ISSN 2229-5518

A Case Study to Reduce the Manufacturing Waste Prior to Improve the Productivity Factors of a Litchi Juice Production Plant by Using Value Stream Map and Six Sigma Scale

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Abstract

This paper depicts how the Value Stream Mapping (VSM) process was used to eliminate the manufacturing waste in a litchi juice production plant of Y food and beverage industry in Bangladesh. A current VSM of litchi juice production line was constructed. Data for constructing the present VSM was collected through production line visits, interviews of workers and observation of machine's function at different production stages. Different causes of non value adding (NVD) activities were discovered by Present VSM. Six sigma central concepts were used to evaluate the present view of manufacturing waste. At present state, it was found three sigma productions, lower PCE (10.68%), and long lead time (86728 sec). After the involvement of Pareto principles, 5S, JIT and Kaizen philosophy in the production system, it was evaluated that future state PCE would be improved to 24.45%, and lead time would be reduced to 37912 sec.

Index Terms- Value Stream Map, Six Sigma, Litchi Juice, Process Cycle Efficiency, Manufacturing Waste

1 Introduction

Litchi is one of the most promising arable fruits in the northern part of Bangladesh; subsequently, its juice has been becoming emerging part in the beverage industry. Recently, one of the largest litchi juice production plants of Y food and beverage industry of Bangladesh has been experiencing a competitive force in the manufacturing world due to their huge manufacturing waste and long lead time; therefore, they are seeking an effective tool to make them competitive by reducing waste, shortening lead time and ultimately improving the Process Cycle Efficiency (PCE). Indeed, it is true that if the unwanted production waste can be reduced this business could be more profitable. In this essence, the authors were motivated in order to implement the lean tools and six sigma central concept in the litchi juice production plant, because lean tools and six sigma scale are widely using at different manufacturing industry around the world as an effective means to reduce the manufacturing waste and lead time. The objective of this study is to use case-based method to illustrate how lean tools and six sigma central concept

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work place that could be promising for the increased productivity of workers through more economical use of when used appropriately, can help the industry to reduce the manufacturing waste, and lead time and obtain better operation control, therefore improve the productivity factors.

2 Literature approach

Nowadays it is well known in the production world that lean philosophy has been introduced in the Toyota Production System (TPS) after the Second World War and during these days it is widely using in different organizations. Over the time, there has been considerable maturation of concept of lean approach; therefore it has no consistent definition. Although, different authors have been providing different corners and languages to substantiate the lean approach, they are focusing into the same goal to remove the unwanted activities from the production line. Ronald [1] expressed that lean is a philosophy of manufacturing that incorporates a set of principles, tools and techniques into the business process prior to optimize time, human resources, assets, and productivity, while improving the quality of products and services to their customers. Wilson [2] defined the lean as a comprehensive set of techniques which in combined allows to reduce and eliminate the wastes that makes the company leaner, more flexible and more responsive to customers. According to Lim and Hoffman [3] lean approach is the improved layout of the hand movements. Bisgaard and Freiesleben [4] mentioned that the most frequently using lean tools are Value Stream Mapping (VSM), Process Cycle Efficiency, 5S, Kanban, Poka-yoke, Key performance indicators, Overall Equipment

Effectiveness, Ishikawa diagram and Spaghetti diagram. Nevertheless, using lean tools can be different from one organization to others due to their nature, but in the case of waste identification and elimination VSM is the most effective and popular tool in the manufacturing industry. Consequently, by this study it was intended to use the VSM in the litchi juice production plant prior to find out and elimination of manufacturing waste and ultimately make its business more competitive and profitable. Looking at available literature the present work is the first attempt in Bangladesh that explores the use of lean principles in a litchi juice production plant and provides direction for future continuous improvement.

3.0 Working methodology of the study

This study aimed at reducing the manufacturing waste and NVD activities so that the company could be able to increase their revenue. In addition, the working procedures have been designed and developed so that the value could be added to the research production line. The working methodology of this case study is depicted in a diagram (Figure-1). The primary data were collected by the direct observation method and the secondary data were collected from regarding journal, books, archives and internet browsing. The value added (VD) and NVD time was measured by using stop watch. The identified manufacturing wastes were quantified as well as rectified by formulating a strategic way in order to remove the causes that were basically responsible for creating wastes. The research work was conducted by following three basic steps- data collection and formulation; data analysis and diagnosis the fitness of work; finalization and validation of the work. Each type of data from the same source was taken for at least three times but mean value was considered to draw the discussion. The mean value was evaluated by the SPSS (version-17) software.

