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Research Article

Performance based New Methodology for Implementing Value Stream Mapping

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Abstract: Value stream mapping 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. Value stream mapping has supporting methods that are often used in Lean environments to analyze and design flows at the system level across multiple processes. Although value stream mapping is often associated with manufacturing, it is also used in logistics, supply chain, service related industries, healthcare, software development, product development, and administrative and office processes. In this paper we proposed a new methodology for implementing Value Stream Mapping, in processes that feature High-Mix, Low-Volume product base. The purpose of our paper is to gather the best practices for controlling and improving High-Mix, Low-Volume processes and merge them with some innovative ideas to create an inclusive Value Stream Mapping methodology which is better fitted with the types of complications in High-Mix, Low-Volume environments. The real-life experimentation allow for the fine-tuning of the methodology.
Keywords: VSM, Learning to See, Lean Manufacturing

INTRODUCTION

Lean is lean since 'it provides a way to do more and more with less and less', that is to say less human effort, less equipment, less time and even less space while simultaneously producing products that customer really want. The concept of mapping a process for visualization has long been well known in many different areas and organizations. The idea was translated into manufacturing almost as early the beginning of scientific management. With the introduction of Lean Manufacturing, new dimensions of tools were added to regular process mapping. In addition to simply visualizing the process, Value Stream Mapping methodology proposed a specific plan to use the visualization, and implement Lean Manufacturing through a series of steps. By proposing these specific tools using the mapping, the authors had to make a series of assumptions about a process. Although some aspects of the methodology were left openly for interpretation, other tools were proposed to improve a specific type of processes.

There are many methods used by manufacturing managers to minimize waste, and properly control High-Mix environments. However, a tool has never been developed that compiles these methods. Even more rarely have these tools been combined with traditional Value Stream Mapping methodology to provide a brand new conceptual and complete approach to improve such processes. This forces supervisors, Industrial Engineers, and managers of such environments to try to control High-Mix environments doing three different things:

- Constantly searching for new tools to improve the process.
- Focusing on one single source of knowledge, thus having an incomplete view of the possibilities that exist to improve the process.
- Ineffectively trying to implement only traditional Lean Tools, which might not be meant to optimize High-Mix, Low-Volume environment?
- Disengage from a central management philosophy, and control the production processes on an instinctual basis, which turns their responsibilities into constantly putting out fires. This might even deteriorate the process, thus discouraging managers from using Lean or VSM [1-2] and [4].

The paper work is focused on compiling all of the best ideas and research currently available for the control of a High-Mix, Low-Volume manufacturing environment.

LITERATURE SURVEY

Definitions

Lean Manufacturing: A manufacturing philosophy now a central and key part of most manufacturing plants centered on the relentless elimination of waste as its main objective. Waste is defined in Lean Manufacturing as any expenditure of resources used for any other reason than the creation of value for the end customer. It is based originally on the Toyota Production System, focusing on the main seven wastes.

Seven Wastes of Lean Manufacturing: Transportation, inventory, motion, waiting, over processing, overproduction, defects.

High-Mix, Low-Volume Manufacturing: A manufacturing process which is used to produce a relatively high amount of different parts, each with separate production processes and routings. It differs from a High-Volume, Low-Mix manufacturing process since the latter has a very predictable process for a relative few number of finished goods. The process can then be run a lot more stabilized.

Value Stream Mapping: A lean implementation methodology based on mapping a process in order to see waste, and establish improvements to reduce waste. It focuses on improving the flow in a particular manufacturing chain, as opposed to improving a singular transformation process.

Pull System: A production control, and stock replenishment system in which all movement of goods is dictated from an initial pull or signal triggered by an upstream process. As opposed to a Push System, in which demand gets forecasted into the future, a pull system relies on a small amount of inventory between two processes. When the process needs an object, it automatically gets replenished using cards, thusly the production is triggered by the pull, which ensures the exact quantity and types of products are produced, as opposed to a forecasted amount [3-5].

Job Shop Manufacturing Environment: A production environment which is based on separate production stations ran discontinuously. Every type of product has a different “routing” or order of operations. It makes for a highly flexible system able to cope with some of the eccentricities of High-Mix, Low-Volume manufacturing.

Production Batch: A group of identical products which is produced. They are aggregated to streamline the fixed costs of activities for the same type of products.

