An Approach to Improve the Process Cycle Efficiency and Reduce the Lead Time of a Mango Juice Processing Line by Using Lean Tools: A Case Study

Md. Monir Hossain, M. Kamal Uddin

Abstract: This study was a case analysis of the effective performance of lean tools adoption in a mango juice processing line-1 of X Food Industry in Bangladesh. This work addresses the implementation of lean tools in order to evaluate present Process Cycle Efficiency and lead time prior to develop an improved strategy to bring the improved PCE and to reduce the lead time. Value Steam Map and Pareto analysis were applied to evaluate the present and future state PCE and lead time. At the present state, the PCE was found 15.28% and after the implementation of lean tools it would be 34.05% at future state where lead time would also be reduced by 55.10%. The production flow was optimized by minimizing several non value added activities and time such as bottlenecking, machine breakdown, queue time, waiting time, material handling time, etc. Eventually, this case study will be useful in developing a more generic approach to design lean environment in management system of the studied X food industry.

Index Terms- Lean Tools, Mango Juice, Value Stream Map, Process Cycle Efficiency, Lead Time

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1 Introduction

In this competitive World, the basic concern of a manufacturing company is to increase their customers' satisfaction by constantly improving their delivery at time by keeping the 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 systems and a relish for improvement wherever it could be possible. In the previous study, it is revealed that vision is as important as action to have the best control on the production system. A company should have also a stiff production philosophy to establish the most effective production system. In this essence, lean philosophies, which were initiated in Toyota Production System (TPS), are seen as bring the revolutionary change in the mindset of manufacturers in the search of quite flawlessness production[1]. Empirically lean thinking and lean enterprise started in Japan, with the attempts of the Toyota Motor Company to become a promising leader in the auto mobile manufacturing business thus surpassing American companies like Ford or General Motors. This concepts and principles later were well known as the lean enterprise model. Lean enterprise is an integrated entity which efficiently creates value for its multiple stakeholders by employing lean principles and practices [2] that had demonstrated their convinced effect in the auto industry in Japan, which was followed and documented by a number of the international motor vehicle companies. It was soon reasoned that the same methods were applicable to other industries and businesses as well. It was deduced that the lean principles is an attempt towards – improving quality, eliminating waste, reducing lead time, ameliorating the PCE and reducing total cost of a process[3,4].

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This study was headstrong with some specific objectives which were-to identify, quantify and to reduce the non value added (NVD) activities and time towards the improved Process Cycle Efficiency (PCE) and therefore to reduce the lead time.

2 Industrial implementation of lean tools

With the flow of time and iridescent aptitude of consumer, today's manufacturing industries are undergoing more and more competition in local and global marketing system to come up with the desired product or service within a limited period of time. Towards reducing the lead time, improving the PCE and ultimately to gain the economic benefit there are a number of pleasing evidence of successful lean tools implementation in the manufacturing world. Lean tools have been successfully applied in many manufacturing organizations such as General Electric, Boeing, DuPont, Kodak, Honeywell, Texas Instruments, etc [5]. Lean tools are also successfully applied in hospitals, pharmaceutical, housing and paper industry, and brought with alluring economic benefit by reducing long lead time and manufacturing waste. It was estimated that over the world by adopting lean tools in pharmaceutical industry a cost could be saved up to $90 billion per year [6]. In 1999, it was evaluated that lean tools significantly brought the benefits of $20 billion to Motorola Inc. since 1986 that inspired many companies in various industrial sectors to adopt lean tools. In USA, it was reported that a food manufacturing industry has gained the benefit of $2 million per year by adopting lean tools [7]. This riveting economic benefit was the ultimate outcomes of reduced NVD activities, lead time and improved PCE. It was shown a frozen fish industry would able to improve its PCE from 5.02% to 17.46% by adopting lean tools [8]. Like these promising studies the authors were provoked to conduct this study with the lean tools in a mango juice processing industry of Bangladesh prior to reduce the lead time and to improve the PCE.

3.0 Observed process line

A flow chart of mango juice processing line-1, is constructed as shown in fig. 1. In this study, the required ingredients towards the finished mango juice were not the concerning matter rather than causes that were responsible for processing wastes and down time. The delay in production due to different causes and downtime were quantified in terms of NVD time.