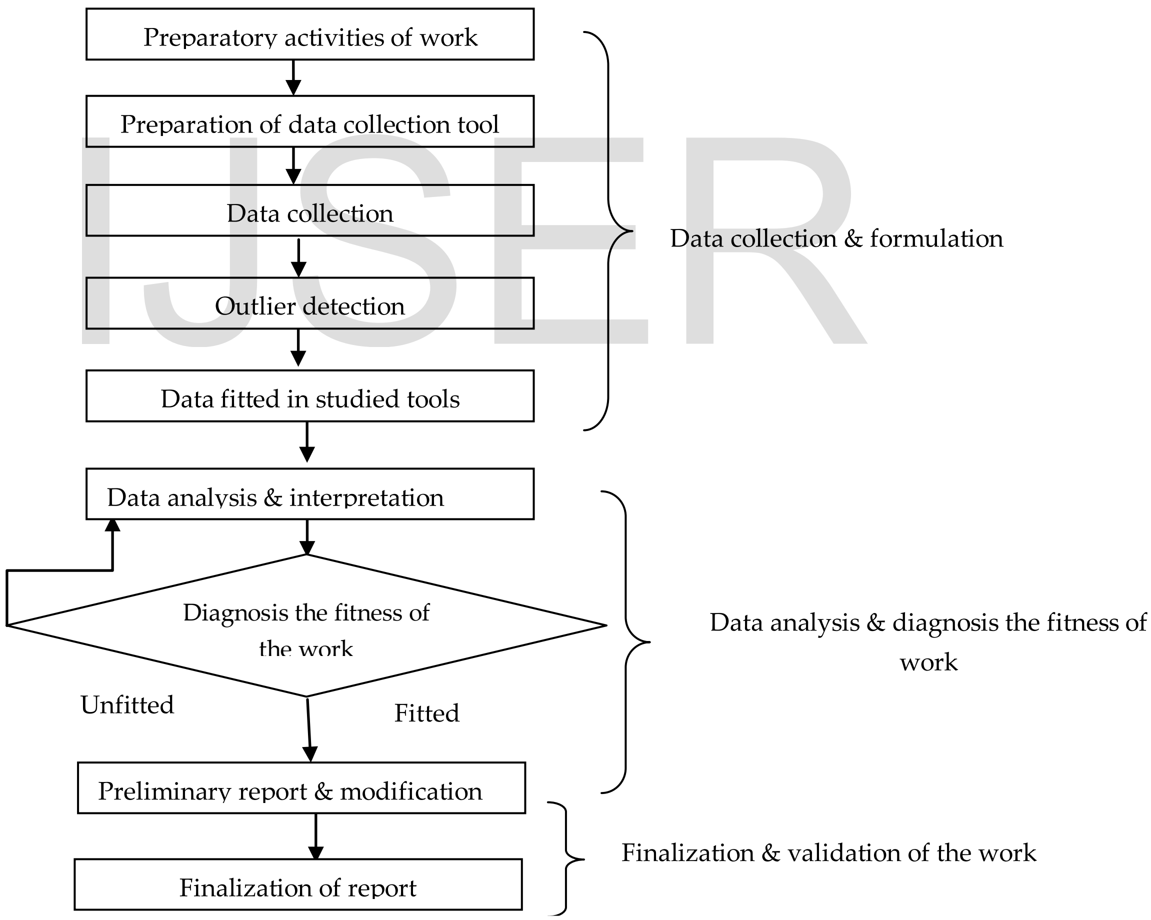

Figure-1: Complete Methodology of the study

3.1 Litchi juice process line

Throughout the different chemical changes litchi juice is formulated but this formulation was not the concerning matter beyond this study rather than make the production system free of wastes. A flow chart of litchi juice production line is constructed as shown in figure-2.

