Process Improvement Through Value Stream Mapping: A Case Study at Vaspal, Mysore

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Vaspal Solutions was started in 2015 to meet the market need for three-piece tin cans for various industrial segments. It is an SSI in Mysore producing aerosol filled metal packages. The average production was 2100 cans per shift. We *studied the process, discussed with employees of the company. The major technique used is Value Stream Mapping (VSP), a lean tool that employs flowchart, documenting every step in the process. The Unique advantage of VSP is, it can be easily interpreted by shop floor employees who can then identify the chances for improvement. After line improvement, the plant produces approximately 3500 cans per shift.*

Keywords: Value Stream Mapping, Takt Time, Current State and Future State Mapping, Non-Value Addition, Waste Management, Cycle Time Reduction

1. Introduction

Lean manufacturing, initiated in Japan has influenced the companies' world over. Reduced inventory, enhanced quality, low cost, less rejection, lesser cycle time and increased productivity are the major features of lean production. Abudul Malek defines[1] "Value stream mapping is a lean manufacturing or lean enterprise technique used to document, analyze and improve the flow of information or materials required to produce a product or service for a customer." It provides a visual representation of the entire value stream, including both value-adding and non-value-adding activities, enabling organizations to identify and eliminate waste, streamline processes, and optimize overall performance[2].

The fundamental objective of value stream mapping is to identify areas of improvement within a value stream by highlighting inefficiencies and bottlenecks. The process typically involves a cross-functional team of individuals who map out the current state of the value stream and subsequently develop a future state map with desired improvements. VSM helps organizations visualize the flow of value from the supplier through various processes to the customer, allowing them to identify and address issues that impede the efficient delivery of value[3].

Key elements of value stream mapping include:

1. Customer: The ultimate recipient of the product or service.
2. Supplier: The provider of materials, information, or services required for the value stream.
3. Value-Adding Activities: Processes or steps that directly contribute to transforming inputs into outputs that meet customer needs.

4. Non-Value-Adding Activities: Steps that do not add any value to the product or service and should be eliminated or minimized.
5. Process Steps: Specific activities or operations involved in transforming inputs into outputs.
6. Information Flow: The exchange of data, communication, and instructions required for the value stream.
7. Material Flow: The movement of physical goods or materials through the value stream.
8. Lead Time: The total time taken for a product or service to move through the value stream, from order to delivery.
9. Cycle Time: The time required to complete a single unit of a product or service.
10. Metrics: Key performance indicators (KPIs) used to measure the effectiveness and efficiency of the value stream.

By creating a visual representation of the current state and desired future state of the value stream, organizations can identify waste, such as excess inventory, overproduction, waiting time, unnecessary motion, defects, and unused employee skills. VSM allows teams to see the big picture and uncover opportunities for process improvement, such as implementing just-in-time (JIT) manufacturing, reducing lead times, increasing productivity, and enhancing customer satisfaction[4].

It is important to note that value stream mapping is not a one-time exercise but a continuous improvement methodology. Once the future state map is implemented, organizations can measure the actual improvements achieved, update the value stream map accordingly, and identify the next set of improvements to pursue. This iterative approach ensures ongoing optimization and responsiveness to changing customer needs and market dynamics.

The researcher has seen value stream mapping as a powerful tool for organizations seeking to streamline processes, eliminate waste, and enhance overall value delivery to customers. It promotes a culture of continuous improvement, facilitates collaboration across departments, and drives organizational excellence.

2. Review of Literature

The researcher has done an extensive review of the literature on value stream mapping:

1. "Application of Value Stream Mapping in Manufacturing: A Systematic Literature Review" by Romero et al. (2017)[5]: This paper provides an overview of the application of VSM in manufacturing environments. It discusses the benefits, challenges, and critical success factors of implementing VSM. The study concludes that VSM is effective in identifying and eliminating waste in manufacturing processes, leading to improved efficiency and productivity.
2. “Improving the quality of Emergency Care Department by Removing Waste using lean Value Stream Mapping" by Cookson (2011)[6]: This study explores the application of VSM in healthcare settings, specifically in the emergency department. The authors discuss how VSM can be used to identify bottlenecks, reduce waiting times, and improve patient flow. The research demonstrates that VSM can significantly enhance the efficiency and quality of healthcare processes.
3. "Application of Lean in Construction through Value Stream Mapping" by Ramani P V and KSD L.K.L. (2021)[7]: This systematic review focuses on the application

of VSM in the construction industry. The authors analyze a range of studies and identify the key benefits, limitations, and challenges of implementing VSM in construction projects. The review highlights the potential of VSM in improving construction processes, reducing lead times, and minimizing waste.