Line Changeover: The time that elapses between the processing of two production orders in a system. Line Changeover time usually includes equipment set-up time, documentation, quality audits, cleaning, gathering materials, and getting approvals.

SMED: Stands for Single-Minute Exchange of Dies, a Lean Manufacturing tool used to dramatically reduce line changeover times.

Takt Time: A manufacturing concept which means how much time passes before a single unit is bought from the customer. It is the customer’s voice and dictates the pace that a manufacturing process should finish manufacturing every unit. The Takt Time is calculated as such:

Takt Time = (Total Customer Demand)/(Total Available Time)

Cell: A group of workstations or machines operating in a true continuous flow fashion. Workflow is linked so if work stops on one station, all work will stop in the cell. Usually in a cell, machines and workstations are placed close together in the order of processing, sometimes in a U shape. Cell operators may handle multiple processes, and the number of operators is changed when customer demand rate changes. The U-Shaped equipment layout is used to allow more alternatives for distributing work elements among operators and to permit the leadoff and final operations to be performed by the same operator.

Continuous Flow Production: Items are produced and moved from one processing step to the next, one piece at a time. Each process makes only the one piece that the next process needs, and the transfer batch size is one. Also called “single-piece flow”.

Dedicated Resources: Machines or equipment that can be isolated and used solely for the purpose of building specific products or product families. They are usually low-cost equipment such as assembly stations and small presses.

Kaizen: Continuously improving in incremental steps.

Kanban: A signaling device that gives instruction for production or conveyance of items in a pull system. Can also be used to perform kaizen by reducing the number of kanban in circulation,
which highlights line problems.

Material Requirements Planning: A computerized system typically used to determine the quantity and timing requirements for delivery and production of items. Using MRP specifically to schedule production at processes in a value stream results in push production, because any predetermined schedule is only an estimate of what the next process will actually need.

Mixed Model: Producing a variety or mix of products or product variations through the same value stream at the pull of the customer. Building and delivering the right quantity of a specific
product when the customer wants it.

Process Kaizen: Improvements made at an individual process or in a specific area. Sometimes called "point kaizen."

Supermarket: A controlled inventory of items that is used to schedule production at an upstream process.

System Kaizen: Improvement aimed at an entire image.

Value Stream: All activities, both value-added and non-value-added, required to bring a product from raw material into the hands of the customer, a customer requirement from order to delivery, and a design from concept to launch. Value stream improvement usually begins at door-to-door level within a facility and then expands outward to eventually encompass the entire value stream.

Value Stream Loops: Segments of a value stream whose boundaries are typically marked by supermarkets. Breaking a value stream into loops is a way to divide future-state implementation into manageable pieces.

WIP: Stands for "work-in-progress", any inventory between raw material and finished goods.

Definition of Waste and Benefits of Waste Elimination

Identification and elimination of non-value added steps in all the processes of an enterprise is the essence of the lean enterprise. There are seven waste categories as follows:

• Errors that require rework
• Production of unneeded goods
• Excessive processing steps
• Unnecessary people, material, and information movement
• Idle people, machinery, or material
• Manufacturing products and rendering services which do not meet customer's needs
• Excessive inventory

Benefits of waste elimination improve overall efficiency of an enterprise. The following benefits are observed when waste is eliminated.

• Improvement in responsiveness to customers, decrease in quality defects reaching customers, decreased cycle time
• Improvement in manufacturing floor organization and overall reduction of floor space
• Labor productivity increase
• Simplification of production and information control systems
• Timely arrival of shipments from the supplier
• Reduction of warehouse space
• No finished goods inventory build up
• Reduction in inventory levels across the value stream [6-7]

Customer, Contracts and Pricing, Engineering, Sourcing, and Suppliers

Customer, Contracts and Pricing, Engineering, Sourcing, and Suppliers work closely with one another to set up and price the contract, design the systems, and order the material. Times associated with each department's involvement in various functions are roughly estimated due to the challenge of separating each department's level of participation [8-9].