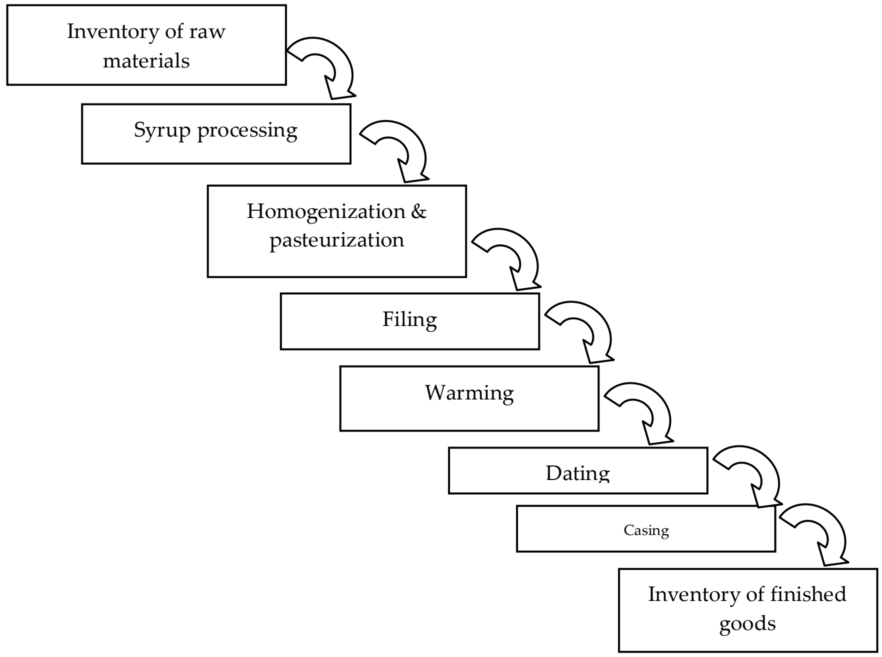

Figure-2: Basic stages of litchi juice production line

3.2 Value Stream Map (VSM)

VSM helps an organization to identify the NVD activities of the observed production line. It is well established by research that VSM is the ideal tool to point out hidden causes for NVD activities. Rother and Shook [5] considered the VSM as one of the most effective lean tools that is widely using to document, analyze and improve the flow of information and materials required to produce a product or service for the customers. In addition, VSM takes into account not only the activity of the product, but also the management and information systems that support the basic process. Basically, VSM helps to identify the flaws in production system that requires redesigning and to prioritize improvement. Gupta, et al. [6] evaluated the VSM as an activity improvement technique to visualize an entire production process, representing information and material flow, to improve the production process by identifying waste and its sources. Throughout this study VSM of observed process line was developed at current and future state prior to depict the contribution of VSM implementation towards the bottleneck reduction. This study has been carried out as a case study in a litchi juice production plant with current state map and future state map after following the different steps starting from raw material to final product.

3.3 Present VSM

The current VSM of the litchi juice production line is constructed to point out the gaps that need to be removed to enhance performance indicators such as cycle time reduction, up time improvement, line balancing efficiency, etc. Throughout the present VSM the whole production system of litchi juice production line were depicted with the flow of order, raw materials, labor, information, VD and NVD times. It helps to draw the required production stage like syrup processing, homogenization & pasteurization, filing, warming, labeling and wrapping with mentioning required labor, cycle time (C/T), up time (U/T), change over (C/O) and batch size (2000 L). By observing the present scenario of regarding production line, it can be known like as what number of labor is needed at different production unit? How much VD & NVD time is present? Where & what kind of improvement should be done? It also helps to calculate the PCE, and Lead time. It was found that filer, labeler and wrapping machine were mainly responsible for down time (D/T). The D/T is the time that is wasted due to breakdown of machine; C/T- the time that is required to produce a single batch production; U/T- the time that is available for machine work or production. The filler machine's cycle time was found 2880 sec, down time 657 sec, up time 77.19%; labeler machine's cycle time was calculated 2940 sec, down time 665 sec, up time 77.38%; wrapping machine's cycle time was found 3900 sec, down time 1074 sec and up time 74.46%. Filler machine speed was observed 245 bottles per minute (BPM); Labeler speed 240 BPM; Wrapping machine speed 30 case per min and each case contains 24 bottles; Batch size was 2000 liter and total labor were 36. The VD and NVD time were documented in Table-1. By this study, it was endeavored to increase the percentage of VD time by reducing the NVD time with the proper implementation of lean tools and six sigma methodologies.

Table-1: VD and NVD time of litchi juice production line

Production stage	Mean VD time (Sec)	Mean NVD time (Sec)
Receiving Inventory	00	27000
Syrup processing	600	1800
Homogenization & pasteurization	1680	240
Filling	2113	1007
Warming	00	1046
Labeling	2028	1362
Wrapping	2849	1803
Shipping Inventory	00	43200
Total	**9270 (10.68%)**	**77458 (89.32%)**