4. "Leading Edge Quality Approaches in Non-Manufacturing Organizations”: by Bane et al. (2002)[8]: This paper explores the application of VSM in non-manufacturing contexts, such as service industries. The authors review the existing literature on VSM in non-manufacturing processes and present a case study on its application in healthcare services. The study concludes that VSM can be effectively adapted to non-manufacturing settings to improve process efficiency and customer satisfaction.
5. "An integrated approach to Value Stream Mapping and Simulation to Process Improvements" by Iqbal Tahir et al. (2015)[9]: This systematic literature review examines the integration of VSM with other lean tools and techniques. The authors identify the main integration approaches, such as combining VSM with Six Sigma or with Kaizen events. The study highlights the potential benefits of integrating VSM with other methodologies for enhanced process improvement.
6. “Investigation and Implementation of VSM in Water Distillation Plants”: Rajeev Rathi et. al.[10] conducted a study on the application of VSM (Value Stream Mapping) in water distillation plants. They highlighted multiple targets of VSM, emphasizing the importance of dedicating time to develop and implement VSM strategies. This approach allows organizations to gain a comprehensive understanding of their entire operation, spanning from clients to suppliers. The primary objective is to detect and eliminate any form of waste within the supply chain, prompting necessary actions to address and eradicate it.
7. “Value Stream Mapping a Versatile Tool for Lean Implementation: A case study of Indian manufacturing industry” by B. Singh et al[11], identifies that organizations can gain competitive advantages (increased efficiency, lower work-in-process inventory, improved quality, lower area usage, and better workplace organization) as well as body advantages (reduction in order process errors).
8. “VSM a Powerful Diagnostic and Planning Tool for a Successful Lean Implementation. A case-based approach” by Lamia Ben Fredj-Ben Alaya (2016)[12], showed how to apply VSM as a qualitative tool for identifying and analyzing process inefficiencies. The research involved studying a methodological approach that follows the guidelines of Rother and Shook[13]. This approach included creating a map of the current state, analyzing it, and then building upon it the desired situation map in order to identify the opportunities for lean projects/tools.
9. The study titled "Applicability of Lean Production with VSM to the Rioja wine sector" by E. Jime´neza, A. Tejedab, M. Pe´rezb, J. Blancob, and E. Martı´nezb (2012)[14] published in the International Journal of Production Research explores the use of Value Stream Mapping (VSM) as a tool for waste identification and process improvement in the Rioja wine sector. The researchers first developed a current state map to understand the existing process and identify waste. This step helped them gain insights into the areas that needed improvement. Based on the

current state map, the researchers then created a future state map that depicted the proposed improvements. This map served as a blueprint for the desired process flow and efficiency.

10. "Analysis and modeling the enablers of Green Lean Six Sigma implementation using Interpretive Structural Modeling" by M. Kaswan et. al[15], observes that waste, according to Womack and Jones[16], is any human activity that consumes resources without producing value. Organizations must identify the supply chain of their products to avoid and eliminate waste in the manufacturing process. VSM is one of the widely used lean producing techniques for destroying waste.
11. Article "Application of Lean Manufacturing using Value Stream Mapping in an Auto-Parts Manufacturing Unit" published by Harwinder Singh and Amandeep Singh (2013)[17] in Journal of Advances in Management Research reveals that in recent times, many organizations have tried to adopt or have already adopted lean manufacturing. Few companies have implemented some specific tools or techniques or practices or procedures (i.e., "elements" in short) of lean Management, while others have implemented a whole spectrum of lean management elements. The objective of lean management is to reduce non- value addition in every part (such as human effort, inventory, time to market and manufacturing space) to become more responsive to customer demand while producing quality products in the most efficient and economical manner.

3. Scope of the Study

This is study is conducted at Vaspal Solutions, Mysore. The process of manufacturing tins for aerosol application is studied for process improvement. There are a few aspects which can be generalized. However, the process improving aspects covered under this study may be limited to Vaspal, as Vaspal being a small-scale industry carries out many activities manually.