Proposed Value Stream Mapping Methodology

In this paper work is focused on compiling all of the best ideas and research currently available for the control of a High-Mix, Low-Volume manufacturing environment. It obtains the best characteristics of many different sources, and creates a merger with Value Stream Mapping. As defined in the problem, Regarding High-Mix, Low-Volume production, there exist many different tools and methodologies to improve on such processes, yet there are few and far between. In addition, most toolsets proposed are contradictory to each other, not thorough enough, or provide too much academic detail to be understood easily by today´s top managers.

The Value Stream Mapping adapted to High-Mix, Low-Volume manufacturing environment developed in this master paper. The base of the paper is the Value Stream Mapping methodology proposed in Learning to See, with many additions to it in order handles the complications of High-Mix, Low-Volume. This methodology can be summarized in the following way:

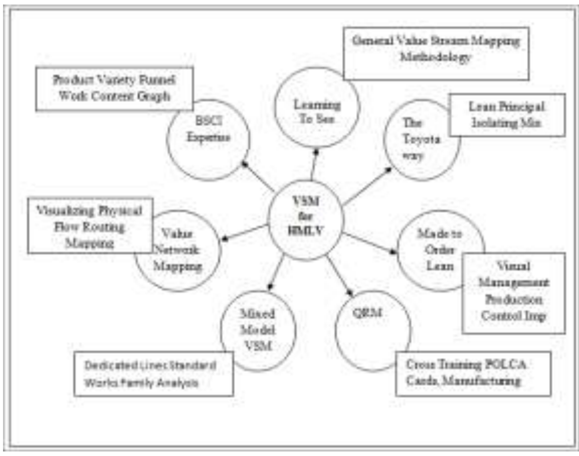

Fig-1: Proposed Value Stream Mapping Methodology Architecture

Methodology Proposed in Learning to See

The methodology proposed in Learning to See is the main contributor to the theoretical framework of Value Stream Mapping adapted to High-Mix, Low-Volume manufacturing environments. The book provided the basis for Value Stream Mapping. Most of the steps proposed in the methodology were followed in what way or another. Some concepts proved to be highly valuable such of the analysis of value added time, the implementation of continuous flow, and the use of demand leveling. Other concepts proved to be either inadaptable, or needed to be customized for their use in High-Mix, Low-Volume manufacturing. The following framework is the Value Stream Mapping methodology proposed in Learning to See as:

First Step:
Selection of Product Families Using Process Matrix:
Although this tool does provide a useful analysis to see which products pass a certain process steps, the process matrix is not fully adaptable. There are two main reasons for this. Firstly, in a job shop environment, the routings of the products through the different stations can vary tremendously, as it does in the case of the production environment. This makes it difficult to use the tool. Although the tool might show that two products are of the same family because they go through the same processes, the routing might be completely different. Therefore the mapping of the process would be completely dissimilar for the different products that might have otherwise been grouped into the same family. The second reason why this is difficult is the variance of cycle times within the processes, depending of the product. This means that the matrix might show that two products are of the same family, they might have totally different cycle times. This complication would give several disadvantages when implementing lean improvement initiatives such as continuous flow, or FIFO lanes, where the processes are sensitive to the cycle times inherent in the process.

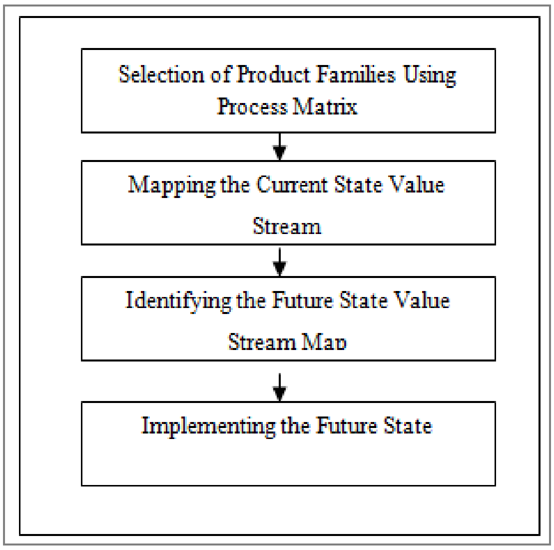

Fig-2: VSM methodologies proposed in Learning to See

Second Step:
Mapping the Current State Value Stream

Once the families are chosen, mapping the current state of the families is also quite an intricate and abstract task. Learning to See imposes that the current state should be mapped in the most true and representative way to show the process. The methodology in Learning to See suggest tackling the different routings, the variance in cycle times, and the differences in inventory by mapping the value stream on top of each other. What creates value in mapping the current state is the following:

- It makes waste visible and apparent
- It diverges the view from process kaizen to flow kaizen. This means that it is used to see waste past a single process.
- It not only maps out material flow, but also information flow.
- It allows users to see the “big picture” of the process in order to better visualize it.
- It creates a blueprint for Lean Implementation.