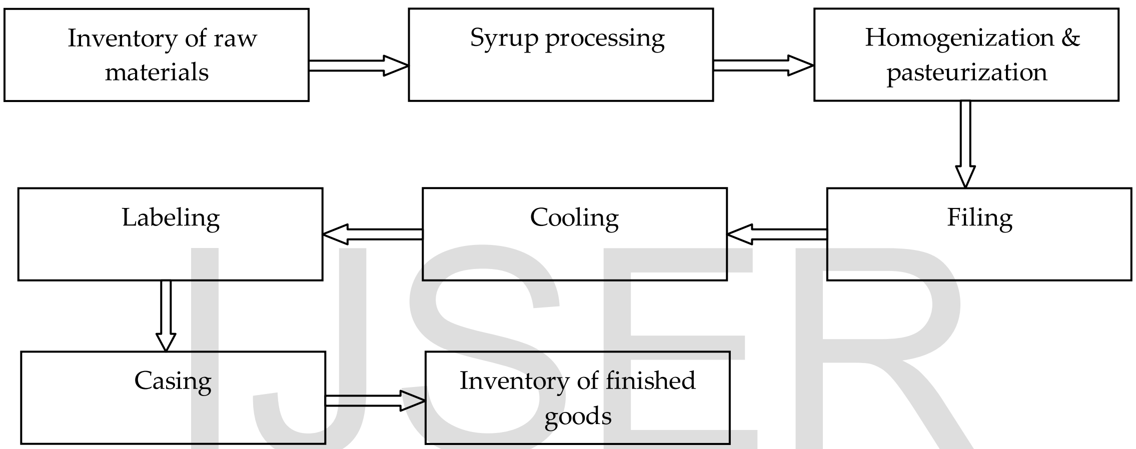

Fig.-1: Different stages of X mango juice processing line-1

3.1 Value Stream Map (VSM)

According to Rother and Shook [9] 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. The VSM is further described by Womack and Jones [4] in Lean Thinking as a tool to identify every action required to design, order, and make a specific product where 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 filing, or production systems; and (3) those actions which don't create value as perceived by the customer and can be eliminated immediately.

3.2 Present state VSM of X mango juice process line-1

The present state VSM is constructed as shown in fig. 1. Throughout the present state VSM the whole processing system of mango juice is depicted with the flow of order, raw materials, labors, and other information. Table 1 outlines the VD and NVD time analysis for present state VSM. At present state VSM, it is revealed that the production of mango juice is controlled by production supervisor. The production starts by taking the order of production from the customers. In order to fulfill the customer demand the required raw materials were collected from the suppliers and stored in the raw materials inventory which was the first stage of mango juice processing that followed by syrup processing, homogenization & pasteurization, filing, cooling, labeling, wrapping and shipment of finished goods. It helps to know the cycle time (C/T), up time (U/T), changeover time (C/O) and batch size of the processing line. Cycle time is the required time to complete one manufacturing process in the value stream. The percentage of available time for machine work or processing of desire product is known as the up time. Change over time is the NVD time required to convert a setup from one product line to another product line. By observing the present state VSM, it can be known such as what number of labor is needed at different processing unit? How much VD and NVD time is present? Where & what kind of improvement should be done? It helps to calculate the PCE, lead time and Takt time. The different types of bottlenecks at different processing stages were identified and quantified in terms of NVD time. The VD and NVD time were also shown at the bottom line of present state VSM. It was found that about 15270 sec or 15.28% were VD activities while 84600 sec or 84.72 % were NVD activities and its batch size was 7000 L. In the stages of raw materials inventory, cooling and shipping inventory of finished goods, there were found no VD rather than NVD time. But a portion of this NVD time is considered as the required time towards the finished mango juice. By this study with the implementation of lean tools, it was endeavored to increase the percentage of VD time by reducing the NVD activities. The up time of filer, labeler and wrapping machine was consecutively 82%, 77% and 66% whereas the up time of syrup processing, homogenization & pasteurization and cooling machine was 100%; subsequently, it was seem that the filer, labeler and wrapping machine were mainly responsible for down time or NVD activities. At present state, total labor were found 25 over the different stages. By this study, it was attempted to reduce the number of labor and NVD activities and therefore, to reduce the ultimate lead time but to increase the up time after the implementation of lean tools.

Table 1: Present state VD and NVD time

Processing stage	VD time (Sec)	NVD time (Sec)
Receiving Inventory	00	32400
Syrup processing	600	1800
Homogenization & pasteurization	1680	300
Filling	4775	1525
Cooling	0	1770
Labeling	4683	1857
Wrapping	3532	1748
Shipping Inventory	00	43200
Total	15270 (15.28%)	84600 (84.72%)