4. Objectives of the Study

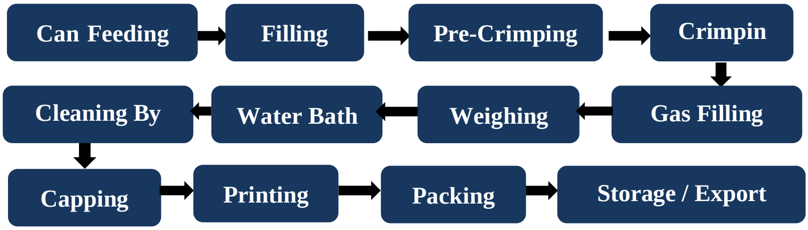
The primary objective of the study is to reduce the overall cycle time and to enhance productivity. The detailed objectives of the study include:

1. Study the current state of process and map value stream
2. Identify the desired future state of process
3. Calculate takt time
4. Identify the areas for improvement
5. Suggest methods for improvement
6. Map the value stream for future state

5. Value Stream Mapping at Vaspal

5.1 Study of Existing Process

To begin with, the process carried out at Vaspal Solutions is represented using a flow chart as shown below.



The above steps of Process of manufacturing tin cans for aerosol application are discussed in detail as below. Every process is done manually.

- Can Feeding: Cans are fed to machines for filling the High Viscous liquid in to it.
- Filling: VASPAL uses a manual filling method for low viscous active material in aerosol cans and automatic process for high viscous active material. The manual process involves the use of a large drum with a small tap at the bottom. Here is a summary of the steps involved in the manual filling process:
    1. Filling: The operator opens the tap on the bottom of the drum containing the low viscous active material. They fill the aerosol can directly from the tap, controlling the flow to ensure proper filling. Once the can is filled, the tap is closed.
    2. Weighing: After filling, the operator weighs the filled can to ensure that the desired amount of active material has been dispensed accurately. This step helps maintain consistency in the product and ensures proper dosage.
    3. Trolley Placement: Once the can is weighed and confirmed, the operator places it on a trolley. The trolley is used to transport the filled cans to subsequent process stations within the facility.
    4. Further Processes: The trolley with the filled cans is manually taken to other stations for additional processes such as pre-crimping and crimping. These processes involve the attachment of the valve and sealing the can to prevent leakage.

Observation: The process is characterized by its slow pace, extensive time consumption, and inefficiency, as explained below:

1. Regular refilling of the drum is necessary as the current drum size is inadequate. This leads to a significant waste of time, with each refill taking approximately 3-5 minutes.
2. The active material experiences a delay as it passes through the drum's tap.

- Pre-Crimping: Once the active material is filled in the can, it is placed on the trolley for further processing. The trolley is transported towards the crimping machine. Prior to crimping, the valve that needs to be sealed is inserted into the can, a step referred to as pre-crimping. Following pre-crimping, the cans are then taken to the crimping process. This process is done manually and requires a longer duration, approximately 3 to 4 seconds per can.
- Crimping: A crimping tool is a device that is utilized to join two metal pieces together by deforming one or both of them, resulting in a secure hold. The outcome of the tool's action is referred to as a crimp. The crimping machine, a straightforward semi-automatic version, allows for the crimping of one can at a time. It is user-friendly, requiring only a single operator. The same person handles both pre-crimping and crimping tasks. The operator's responsibilities involve correctly positioning the can by making necessary valve adjustments, followed by simultaneously pressing two buttons with both hands. The machine takes care of the crimping process.

    Observation: The machine operates solely on pneumatic power, without using electric or hydraulic power. As a result, it is classified as a semi-automatic pneumatic crimping machine. Within the plant, there are two crimping machines.

One is located at the main line, where low viscous material is filled, while the other is situated at a separate line for high viscous active material. The machine handling the highly viscous material is also semi-automatic, requiring operation through a pedal. When the pedal is pressed, the machine proceeds to crimp the can positioned beneath it. Following each process, the cans are manually transferred to the subsequent stage.

- Gas Filling: In VASPAL, there are two semi-automatic propellant filling machines. One is located at the low viscous active material filling line, while the other is at the high viscous active material filling line. These machines are used to fill gases such as LPG, CO_2, NO_2, and nitrogen, which are known as propellants. Propellants are materials used to move objects by applying a motive force, either with or without a chemical reaction. In the aerosol industry, propellants are used to make sprays come out. At the low viscous filling line, cans are sent through a conveyor to the propellant filling machine after the crimping process. The operator manually places the cans under the propellant filling head and presses two buttons to start the process. After filling the propellant, the operator weighs the can for the right quantity and further the cans are shifted to the hot water bath process.

Observation: The propellant filling machine on the high viscous filling line is a semi-automatic machine with a single head. Its main purpose is to fill deodorized LPG into cans.