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

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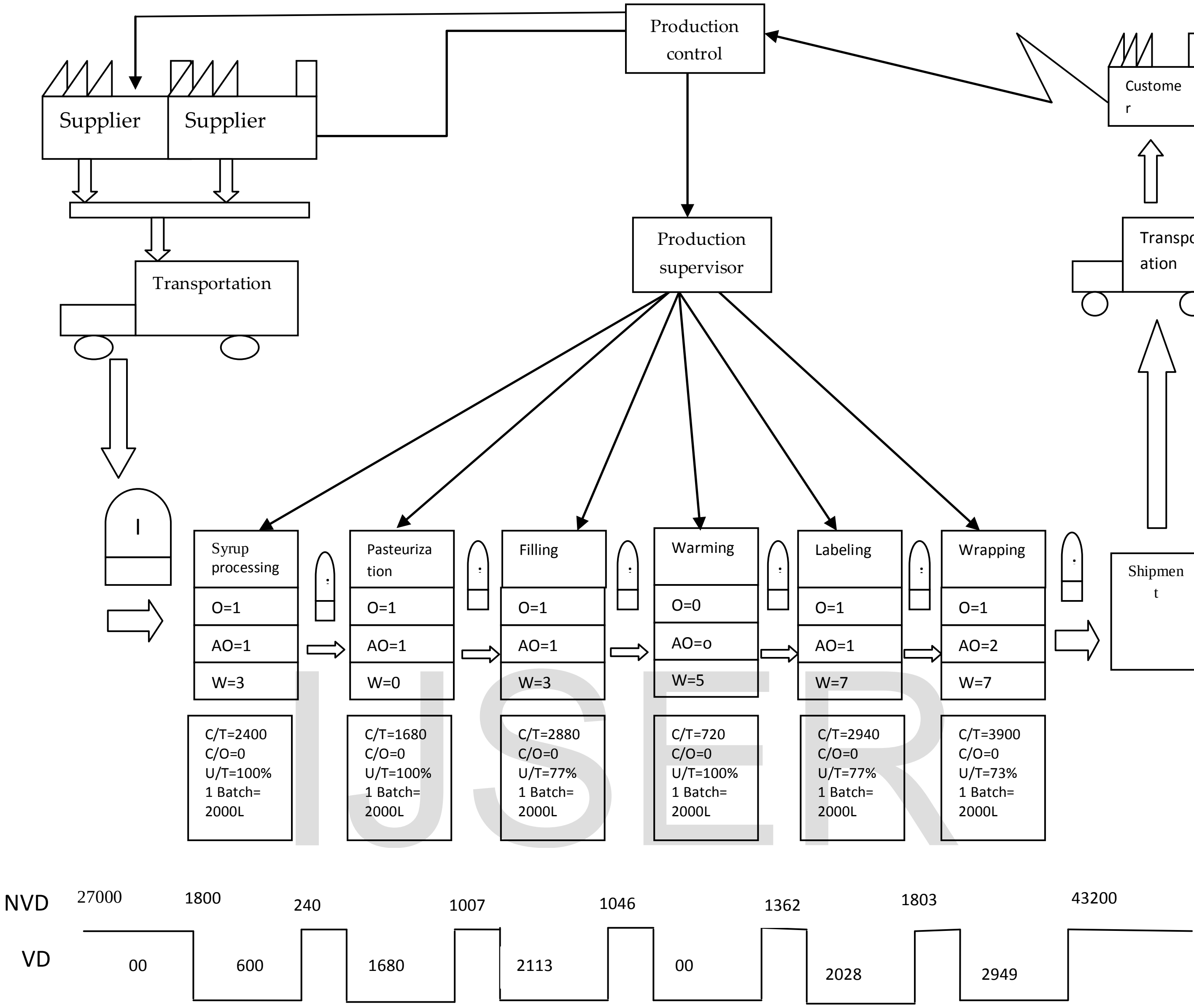

Figure-3: Present VSM of litchi juice production line

3.4 Present state PCE of litchi juice process line

At the litchi juice process line,

VD time = 9270 Sec

NVD time = 77458 Sec

Lead time = VD time + NVD time

= 9270 Sec + 77458 Sec = 86728 Sec

ISSN 2229-5518

PCE = (VD time / Lead time) × 100
= 10.68 %

However, according to Zhen [7] PCE of any organization need to be more than 25% in order to be globally competitive.

