	130 (70%)	1310	130 (70%)	90.07	10	5
Shipping inventory	00	5800 (50%)	-	-	-	-	2
Total	**5619**	**13123**					**22**

Note: VD time that is desired which add the value to goods or service NVD time- that is not desired or that does not add any value to goods or service

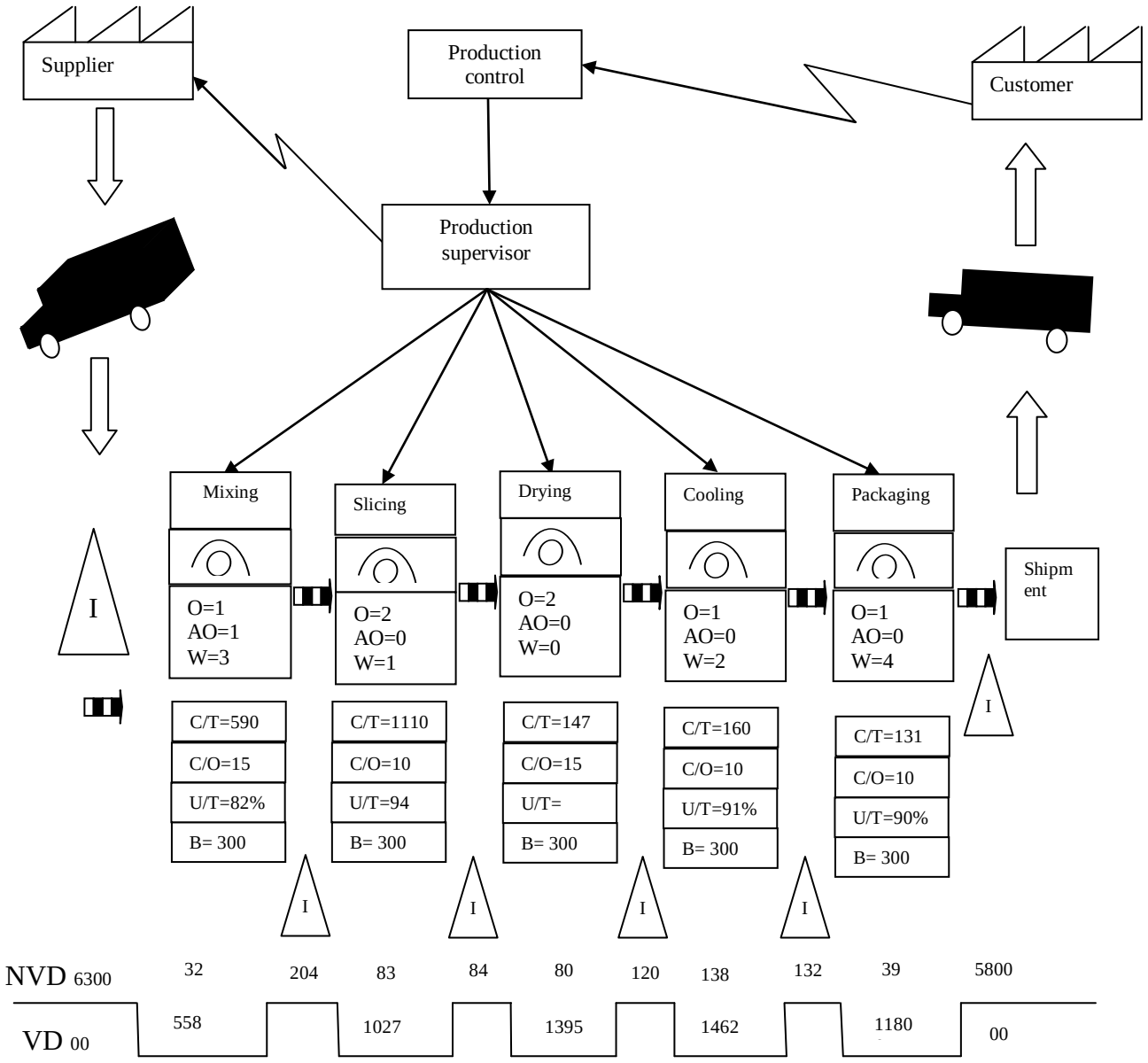


Figure 4: Future VSM of Z Bread production floor

At future VSM, it is observed that NVD time and total number of labor are reduced; VD and up time are increased; in process inventory delay time is also reduced. Ultimately it seems that after the implementation of lean tools or lean philosophy lead time would be reduced.

Future PCE of Z Bread production floor

At future VSM, in the Z brad production floor, reduced NVD time and increased VD time were observed, therefore, an improved PCE was calculated.

Value Added time = 5619 sec
Non Value Added time = 13123 sec
Lead time = Value Added time + Non Value Added time
= 5619 sec + 13123 sec

$$= 18742 \text{ sec}$$

$$\text{PCE} = \frac{Value\ Added\ time \times 100}{Lead\ time}$$

$$= 29.98\ \%$$

It seems that at future state, the PCE would be 29.98% which could be globally competitive [14].

Future Takt time of Z Bread production floor

Working shift per day	= 2 shift
One shift time	= 5 hours and 13 minutes or 18742 sec
Two shift time	= 10 hours and 26 minutes or 37484 sec
Total change over time	= 1 hour or 3600 sec
Lunch time	= 30 minutes or 1800 sec
Net available time per day	= Two shift time – (Total change over time + Lunch time)
	= 37484 sec – 5400 sec
	= 32084 sec
Daily saleable demand	= 300 kg or 3000 Bread (each brad is 200 g)

$$\text{Takt time} = \frac{32084}{3000} = 10.69 \text{ sec/Bread}$$

V. CONCLUSION

In this study, an attempt has been made to improve the productivity and make the speed up of Z Brad company by using lean tools. The basic improvements were observed for lead time, PCE, and Takt time between present and future state. At present state, the lead time, PCE and Takt time were observed consecutively 32605 sec, 12.82% and 19.94 sec/bread (200g). However, it was calculated that after the implementation of lean tools at future state, the lead time, PCE and Takt time would be consecutively 8742 sec, 29.98% and 10.69 sec/ bread (200g). Finally, it was suggested to Z Brad company to implement the proposed lean tools prior to get the expected short lead time.

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