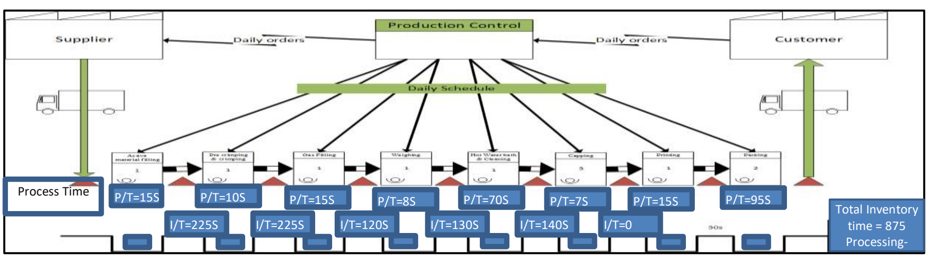
To begin the filling process, the operator positions the can underneath the propellant filling head and activates it by using a pedal. Once the pedal is pressed, the machine starts filling LPG into the cans. After the cans are filled, they are weighed and then subjected to a hot water bath process. Each machine takes approximately 7 seconds to complete the entire process for one can.

- Weighing: This process involves weighing cans after propellant filling and determining if they fall within a specified weight tolerance range. The steps involved are as follows:
    1. After the propellant filling stage, the cans are collected for further processing, including weighing.
    2. The cans are taken to the weighing stage, where their weights are measured. Each product may have its own specific weight tolerance range.
    3. The plant considers only the positive side of the tolerance range. This means that if the weight of a can falls within or above the specified range, but within upper limit tolerance zone, it is considered acceptable.
    4. However, if weight of a can is less than standard range set (lower tolerance zone) or more than the upper limit of the tolerance zone, it is rejected.
    5. Such cans which are rejected are taken for rework i.e., refilling process or weight reduction process is undertaken to address the weight issue. This process may involve adding or adjusting the amount of propellant in the can until it falls within the acceptable weight range.

By implementing this process, the plant can ensure that only cans within the desired weight range are considered acceptable, while any cans outside of this range are identified and corrected through the refilling process.

- Water Bath: After being weighed and accepted, the cans are transferred to a hot water bath. The purpose of this bath is to easily identify any leaks in the cans. Using cold water is avoided because it could cause the active material to freeze or condense, making it difficult to detect leaks. The hot water bath is set at a temperature of 45ºC. If the propellant leaks from the can, the aerosol's active material becomes unusable for the customer, leading to dissatisfaction. Hence, the hot water bath is crucial. The cans undergo a hot water bath at a temperature of up to 45ºC, or lower depending on the product. The immersion time is limited to a maximum of 30 seconds to prevent an increase in internal pressure that could cause the cans to explode.
- Cleaning by Air: Following immersion in a hot water bath, the cans undergo a cleaning process utilizing an air compressor to blow air over them. The air compressor serves as the primary source of air for all pneumatic machines, supplying the necessary air for their operation. The cans are thoroughly cleansed by the forceful air jet, after which they are wiped with a cloth to ensure optimal cleanliness.
- Capping: In the capping process, pressure is applied so that the actuator gets firmly attached to the valve. After that, caps are applied to protect the actuator to avoid any physical damage. This process ensures that the contents do not get contaminated due to dust or foreign particles.
- Printing: The printing task involves manual execution. At the base of each can, the Product ID, Manufacturing date, and Expiry date are meticulously printed. Both capping and printing processes are performed by hand.
- Packing: Once the printing process is complete, the cans are then directed to the packing phase. Here, each can be carefully arranged within a box and sealed.
- Storage and Export: The sealed boxes are subsequently transported to the storage area, where they are securely stored until they are ready for dispatch. Due to a high demand for the product overseas, it is also exported in accordance with the terms and conditions specified by the importer.

5.2 Current State Mapping



Identified Areas of Non-Value Additions and Scope for Improvement

The process is observed for every minute activity. After a detailed study of the process, the current state is mapped as shown above.

The scope for improvement and non-value adding activities are identified after a detailed deliberation with the team. The above diagram gave them a clear idea about how to improve the process and identify the non-value-adding items. They understood that these non-value-adding items have to be removed in order to reduce cycle time. The following observations are made during deliberation.

1. It was found that there are more nonvalue-added times.
2. There is a need for improvement and rearrangements to improve productivity.
3. The plant is able to produce approximately 2000 shifts per can in the current state.
4. The crimping machine head has a six-segment collet. A collet is a form of chuck, but it is not identical.