3.5 Manufacturing waste of litchi juice production line

The failure of many manufacturing companies to keeping them feasible in today's manufacturing world has been criticized extensively on their futile effort to identify, reduce, and possibly eliminate wastes (muda in Japanese language) that are inherent in their manufacturing processes. In lean manufacturing world waste is defined as anything that destroys the resources and does not add any value to the customer requirement. According to Okpala [8] any activities or processes for which the customer is not willing to pay is considered as a waste that must be identified and eliminated. In addition, all NVD activities are known as waste in the lean manufacturing world. Womack and Jones [9] defined the waste as any human activity which absorbs resources, but creates no value. Still now, seven types of waste were identified in the manufacturing and service sectors [10], [11]. Nevertheless, this list of waste has been modified and extended by the practitioners of lean manufacturing. The seven types of manufacturing wastes are overproduction, defect, waiting, unnecessary production, unnecessary inventory, unnecessary transportation between work sites, and unnecessary motion of labor in the work place. Based on the nature of production the manufacturing wastes are varied. In this study only defect, waiting and unnecessary motion wastes were observed most frequently. The Lean Enterprise Research Centre (LERC, 2004) at Cardiff Business School highlighted that for most production operations: 5% of activities add value; 35% are necessary non-value activities; 60% add no value at all [12]. Therefore, there is no doubt that the elimination of waste represents a huge potential in terms of manufacturing improvements.

3.6 Waiting time calculation of litchi juice production line

The waiting time derived from various causes at different production stages were documented in Table-2. The waiting time was calculated in second. The most frequent waiting time was observed in filing, labeling and wrapping stages.

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Table-2: Waiting time calculation

Stage	Causes for waiting time	Waiting time (Mean)	Waiting time (%)
Filler	Bottle short in supply	312	13.11
	Bottle queue in warmer line	105	4.41
	Crock changing	67	2.82
	Caper sensor problem	173	7.27
Labeler	Bottle short in supply	353	14.83
	Label defect	112	4.70
	Label changing	72	3.02
	Machine cutter problem	77	3.23
	Machine sensor problem	51	2.14
Wrapping	Insufficient bottle supply	282	11.85
	Case cover changing	46	1.93
	Case queue in front	34	1.42
	Case cover breaking	109	4.58
	Disarray of bottle array	478	20.09
	Machine problem	108	4.53
Total		**2379 sec**	

3.7 Defect waste calculation of litchi juice production line

In this study, defect bottle production was considered as the defect waste which was very common in the litchi juice production line. Defect production is also a common scenario of any manufacturing company, but it's a concerning matter that what the amount or volume of defect? Is that amount or volume is acceptable or not? With the help of six sigma rating these questions answer can be achieved. According to Antony and Jiju [13] a defect is defined as any process output that does not meet customer specifications. They also provided a central concept of six sigma rating scale which can be inferred from Table-3. The amount of defect bottle production was documented in Table-4. Based on central six sigma concept it seems that if the amount of defect product is more than 6,210 but less than 66,807 Defect per Million Opportunities (DPMO), is considered as the three sigma productions. From Table-4, it seems that the total defect product of litchi juice production line was 14875 DPMO which is considered as the three sigma productions. But the prime target of any manufacturing industry should be six sigma productions where the amount of defect product should not be more than 3.4 DPMO. Throughout this study it is expected that 80% of the present manufacturing waste could be reduced after the implementation of lean tools and six sigma methodologies. To attain the specific sigma scale of production, it's an important aspect to select the right tools or techniques when embarking any six sigma project. Different tools and techniques of six sigma are used for different aspect, so it is important to apply the right tool in the right situation in order to achieve successful results. The output also depends on the proper implementation of tools and techniques of six sigma. Raja [14] mentioned sometimes it seems that simple tools are enough to reduce the defects of a complex manufacturing system. In this study, Pareto chart, 5S, Just in Time (JIT) and Kaizen techniques were used to reduce the defect productions.

Table-3: Six sigma central concept

The percentage of successful outputs or operations	Defects per million operations (DPMO)	'Process Sigma'
99.99966	3.4	Six
99.98	233	Five
99.4	6,210	Four
93.3	66,807	Three
69.1	308,538	Two
30.9	691,462	One

Table-4: Defect product calculation

Name of stage	Mean rejected bottle per batch	Mean rejected bottle per day (per day 12 batch)	Rejected bottle per million opportunity	Gap at Six Sigma level	Remarks
Filling	24	288	2040	2037	Contains at three sigma level
Date coding	32	384	2720	2717	
Labeling	98	1176	8330	8327	
Wrapping machine	26	1512	1785	1782	
Total	280	3360	14875		

3.8 Motion waste of litchi juice production line

The unnecessary labor movement in the production floor was considered as the motion waste. After the implementation of lean tools and six sigma methodologies in litchi juice production line it is expected that a number of unwanted labors could be eliminated that are documented in the Table-5. At present state, from Table-5, it is seen that 36 labors are engaged in the litchi juice production floor and it can be assumed after the implementation of lean tools and six sigma techniques the number of labor would be reduced to 22. It seems that a number of unwanted labors are engaged to manage the different types of bottlenecks and NVD activities.