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

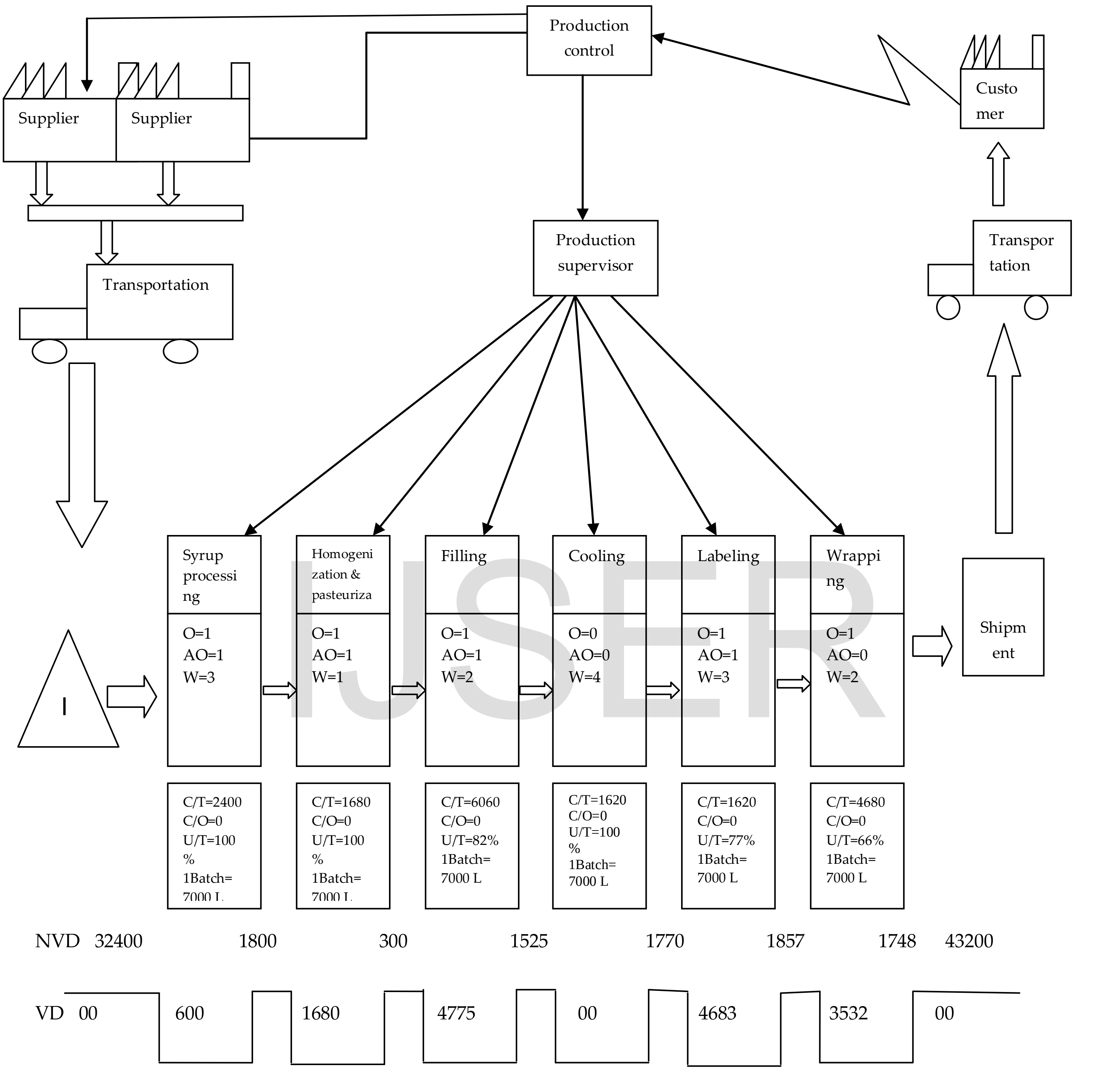

Fig.-2: Present VSM of X mango juice processing line-1

3.3 Present state PCE of X mango juice process line-1

PCE is measured as the percentage of ration of VD time and lead time, where lead time is the summation of VD and NVD time. In the observed processing line, the VD and NVD time were found as 15270 sec and 84600 sec, so the lead time was 99870 sec and consequently, the PCE was

15.28 % which could be considered as the below of internationally competitive level 25% [8]. Throughout this study, it was strived to improve the present PCE with the proper adoption of lean tools such as VSM, Pareto analysis, Pareto chart, 5S and JIT.

3.4 Present state Takt time of X mango juice process line-1

Takt time is considered as the time that is required to produce a single unit of daily salable or capable quantity of commodities [10]. The studied process line runs for two shifts per day, each shift was for 33600 sec excluding lunch time and planned down time; therefore, the available time for the run of the studied processing line was 67200 sec with the daily customer demand of 5094 cases where each case contains 24 single bottle and every single bottle contains 250 ml mango juice. Takt time is considered as the heart beat of any process line. By this way the present Takt time of studied processing line was 13.19 sec. i.e. it was taken 13.19 sec to produce a single case of mango juice production. By this study it was tried to reduce the present Takt time with the proper implementation of lean tools.

3.5 Pareto Analysis

It is a statistical technique in decision making that is used for selection of a limited number of tasks but to produce significant effect. It uses the Pareto principle-the idea that by doing 20% of work, 80% of the advantage can be generated in terms of quality improvement. Another way, it can be expressed as a large majority of problems (80%) are produced by a few key causes (20%). The Pareto principle – also known as the "80/20 Rule" – which is the idea that 20% of causes generate 80% of results. In this study, by using this tool it was tried to find out the 20% of causes that is generating 80% NVD activities. This tool focuses on the most damaging causes on a project. In this essence, David [11] 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. This tool was performed by drawing the Pareto chart consisting of causes for downtime or NVD activities along with the X axis while the Y axis represents the cumulative percentage of down time. Most of the NVD activities were documented on filing, labeling and wrapping stages where these were frequently observed due to different causes. The highest frequency of NVD activities that derived the down time were found for insufficient bottle supply while bottle queue in front of filer machine was the lowest frequency.