5.3 Process Improvement

In order to improve the process, the future desired state is identified. The major areas identified for process improvement are as below.

Filling: The installation was made of a semi-automatic machine with two heads, enabling the simultaneous filling of two cans using two cylinders (syringes). This machine operates using pneumatic power. To simplify and save time during the process, a conveyor was incorporated. The cans are then placed on a conveyor by the operator so that they can move to the crimping process automatically. These enhancements resulted in reduced manpower requirements and saved time.

Challenges Faced: The active material filling machine given by supplier must use different syringes for different volumes of the active material. The filling machine supplier had provided a limit switch for feeding of cans to LPG filling stations, this needed a skilled operator, and a lot of inconsistency was observed in the beginning. There was a 50-cfm air compressor. The output pressure of the air compressor was unequal.

Changes Made

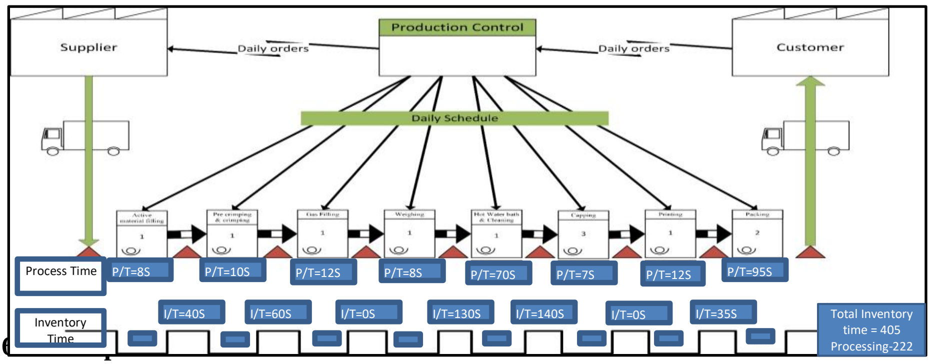
- New syringes were developed locally which can fill the variable volume of the active material.
- The cans are fed to the filling station at regular time intervals using a pneumatic timer.
- A 100-cfm air compressor was installed. A pneumatic grid was provided for equal distribution of compressed air in the entire plant. Further as a part of the improvement process and to solve the problem faced manifold in the LPG filling station, a booster pump was purchased and installed.
- The layout of the plant is changed without major reinvestment.
- Pressure drop across the grid was eliminated.

Results

- The existing cylinder can fill up to 350ml with variable volumes. No change in cylinder is required. This saves change over time.
- Cans are fed automatically to the propellant filling machine.
- All machines can run at the same time without any pressure drop.
- Two parallel lines can be run without interruption.
- Booster pump has increased the filling volume of LPG for both lines.
- The reduction in cycle time is shown below.

5.4 Value Stream Mapping for the Future State

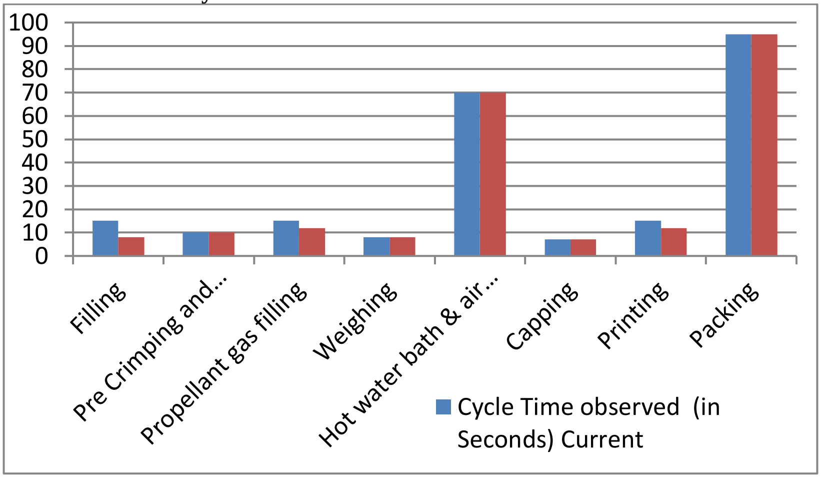
The researcher thoroughly analyzed the existing system and discussed it with the team; it was determined that a significant amount of non-value-added time existed by identifying non-value-added activities[1]. It was identified that improvements and rearrangements were necessary. By implementing upgrades such as a conveyor, new machinery, and a pneumatic timer, we successfully reduced non-value-added time. Initially, the value added (VA) time stood at 235 seconds, while non-value added (NVA) time was at 875 seconds. Presently, we have managed to decrease VA time to 222 seconds, and more notably, NVA time has significantly reduced to 400 seconds. Additionally, the inventory numbers have also decreased. The future state VSM can be seen in the Figure indicated below.