When one analyzes what are the characteristics of the Current State Map which create value, then one can more easily understand the complications in high-mix, or which features of mapping high-mix, low-volume value streams minimize some of the value in mapping the current state. Some of these complications include:

1) With the great number of different routings in a job shop environment, it is very difficult to map out the flow of the operations that is mostly representative of the entire process.
2) The high variance of cycle times depending on the product make it difficult to find what is the best data to put in the data boxes. The data boxes are boxes of information placed next to the station box that contain some of the most important characteristics of that station including the cycle time, the changeover time, the number of operators, and the pitch.
3) Since there is a relatively long lead time, and may open orders at a time, it is very difficult to properly map out the information flow in order to have a fully representative view of the process.
4) There are a great number of processes and operations, which are all run separately as a batch-and-queue operation.

Third Step:
Identifying the Future State Value Stream Map

The Future State of a Value Stream Map represents the mapping of how a process should run when different lean improvement implementations take place. The methodology proposed in Learning to See elaborates on the steps to create the Future State Value Stream Map, from the Current State. It takes into account the different Lean tools used to minimize waste such as Takt Time, supermarket pull systems, and releasing work at a constant pitch. The following section will outline the 8 different steps to create the Future State and the complications that arise at each of the steps.

1) ***Producing to our Takt Time.*** The takt time is defined as the time the maximum time that must elapse between two finished goods in order to meet the customer demand.

The concept of having one specific Takt Time that dominates all of the manufacturing processes is almost irrelevant in an environment. The reason for this is that since each product has different routings, the demand in units of all of the stations is highly variable.

2) ***Building to a finished goods supermarket***, or straight to the shipping. High-mix, low volume manufacturing means that there are many product part numbers being manufactured. This makes the question of building to a finished goods supermarket, or straight to shipping, almost obsolete for three main reasons:

- Creating the WIP to sustain a supermarket pull system that includes all of the part numbers would be very expensive. By having an order of each of the part numbers available at the end of the process would require over 100 orders of Work in Progress Inventory. This would cost as much as all of the other Work in Progress combined.
- The great variance in lead-time would make the pull system very difficult to properly replenish. This is due to the fact that there are many different routings available for the process. Whereas a particular part number might go though 10 different stations, another part number might go through over 20 stations. This variance in lead-time would make it very difficult to properly control the finished goods pull system.
- The fact that the manufacturing operations are settled overseas makes the operation less crucial in terms of cycle time. In the total cycle time of the whole supply chain, the time the materials spend inside the factory is less than 10% of the total lead-time. This shifts the priorities from responding from planning as fast as possible, to reducing Work in Progress by avoiding a supermarket pull system.

3) ***Where to implement continuous flow*** although this step is particularly relevant for a high-mix, low-volume operation, the problem can be augmented by the following issues.

- The variance in cycle times depending on the products might create shifting bottlenecks in the process that might make it inefficient. This means that if I one particular product is ran in continuous flow, would have completely separate capacity requirements from each of the stations.
- The variance in the routings also creates difficulties in establishing constant continuous flow. The reason for this is because certain processes might me joined with continuous flow, there might come a product that has to go through a different series of processes, thus shifting the requirements. Most of the literature attempts several ways to solve this problem such as creating flexible manufacturing cells. Another High-Mix, Low-Volume manufacturing line called Blazer inside Boston Scientific created a special rotatable table used to align the different processes that an operator can run.

4) ***Where to implement supermarket pull systems***: Supermarket pull systems are very difficult to implement in a high-mix low-volume manufacturing environments for the same reasons why implementing a finished good supermarket pull system is difficult. Although it is possible to implement supermarket pull system by analyzing the variety of the part numbers at each different processing step.