Table 2: Cumulative percentage of down time derived from different causes

Causes of delay time	Down time	Percentage of down time	Cumulative percentage of down time
Insufficient Bottle supply	1852	47.86766	47.86766
Caper sensor problem of filer machine	546	14.11217	61.97983
Machine sensor problem	469	12.12199	74.10182
Case cover changing at wrapping machine	311	8.03825	82.14007
Label changing at labeler	263	6.79762	88.93769
Label wrapping in labeler	169	4.36805	93.30574
Bottle queue in supply at filer machine	141	3.64435	96.95009
Case queue in front of wrapping machine	65	1.68002	98.63011
Bottle queue in front of filer machine	53	1.36989	100.00000

Different causes of NVD activities or down time at different processing stages were documented in Table-2 with their frequency in terms of percentages and cumulative of percentages. Pareto chart is constructed in fig. 3 where the responsible causes for NVD activities were arranged in downward movements in terms of their frequency.

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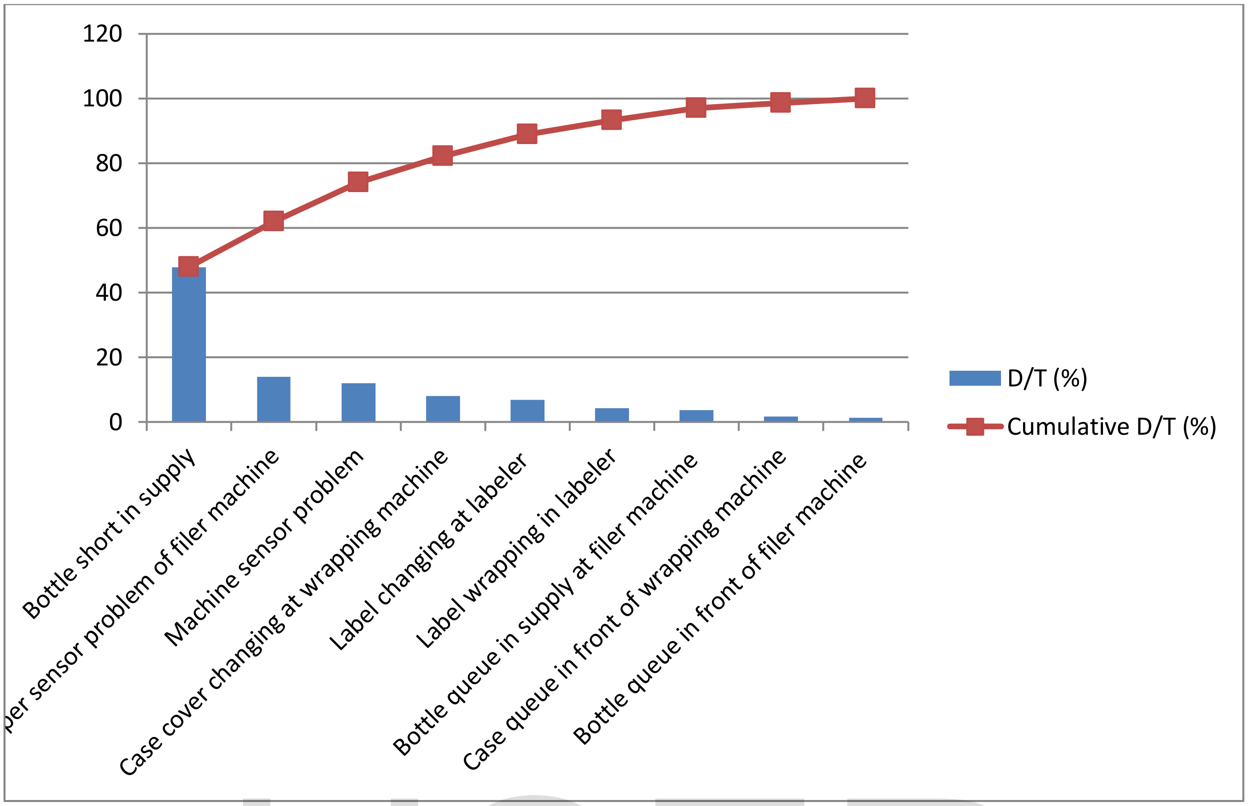

Fig.-3: Pareto chart of X mango juice processing line-1

From Pareto chart the most responsible causes are easily observed and therefore the effective initiatives can be taken to remove these causes. It is expected that if the most frequent first three causes (20%) like as bottle short in supply (47.86%), caper sensor problem of filer machine (14.11%), and machine sensor problem (12.12%) could be removed, the 80% NVD activities will be removed. 5S and JIT would be effective initiatives to remove these most frequent causes.