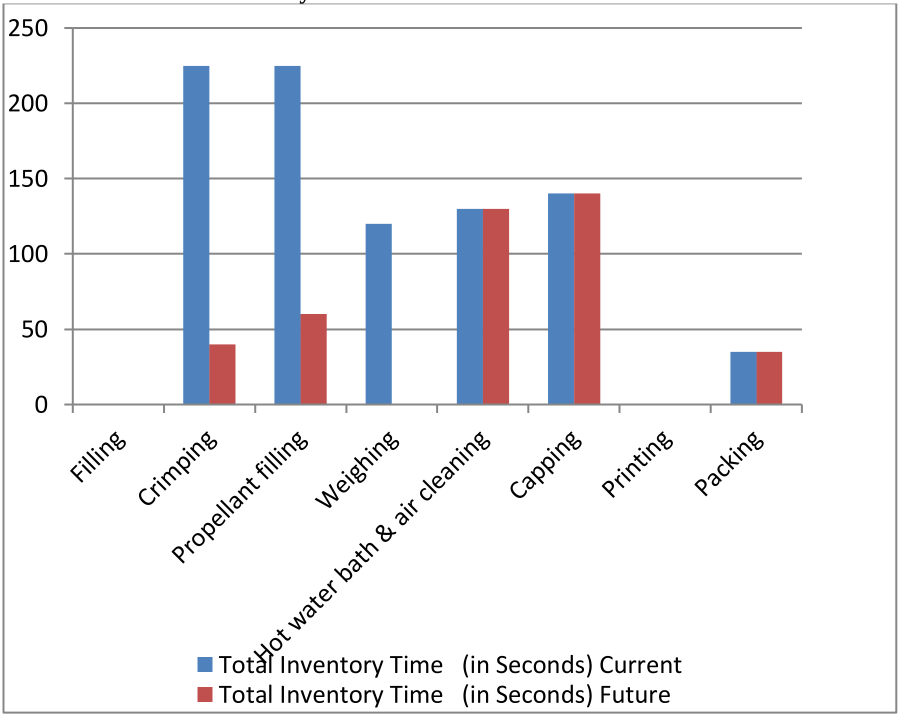
Based on the improvements made the following changes were observed in the time taken

Process	Cycle Time observed (in Seconds)		Total Inventory Time (in Seconds)		In-Process Inventory (in Numbers)	
	Current	Future	Current	Future	Current	Future
Filling	15	8	0	0	0	0
Pre-Crimping and Crimping	10	10	225	40	50	10
Propellant gas filling	15	12	225	60	35	10
Weighing	8	8	120	0	18	0
Hot water bath & air cleaning	70	70	130	130	15	15
Capping	7	7	140	140	15	15
Printing	15	12	0	0	0	0
Packing	95	95	35	35	3	3
Total	235	222	875	405	136	53

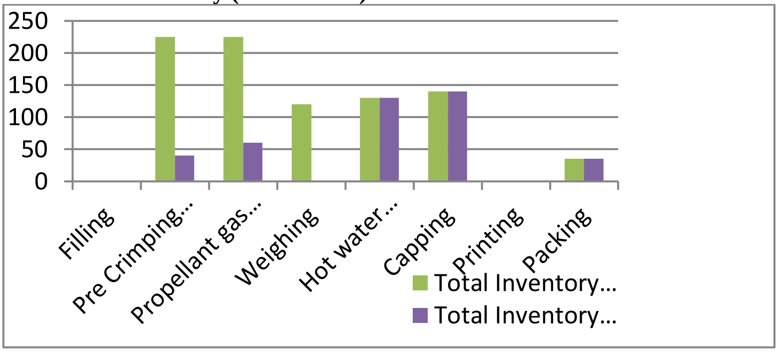
Total Cycle Time Observed in Current and Future State



Total Inventory Time Observed in Current and Future State



In Process Inventory (in Numbers) Observed in Current and Future State



6.2 Efficiency of the Plant

There is a significant difference between the current and future state maps, specifically in terms of non-value addition time. In the current state, inventory time is 875 seconds, whereas in the future state after due modification, inventory time is reduced to 405 seconds. It can be witnessed that inventory time has also experienced a dramatic decrease in the future state map. The process time has decreased as well, albeit in smaller increments, from 235 seconds in the current state to 222 seconds in the future state.