5) ***Where to place the pacemaker.*** The concept of a pacemaker is defined can be compared to a “gas pedal on a car”. The pacemaker in a Value Stream determines the speed at which the value stream will operate. Many times the pacemaker is defined as the most upstream process in which continuous flow occurs. The pacemaker can also but not always be the bottleneck of the process. The pacemaker also refers to the single point in the production chain in which the scheduling will be completed.

6) *How to Level Mix at Production:* Leveling the mix is quite a useful tool in order to eliminate one of the most common wastes, which is overproduction. Leveling the mix means making the interval as small as possible. The interval in Lean Manufacturing is defined as the amount of time needed to be able to product every single high runner, while still meeting the demand. This is also called the EPE Interval, or the Every Part Every Interval. The basics of leveling the mix are in lowering the set-up, or changeover time as much as possible between given customer orders. Doing this gives the manufacturing lines to reduce lot sizes as much as possible. Whereas traditional Economies of Scale manufacturing dictated large lot sizes run for a long time, Lean Manufacturing seeks to reduce the lot sizes. By doing this, it is a lot easier to respond to changes in the product mix from the customer, and makes the line more resilient. The complications, in a High-Mix, Low Volume manufacturing environment, it is even more crucial to level the production mix in order to accommodate the manufacturing process of many part numbers.

7) What consistent increment of Work should Acme release and take away a pacemaker process? Or what is the Pitch? The pitch is defined as the pace at which the pacemaker is measured to see if it is meeting takt. By creating a pitch, constant pitch at which work is released and check can bring many benefits and control to the production control. A complication that arises with the use of pitch in a High-Mix, Low- Volume manufacturing environment is the existence of Variable Lot Sizes. This complication makes it difficult to establish the pitch. Some value can still be extracted by the usage of pitch, mostly in the real of controlling and having visibility of a process.

8) What process improvements are necessary for the Value Stream to flow as the future state describes? After the future state is identified, there usually need to be some process improvements in order to be able to establish the flow. The tipping station had many quality, yield and output problems in order to be run continuously with buffing, a fairly stable process. For this reason, there had to be some improvements including the purchasing of a new machine. **Fourth Step:**

Implementing the Future State: Although the main focus of Learning to See is not on the implementation, the book does propose a plan to execute the implementation in loops, or iterations. Starting with the "Pacemaker Loop" or the group of processes run continuously from the Pacemaker downstream. Then the flow is established by creating the implementation in the rest of the loops which run upstream, until the supplier loop, or the process to gather the materials, etc. In conclusion, the Value Stream Mapping methodology in Learning to See introduces the concept of value stream mapping, and many other tools that are still of use in a High-Mix, Low-Volume manufacturing environment. However, a collection of other tools should be explored to either adapt the steps in Learning to See.

Creating Mixed Model Value Streams

For Creating Mixed Model Value Stream elaborates on the concept of Value Stream Mapping by making several other adaptations which would allow it handle some of the complications of high-mix, low-volume manufacturing environments. Many of the concepts proposed are not really adaptations to high-mix, low-volume, but more like reiteration of information.

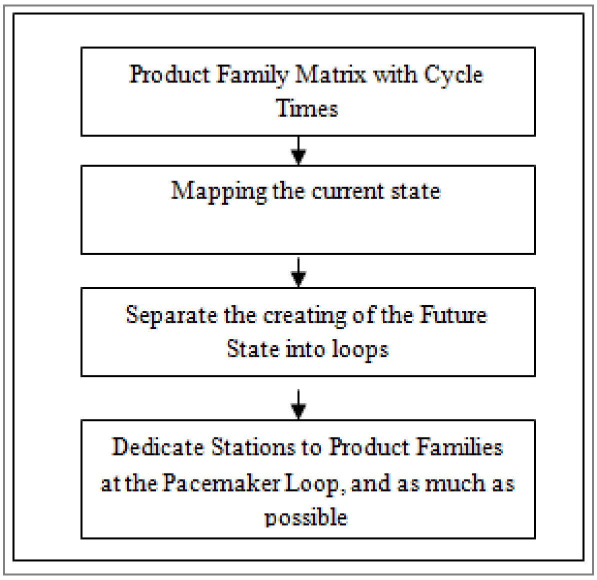

Fig- 3: Methodologies for Creating Mixed Model Value Streams

Mapping the current state: A big concern when the developing the Current State Value Stream map is how properly map the process to add value and visualization, without making it so clustered that it does not add value. The book suggests the following tips

- Establish process boxes only in the places where flow stops, and inventory is accumulated.
- For products with multiple parts, identify one part that travels along the main route through the value stream and walk the path as if you were this part.
- For products with multiple branches, only show one or two complete branches of the value stream map to begin.
- Do not map only a segment of the value stream. The value stream map might be too complex if all of the branches are mapped out.
- To map the inventory in front of shared resources, map out all of the parts, as they signify the real waiting time of that process.