4.0 Improvement strategies

In order to remove the 80% NVD activities, indeed it is emergence to take some improvement strategies such as increase skill manpower, continuous improvement and involvement of JIT philosophy within the production management system.

4.1 Increase skill manpower

It was observed that most of the assistant operators were not enough skilled to handle the machine breakdown immediately. But for this reason the maintenance time was as high as not acceptable. So, it is suggested to hire some skill manpower as operator and assistant operator especially for labeler, filer and wrapping machine. Effective training program should be arranged prior to make capable of operator and assistant operator towards reducing the maintenance time.

4.2 Continuous improvement

Continuous improvement is one of the most effective and basic tools of lean production which is also known as Kaizen. It is a long-term approach to work systematically to seek and to achieve small, incremental changes in processes in order to improve the efficiency and quality. Kaizen can be applied to any kind of work, but it is well known for being used in lean manufacturing. Kaizen is a Japanese term that reveals the meaning as "good change". Basically Kaizen is considered as a systematic approach for continuous improvement. 5S is one of the most popular tools for effective continuous improvement. Towards the NVD activities reduction 5S is the first modular step. 5S is not only a means to increase profitability of a firm but also allow companies to reveal potential strengths and capabilities that were hidden before [12]. It consists of Japanese words- Seiri (Sort), Seiton (Straighten), Seiso (Sweep and Clean), Seiketsu (Systemize), and Shitsuke (Standardize). By considering these five words a basic and underlying concept of 5S is assumed that is to look for NVD

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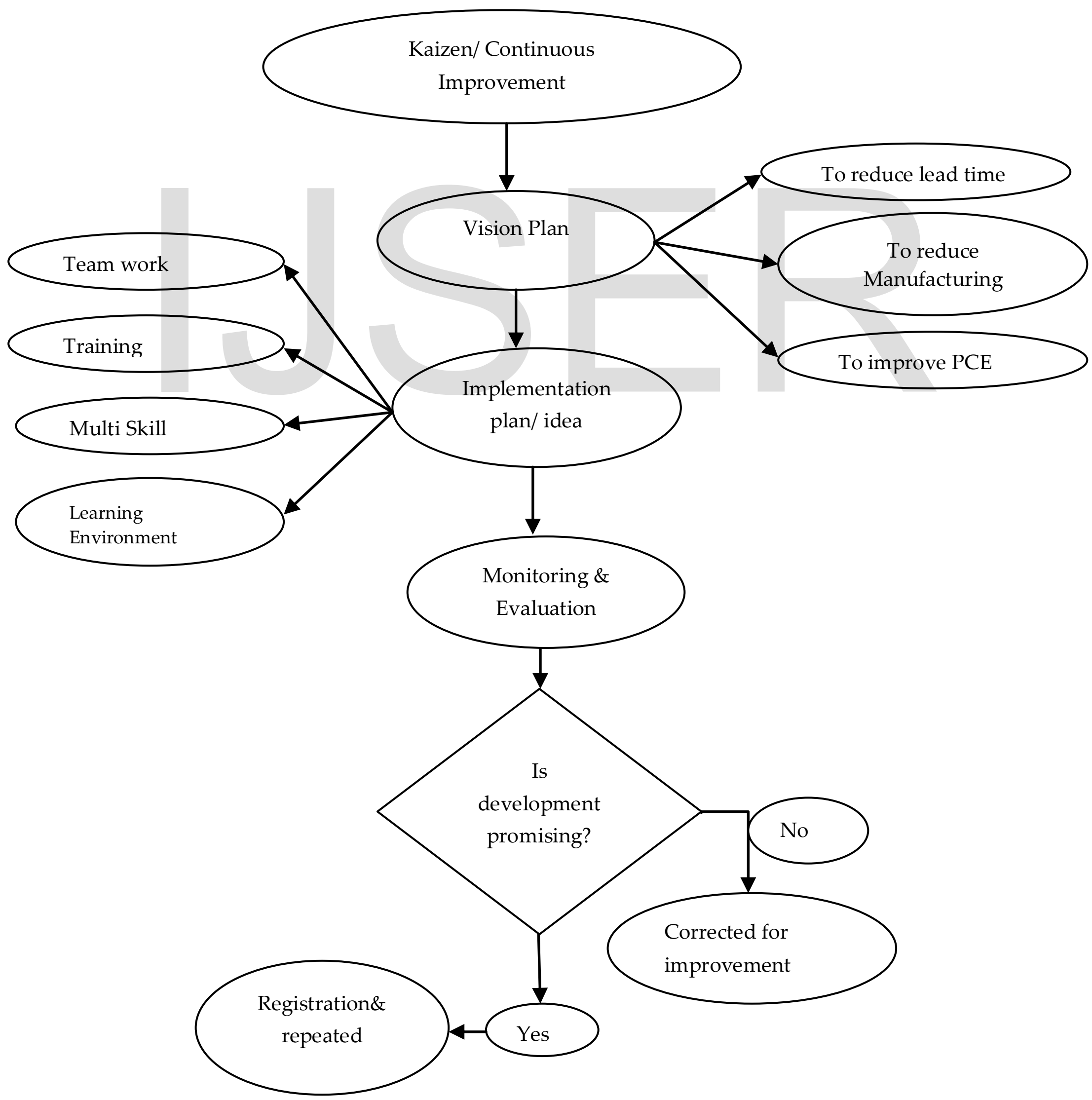
activities and then tries to eliminate it. This concept implies that go there instantly where a problem is occurred; check out the problem; take a temporary measure on spot; find out the main causes beyond the problem, if need use the five WHY? Question; and finally standardized to prevent reoccurrence. In a production process line, a good change or the improvement can be achieved by many ways such as reduction of inventory, reduction of production time, reduction of defective parts etc. In this essence, a strategic plan is developed prior to implement the 5S in the observed mango juice processing line in order to remove the recognized NVD activities. Towards the implementation of 5S, it would be needed a proper plan or vision which could be formulated by the management of X juice and beverage sector. The vision plan should be incorporated with the theme of reducing lead time, NVD activities or manufacturing waste and improving PCE. The plan of 5S implemented consisting of team work, training work, multi skill scope and learning environment. To implement a new plan, a team work will be an effective wheel to bring the plan into practical. An effective training program should be arranged frequently prior to need for the sake of 5S incorporation within the existing production management system. An attempt should be constant in order to find out the problem at each and every stage of the mango juice process line. A persistent endeavor should be kept on creating a way to eliminate the arising problems and if this way being effective, it must be documented and if not keeping on try towards an effective way beyond the elimination of problems for NVD activities.