Table-5: Present and expected labor of litchi juice production line

Name of Stages	No of labor at present state			No of labor at future state		
	O	AO	W	O	AO	W
Syrup processing	1	1	3	1	1	3
Homogenization & pasteurization	1	1	0	1	1	0
Filing	1	1	3	1	1	1
Warming	0	0	5	0	0	2
Labeling	1	1	7	1	1	3
Wrapping	1	2	7	1	1	3
Total	5	6	25	5	5	12

3.9 Pareto analysis of litchi juice production line

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 principles – the idea that by doing 20% of work, 80% of the advantage of doing the entire job can be generated. According to David [15] in any operation a large majority of problems (80%) are produced by a few key causes (20%). Therefore, by removing this 20% causes 80% problems can be removed from any production floor which is also known as "80/20 Rule". In this study, Pareto analysis was performed by drawing the Pareto chart consisting of causes for delay along the X axis and cumulative percentage of waiting or down time along the Y axis. The highest frequency of down time was found for bottle short in supply, while bottle queue in front of filer machine showed the lowest frequency. Different causes of down time with their frequency in terms of percentages and cumulative percentages were documented in Table-6. Pareto chart (Fig. 4) was depicted from Pareto table (Table-6) by aligning the different causes along with X axis; percentage and cumulative percentage of these causes for NVD activities were aligned along with the Y axis. From Pareto chart (Fig. 4) the most responsible causes are easily observed and therefore, effective initiatives can be taken to remove these causes. It is expected that if the most frequent first three or 20% causes like as insufficient bottle supply (39.80%), disarray of bottle at wrapping machine (20.09%), and sensor problem of machine (13.95%) could be removed the 80% NVD activities or down times could also be removed. 5S, JIT, and Kaizen strategies would be effective initiatives to remove these most frequent causes.

Table-6: Cumulative percentage of down time (D/T) for Pareto analysis

Causes of delay times	Down Time(D/T)	Percentage of (D/T)	Cumulative of percentage of D/T
Insufficient bottle supply	947	39.80664	39.80664
Disarray of bottle at wrapping machine	478	20.09247	59.89911
Sensor problem of machine	332	13.95544	73.85455
Label defect at labeler	112	4.70786	78.56241
Case cover splitting	109	4.58175	83.14416
Bottle queue in front of filer	105	4.41361	87.55778
Machine cutter problem of labeler	77	3.23665	90.78443
Label changing at labeler	72	3.02648	93.81091
Crock changing of filer	67	2.81630	96.62721
Cover case changing of wrapping machine	46	1.93358	98.56079
Case queue in front of wrapping machine	34	1.43921	100.00000