Separate the creating of the Future State into loops. This makes it easier to separate the process into ideal situations. There should be a loop for the pacemaker process and downstream, called the Pacemaker Loop. The Second Loop should include the shipping operations and is used to control the load leveling and finished goods strategy. The third loop consists of all of the other shared processes, which must be controlled using Pull Systems. Finally the fourth loop consists of the Supplier Loop, which should also be controlled using pull systems.

Dedicate Stations to Product Families at the Pacemaker Loop, and as much as possible: By having a pacemaker loop control only one product family, it makes it easier to use several other lean tools for controlling the dedicated lines such as takt time, interval, and balance charts. Being able to have dedicated stations or production lines to the final "assembly" process is much more likely to be possible in a job shop environment. This is because the assembly process is rather consistent throughout the different products and can consist of simple processes such as packing and boxing. In the urethral stents, the top assembly portion of the production process is exactly the same for most production units. This process consists of the flow from Side port – Inspection – Stringing – Packing – Sealing – Labeling – Final Inspection.

VSM from Made to Order Lean

1) **High-Mix Low Volume Implementation Chart.** A customized tool used for the implementation of Lean Manufacturing activities in a job shop environment. Provides with many useful insights such as prioritizing the quality, using visual management, and utilizing day-by-hour boards. It also suggests different improvements to handle as a decision chart. It is quite a useful adaptation that provides feedback to many of the issues facing a high-mix, low-volume manufacturing environment.

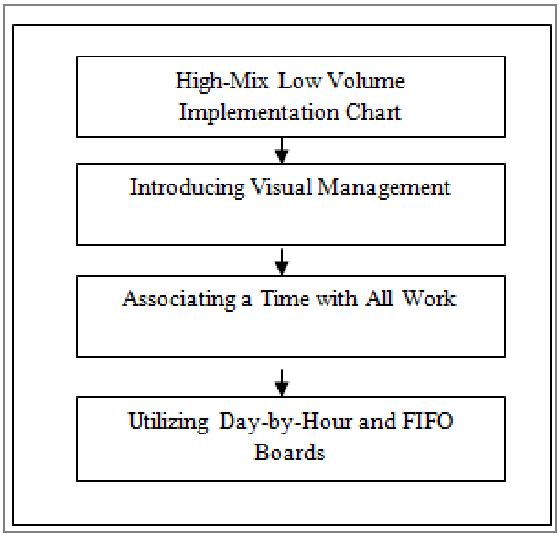

Fig-4:Methodologies for VSM from Made to Order Lean

2) **Introducing Visual Management:** Although this point could be considered outside the regular realm of value stream mapping, many useful insights regarding the implementation of visual management. The "visualization is an important starting point for managing in real time, either on the shop floor or in the department where the work is being completed. If you cannot clearly and quickly understand the status of your system, you will have a hard time prioritizing your limited resources." They also propose the concept of using colors to easily understand the status of a system. They separate the use of visual management into different categories:

a. Metrics; Charts; Value Stream Boards

3) **Associating a Time with All Work:** Although it can be inferred when mapping the value stream of a high-mix, they establish that every single work should be measured, controlled and improved in a high-mix, low-volume manufacturing plant. Although it can be fairly difficult to measure the time for all of the products made in a job shop, doing so will give benefits to the efficiency. They state that by handing someone a work order to complete without associating a time, is like giving someone a blank check. Another reason why they establish that it is useful to associate a time with all work is because it makes estimates more accurate, which leads to better planning.

4) **Utilizing Day-by-Hour and FIFO Boards:** The book talks about a very useful tool called day-by-hour boards, which are best utlized by "shared processes where you are usually working without a solid forecast". Day-by-hour boards should enable the Capacity Planning at a glance, An ability to prioritize, An ability to visualize the current status versus the plan, Indicates where you currently have an imbalance of work, e. A way to encourage operators to list problems that cause delays.