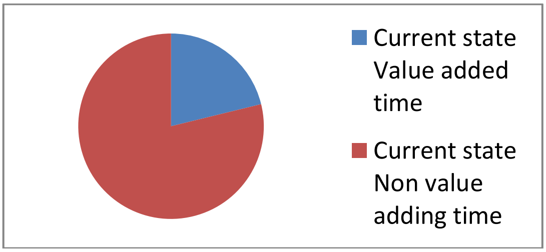
In the current state, the plant has a production capacity (per shift) of 2000 cans. This posed a big limitation as the company could get more orders, like approximately 10000 per day; the plant was no longer able to meet customer requirements. After implementing line improvements, the plant can now produce approximately 3800 cans per shift, resulting in an average production of 7500 to 8000 cans per day. This increased efficiency aligns with meeting customer demands.

Improvement can be seen in the plant efficiency which would fetch a good rate of return. Before the study was taken up, the plant efficacy was 21.36%. After studying and making required modification in the current process, the efficiency of the plant increased to 35.41%. This translates to a 65.77% increase compared to the previous value, as depicted on the chart below.

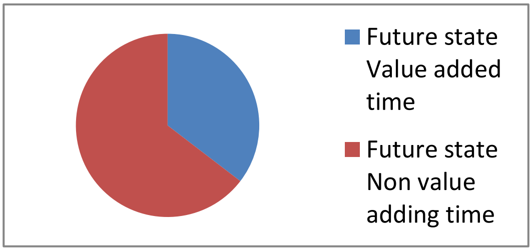
Efficiency = (total process time / total lead time) × 100

Efficiency of current state map = (235/1100) × 100 = 21.36%Efficiency of future state map = (222/627) × 100 = 35.41%

Efficiency of the Plant before Line Improvements



Efficiency of the Plant after Line Improvements



6.3 Takt Time Calculations

Takt time is an important concept in Lean manufacturing that ensures production processes align with customer demand. It measures the time available per unit to meet customer requirements efficiently. By determining the pace at which products or services should be produced, takt time helps maintain an optimal production rate.
Takt time is calculated using the formula below.
"Takt Time = Available Production Time / Customer Demand". To calculate takt time accurately, two key pieces of information are needed:

1. Available Production Time: This is the total time available for production during a specific period, excluding non-working hours, breaks, planned maintenance, and unproductive time.
2. Customer Demand: This represents the total number of units or services required by customers within the same period.

After conducting the study, it was found that the total lead time in the current state was 1110 seconds, while the total lead time in the future state was 627, which is almost half. The plant operated in two shifts per day, with each shift having 8 hours of working time. Earlier, 2000 cans were produced in each shift. After line improvement, the company could now produce 4000 cans per shift. Calculating the TAKT time, which represents the time available for work per shift divided by the customer demand per shift, we got a result of 7.2 seconds.
"Takt Time = Available Production Time per shift (in seconds) / Customer Demand per shift"

8 X 60 X 60/4000 = 7.2

Overall, takt time serves as a vital tool for achieving a balanced production system that matches customer needs. It aids in identifying areas of improvement, as well as potential bottlenecks, and inefficiencies within the production process.

7. Conclusion

This case study, conducted at Vaspal Pvt Ltd, based on lean thinking, describes an improvement process in order to reduce cycle time of filling aerosol in cans. For implementation of the VSP technique, it is important to know about the time consumed at each step and detailed production process. The improvement process involved changing the infilling process from manual to semi-automatic. The researcher conducted Value Stream Mapping. Detailed visual representation of activities performed in the production lines was done, followed by identification of opportunities to reduce production time in the aerosol filling. The results of the study are again visually represented through future value stream mapping.

It can be noted here reduction of non-value adding time can significantly increase total production. To reduce value adding time, heavy investment may be required whereas reduction in non-value adding time may not require investment. It needs ideas from the people who are working hands on. Explaining these details to them needs value stream mapping. Hence VSP is a crucial tool in such cases.

Manufacturing time reduction can be a daunting task due to the many factors that influence it and their complex interactions. However, there are basic principles that, if applied correctly, can be used to reduce cycle time. The result indicates 65% improvement in production output at VASPAL.