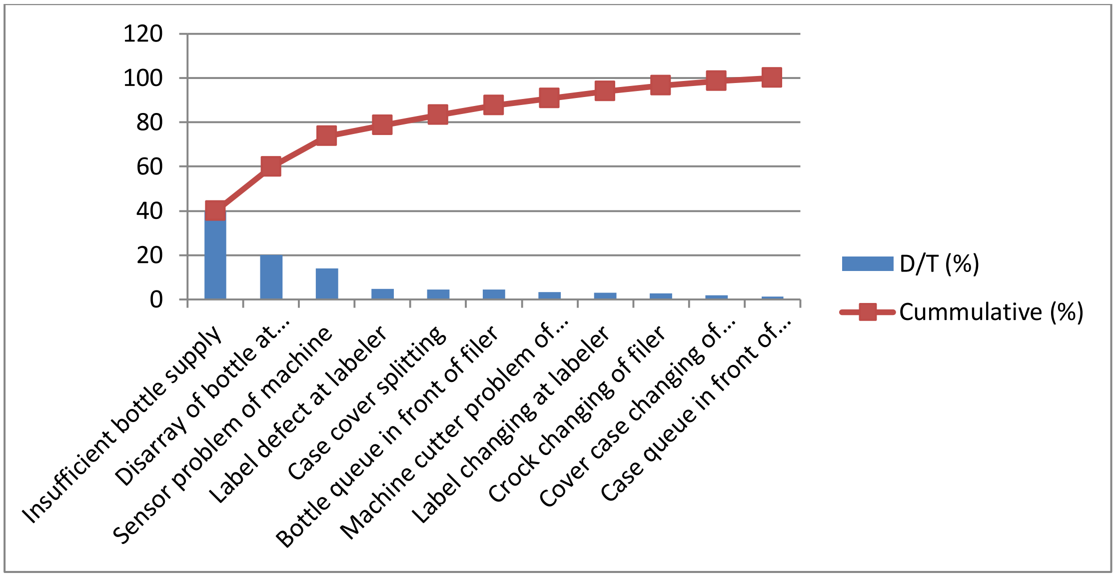

Figure-4: Pareto chart for litchi juice production line

4.1 Kaizen

Kaizen is the Japanese word. Kaizen means continuous improvement, "Kai" means take apart and make new and "Zen" means think about so as to help other. The meaning of this word is continuous improvement. Kaizen process is based on common sense and lowest approach. It is a promising philosophy for continuous improvement of any process or operation. Indeed, nothing could be a big achievement without a continuous improvement even though the progress is a little bit one which is the core principles of Kaizen philosophy. Antony and Desai [16] believed that the basic effort of this method is to implement big and also small changes and after this it will be able to achieve more productivity. According to Lareau [17] in the office environment, Kaizen focuses primarily on the improvement of an individual endeavor through the appreciation of process owners by using their experience. Womack and Jones [9] revealed that normally, there are three steps to perform the Kaizen activity which are:

1. Utilize the *5 why's method* to find the basic cause of wastes by adopting the following guidelines:
   i. Writing down the problem that helps you grasp the problem and describe it completely.
   ii. Ask why the problem happens and write the answer down below the problem.
   iii. If the provided answer doesn't identify the root cause of the problem that you have written, ask why again and write that answer down.
   iv. Repeat above steps until the team is in agreement that the problem's root cause has been identified.
2. Brainstorm and develop the resolution to meet the goal
3. Implement resolution and sustain

4.2 5S

5S is the name of a workplace organization method that uses a list of five Japanese words: *seiri, seiton, seiso, seiketsu,* and *shitsuke*. There are five primary 5S phases: sorting, set in order, systematic cleaning, standardizing, and sustaining. The list describes how to organize a work place or an operation plant efficiently and effectively by reducing waste hidden in the plant, improve quality and safety, reduce lead time and cost, increase profit. In this study, it was evaluated that by using 5S philosophy the lead time, NVD time and waste would be reduced with improved PCE.

4.3 Just In Time (JIT)

JIT is a philosophy of continuous improvement. The basic principle of JIT is to eliminate the sources of manufacturing wastes by getting right quantity of raw materials and producing the right quantity of products in right place at the right time [18]. According to Slack, et al. [19] JIT is a stepped technique, aiming at improving global productivity and eliminating waste. It comes as a consequence of the use of a balanced production. It has been widely reported that the proper use of JIT manufacturing has resulted in increases in quality, productivity and efficiency, improved communication and decreases in costs and wastes. It was observed that with the implementation of JIT in the litchi juice production plant the right amount of product could be produced at the right time by using the minimum capacity of facilities, equipments, materials and people; ultimately productivity would be improved.

5.1 Future VSM of litchi juice production line

At future state map right allocation of resources were made by taking necessary modification. After a deep brainstorming and an intense observation in litchi juice production line the VD and NVD time were calculated and documented in Table-7. It was observed that in process inventory time and NVD activities can be reduced from 50% to 80% (Table-7). In future VSM, improved U/T was observed at every production stage. The U/T of filer, labeler, and wrapping machine would be consecutively 96%, 95%, and 94% whether at present state the U/T of filer, labeler, and wrapping machine were consecutively 77%, 77% and 73%. The total labor including operator, assistant operator and worker would be 22 which was 36 at present state i.e. after the implementation of lean tools at least 14 labors could be reduced.

5.2 Future state PCE of litchi juice production line

It was evaluated that after the proper implementation lean tools and six sigma methodology VD and NVD time would be 9270 sec and 28642 sec and lead time would be 37912 Sec. Therefore, future state PCE would be 24.45% which was observed at current state10.68 %.

5.3 Improvement through lean tools implementation

It was assumed that after the implementation of lean tools lead time, total number of labor and NVD activities or down time would be reduced, up time and PCE would be improved. The NVD time would be reduced from 77458 sec to 28642 sec and lead time would be reduced from 86760 sec to 37912 sec. PCE would be 24.45% from 10.68%, up time of filler, labeler and wrapping machine would be consecutively 96%, 95% and 94% from consecutively 77%, 77% and 73%, total labor would be eliminated to 22 from 36 that's can also be assumed from graphical presentation

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Table-7: Future state VD and NVD time analysis of litchi juice production line