Strategic plan for kaizen Implementation

4.3 Just in Time (JIT)

JIT is a Japanese management philosophy which has been applied in many Japanese manufacturing organizations since the early 1970s. It was first developed by Taiichi Ohno in the Toyota manufacturing plants as a means of meeting consumer demands within the minimum delays [4]. The lean production firstly focus on what is most commonly thought of as 'just in time' management which is considered as one of the basic principles of lean manufacturing. It is the idea of producing exactly what the customer wants, in the quantities they want, where they want it, when the customer wants it without being delayed or held up in inventory [13]. Inman and Bulfin [14] implied that JIT implementation provokes to reduce hurdles like as long change over time; unleveled production schedules; highly variable production processes; large container sizes; severe bottlenecks, and long lead time.

Actually there is no unified steps towards the JIT implementation; because, the production phenomenon of different factories varies from each other. Moreover, the ability of the different techniques in different factories depends deeply on a specific manufacturing environment. However, benefits from these programs have often been limited because of unreliable or inflexibility [15]. Indeed, it is needed a reliable and flexible environment towards the JIT implementation. In the observed mango juice processing line unwanted and unnecessary NVD waiting time were observed as very common between each two stages, especially in raw material inventory and finished goods inventory which could be reduced by JIT implementation. In order to JIT implementation, some suggestions were proposed like as-