8. References

1. Abdul Malek, F.A. and Rajgopal, J. Application of VSM to process industry, International Journal of Production Economics, 107(1) (2007) 223-236.
2. Hines, P. and Rich, N., The seven value stream mapping tools, International Journal of Operations and Production Management 17(1) (1997) 46-64.
3. Hines, P., Rich, N., Bicheno, J., Brunt, D., Taylor, D., Butterworth, C. and Sullivan, J., Value stream management, The International Journal of Logistics Management. 9 (1) (1998) 25-42
4. Guru Murthy, A. and Kodali, R. Application of benchmarking for assessing the lean manufacturing implementation, Benchmarking: An International Journal, 16(2), (2009) 274-308.
5. Romero, L.F. and Arce, A., 2017. Applying value stream mapping in manufacturing: A systematic literature review. IFAC-Papers Online, 50(1), pp.1075-1086.
6. Cookson, D., Read, C., Mukherjee, P. and Cooke, M., 2011. Improving the quality of Emergency Department care by removing waste using Lean Value Stream mapping. International Journal of Clinical Leadership, 17(1).
7. Ramani, P.V. and KSD, L.K.L., 2021. Application of lean in construction using value stream mapping. Engineering, Construction and Architectural Management, 28(1), pp.216-228.
8. Bane, R., 2002. Leading edge quality approaches in non-manufacturing organizations. In ASQ World Conference on Quality and Improvement Proceedings (p. 245). American Society for Quality.
9. Tahir, I., Jahanzaib, M., Wasim, A. and Hussain, S., An integrated approach of Value Stream Mapping and simulation for process improvements. J. Manuf. Technol. Manag, 20(2), p.20115.
10. Rajeev Rathi et al, Investigation and implementation of VSM in water distillation plants, Materials Today: Proceedings 50 (2022) 751-758
11. B. Singh et al, Value stream mapping a versatile tool for lean implementation: an Indian case study of the manufacturing industry, Measuring Business Excellence13(3) (2009)58-68.
12. Lamia Ben Fredj-Ben Alaya, VSM a powerful diagnostic and planning tool for a successful Lean implementation, Production Planning & Control. 27(7-8), (2016) 563-578.

13. Rother, M. and Shook, J., Learning to See: Value Stream Mapping to Create Value and Eliminate Muda, Lean Enterprise Institute, Cambridge, MA. (1999)
14. E. Jime´neza, A. Tejedab, M. Pe´rezb, J. Blancob and E. Martı´nezb, Applicability of lean production with VSM to the Rioja wine sector, International Journal of Production Research. 50(7) (2012) 1890-1904.
15. M. Kaswan et al, Analysis and modeling the enablers of Green Lean Six Sigma implementation using Interpretive Structural Modeling. Journal of cleaner production 231 (2019)1182-1191
16. Jones, D. and Womack, J. Seeing the Whole: Mapping the Extended Value Stream, Lean Enterprise Institute (2000)
17. Harwinder Singh and Amandeep Singh Application of lean manufacturing using value stream mapping in an auto-parts manufacturing unit, Journal of Advances in Management Research. 10(1) (2013) 72-84.
18. Hines, P., Value stream management: next frontier in supply chain, Logistics Focus, 1 (3) (1999)36-39
19. Rathi, R., Jagadeeswaran, M., Imran, G. M., Kumar, K. V., Eswar, K. V. R., & Sameer Pasha, S. (2022). Investigation and implementation of VSM in water distillation plant., 50, 751-758.
20. Guru Murthy, A. and Kodali, R. Design of lean manufacturing systems using value stream mapping with simulation: a case study, Journal of Manufacturing Technology Management, 22(4) (2011) 444-473.
21. Lian, Y.H. and Van Landeghem, H., Analyzing the effects of lean manufacturing using a value stream mapping-based simulation generator, International Journal of Production Research 45 (13) (2007), 3037-3058.
22. Mahapatra, S.S. and Mohanty, S.R., Lean manufacturing in continuous process industry: an empirical study, Journal of Scientific and Industrial Research, 66(1), (2007)19-27.
23. Lasa, I.S., Laburu, C.O. and de Castro, V.R., An evaluation of the value stream mapping tool, Business Process Management Journal, 14(1) (2008) 39-52
24. Grewal, C.S., An initiative to implement lean manufacturing using value stream mapping in a small company, International Journal of Manufacturing Technology and Management, 15(3), (2008) 404-417
25. Braglia, M., Carmignani, G. and Zammori, F. A new value stream mapping approach for complex production systems, International Journal of Production Research, Vol. 44 (18) (2006) 3929-3952