Production stage	VD time in sec.	NVD time in sec. (% reduction of present state)
Receiving Inventory	00	13500 (50%)
Syrup processing	600	900 (50%)
Homogenization & pasteurization	1680	240 (0%)
Filling	2113	201 (80%)
Warming	00	209 (80%)
Labeling	2028	272 (80%)
Wrapping	2849	360 (80%)
Shipping Inventory	00	12960 (70%)
Total	9270 (24.45)	28642 (75.55)

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

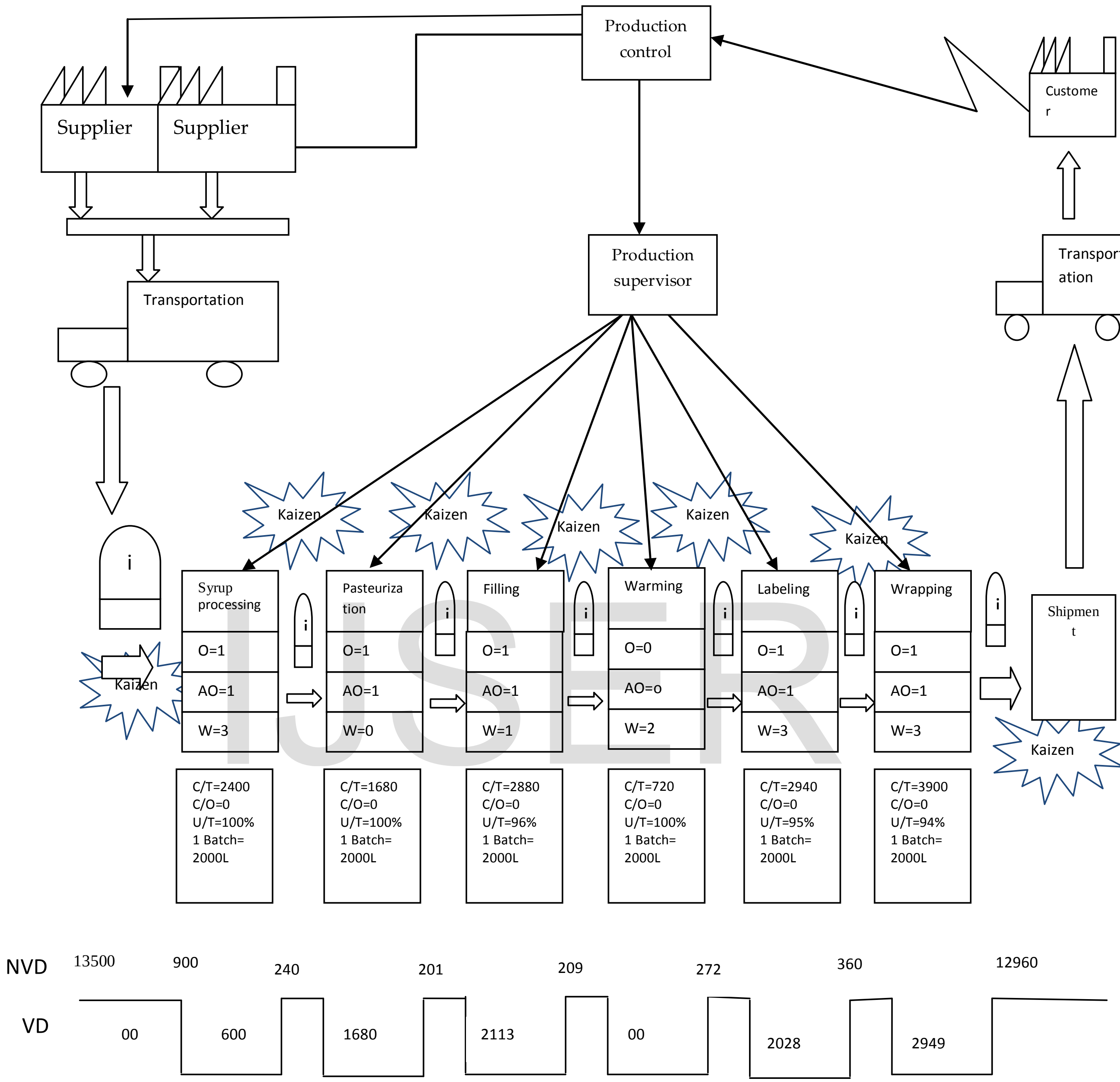

Figure-5: Future VSM of litchi juice process

This case study was conducted to renovate the current production philosophy of a litchi juice plant by using lean tools and six sigma scale rather than changing the layout. Eventually, it was pictured that after implentation of VSM, Pareto analysis, JIT, 5S and Kaizen the plant's productivity factors like PCE, lead time, and down time were improved as noticeable.

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