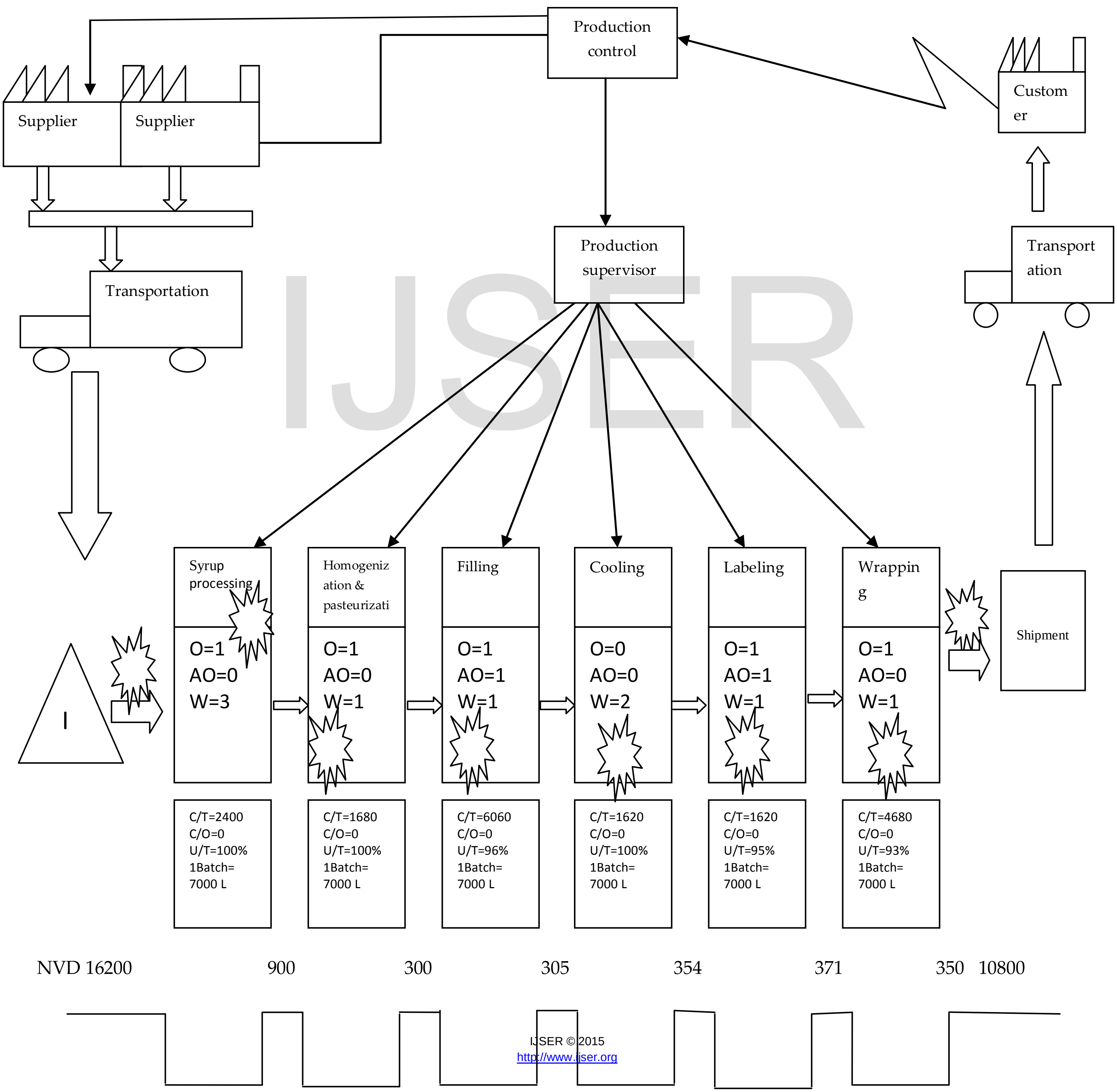
- Prepare the plant and its personnel for flexibility towards involve themselves within the JIT principles;
- Regarding personnel should be careful to the shortest lead time and high quality by concentrating maintenance and quality;
- Strive to produce with no waste by focusing on inventory control;

5.1 Future VSM of X mango juice processing line-1

Finally, the future VSM is constructed as shown in fig. 4 which reported a promising reduction in NVD time and lead time with improved PCE and up time. Table 3 outlines the value stream analysis report for the future state. It is found that after the implementation of lean tools PCE will be improved at internationally competitive level. Based on intense observation, brainstorming and previous regarding studies it is predicted that 50% NVD time of raw material inventory and syrup processing stage could be reduced. The 80% NVD time of filing, cooling, labeling and wrapping stages could be reduced after the implementation of lean tools. At future state, the total labor is found 17, but it was 25 at present state i.e. after the implementation of lean tools at least 7 labors could be relief for another work. The up time of filer, labeler and wrapping machine is found consecutively 96%, 95% and 93% while it was consecutively 82%, 77% and 66% at present state. At future state, it is also found the PCE will be 34.05% while it was 15.28% at present state. Therefore, at future state, the promising outcomes bring with the reduction of labor, NVD time, lead time and improved up time and PCE.

Table 3: Future state VD and NVD time

Processing stage	VD time (Sec)	NVD time (Sec)
Receiving Inventory	00	16200
Syrup processing	600	900
Homogenization & pasteurization	1680	300
Filling	4775	305
Cooling	00	354
Labeling	4683	371
Wrapping	3532	350
Shipping Inventory	00	10800
Total	15270 (34.05%)	29580 (65.95%)


Production control
Supplier
Supplier
Custom er
Production supervisor
Transportation
Transport ation
Syrup processing
Homogeniz ation & pasteurizati
Filling
Cooling
Labeling
Wrappin g
Shipment
I
O=1
AO=0
W=3
O=1
AO=0
W=1
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C/T=2400
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1Batch=
7000 L
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1Batch=
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C/T=6060
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U/T=96%
1Batch=
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371
350
10800

VD	00	600	1680	4775	00	4683	3532	00

Fig. 4: Future VSM of X mango juice processing line-1

5.2 Expected PCE at future state

At future state, it is expected that after the proper implementation of lean tools NVD time could be reduced from 84600 sec to 29580 sec, and thus the lead time would be reduced from 99870 sec to 44850 sec. As earlier, it is mentioned that PCE is measured as the percentage of ratio of VD time and lead time and consequently at future state, the PCE is found 34.05 % which is considered as the internationally competitive level 25% [8].

5.3 Expected Takt time at future state

In earlier, it is mentioned that Takt time is the heart beat of a production process line. Takt time is the time that needs to produce a single unit of production. As it is lower indicates the faster of production. Throughout this study it was tried to reduce the Takt time. At future state, after the adoption of lean tools the Takt time is found 12.89 sec while at present state production phenomenon it was found 13.19 sec.

5.4 Achievement of lean tools adoption

A promising achievement is predicted with the reduced NVD time and lead time and with the improved Takt time and PCE. An improvement comparison between present and future state is given in fig. 4.

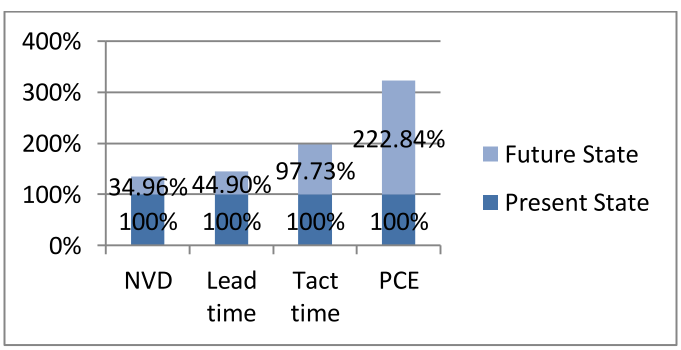

Fig. 4: Improvement comparison between present and future state

At future state, it is seen that the NVD time will be reduced 65.04%, lead time will be reduced 55.1%, Takt time will be improved 2.27% and PCE will be improved 122.84%. But all of these alluring achievements basically depend on the successful implementation of proposed lean tools.

6.0 Conclusion

This study provides a case analysis of the improvement of a mango juice processing line by reducing the lead time and improving the PCE by means of lean tools. It focuses the renovation of operations by eliminating the NVD time and lead time and improving the PCE through VSM, Pareto analysis, 5S and JIT. In a nutshell, it is inferred that a set of lean tool is an effective way to identify and eliminate the manufacturing NVD activities and time.

References

[1] P. Dennis, "Lean production simplified: a plain language guides to the world's most powerful production system". *Productivity Press,* A division of The Kraus Organization Limited New York, 2002.

[2] G. Ignacio, "Stakeholder Analysis in the Context of the Lean Enterprise", *Massachusetts Institute of Technology*, pp. 20-21, March 2003. Available at http://ocw.mit.edu/courses/aeronautics-and-astronautics/16-852j-integrating-the-lean-enterprise-fall-2005/readings/grossi_thesis.pdf

[3] T. B. Mintz, "Lean Manufacturing: Processing Buzzword or Operational Lifesaver?" *Engineered Wood Journal,* Vol. 6, No.1, pp. 12-15, 2003.

[4] J. P. Womack, and T. J. Daniel, "Lean Thinking: Banish Waste and Create Wealth in your Corporation", *New York,* 1996. NY: Simon & Schuster.

[5] H. K. Young, and T. A. Frank, "Benefits, obstacles, and future of Six Sigma approach", *Technovation,* Vol. 23, pp. 708-715, 2006.

[6] K. Pavlović and V. Božanić, "Lean and Six Sigma concepts", *International Journal for Quality research UDK - 615:005.6.* Vol.6, No.1, 2012.

[7] W. M. Carlos, "Optimization in Production Operations. Optimal "Lean Operations" in Manufacturing" © *2005-06 Ultramax Corporation,* Oct. 5, 2006.

[8] Y. Zhen, "Food safety and lean Six Sigma Model", *University of Central Missouri.* Oct. 2011.

[9] M. Rother, and J. Shook, “Learning to See: value-stream mapping to create value and eliminate muda. Brookline”, *MA: Lean Enterprise Institute,* 2003. ISBN 0-9667843-0-8.

[10] D. Rajenthirakumar, P. V. Mohanram, and S. G. Harikarthik, “Process Cycle Efficiency improvement through lean: A Case Study”. *International Journal of Lean Thinking,* Vol. 2, No. 1, pp.46-58, 2011.

[11] L. David, “Project Risk and Risk Management”, Retrieved May 16, 2010.

[12] M. J. Harry, “Six Sigma: a breakthrough strategy for profitability”. *Quality Progress,* Vol. 31, No. 5, pp. 60-64, 1998.

[13] Hubpages: URL- http://leanman.hubpages.com/hub/JustInTime

[14] R. Inman, and R. L. Bulfin, “Sequencing of JIT Mixed Model Assembly Lines”. *Management Science,* Vol. 37, pp. 901-904, 1991.

[15] M. Tajiri, and F. Gotoh, (1992), “ TPM Implementation: A Japanese Approach” *McGraw-Hill Inc.*, New York, 1992.