5) Quick Response Manufacturing

Although Value Stream Mapping is a Lean Manufacturing Tool, many authors have criticized the use and implementation of Lean Manufacturing as a set of tools. Lean manufacturing is a management philosophy focused with the relentless elimination of waste throughout every opportunity. In its purest view, one should research what are the best tools that mostly eliminate

Manufacturing cells in a high-mix, low volume production environment can bring improvements in the following aspects:

• ***Efficiency:*** By having teams that support each other, and can quickly rearrange itself to work on a new process, the efficiency of the process is maximized.

• ***Quality:*** By having processes close to each other, all of the mistakes can more easily be identified by the team members. In addition, the motivation of being part of a group of people inspires worker to perform their best, especially for high-mix, low volume production environments.

RESULTS

Experimental Results

Using the 10 steps to improve on the current state value stream map, a future state was developed for the production process which greatly improved on many initiatives.

The methodology proposed gives far greater value than if Value Stream Mapping as proposed in Learning to See would have been used for High-Mix, Low-Volume environments.

Although the future state was not fully implemented, there were many initiatives that were implemented to start reaching the future state. The following were the improvements fully implemented that dramatically impacted the process:

a. Establishing dedicated production lines for the top assembly process.
b. Eliminated tollgate quality audits-They are now included within the production line.
c. Established flexible manufacturing cell for the merge of the Cut, Cut-to-Length, Infrared Forming, and Buff Blunt End.
d. New tipping machines were purchased in order to establish flow between tipping and buffing.
e. The Electronic Work Order Board was fully implemented, bringing unseen levels of visibility and statistical control to the manufacturing process.
f. The priority unit numbers were implemented, ensuring FIFO in the manufacturing process. Also back order costs were substantially reduced.
g. The side port operation was included in the continuous flow top assembly lines. The process was previously performed in the sub assembly area. By separating the operation into two different components, the need to run the station in two different shifts was eliminated.
h. Top assembly completed run in continuous flow. There were other initiatives that were not implemented due to the time constraints; however, they were scheduled to be completed in the future. These initiatives were:

- Establishing flexible manufacturing cells in the entire subassembly area.
- The implementation of a supermarket pulls system before the Cut-to-Length Process. This change could not be easily implemented due to the necessary documentation changes required.

The following table 1 and figure 5 are summarize the benefits out of the implemented initiatives used for Value Stream Mapping.

Table-1: Implemented initiatives used for VSM.

	Top Assembly Dedicated Productio n Lines	Electronic Work Board	Prioritizati on of Unit numbers	Core Metrics at Every Loop	Super market Pull System	Better Mix Leveing
Schedule Adherence	15%	60%	0%	40%	30%	10%
Increase in Visibility	41%	100%	2%	50%	30%	0
Reduction in Backorder	60%	28%	40%	9%	30%	0%
Productivity Increases	22%	0%	15%	8%	8%	0%
Reduction in Lead	35%	2%	22%	12%	1%	0%
Completed	100%	100%	100%	0%	1%	65%

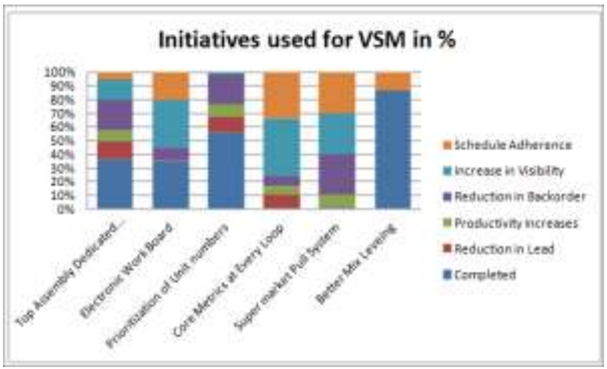

Fig-5: Implemented initiatives used for Value Stream Mapping.

DISCUSSION

The proposed methodology of Value Stream Mapping adapted to High-Mix, Low-Volume manufacturing environments can help lean enthusiasts worldwide improve on their process. Although Value Stream Mapping as described in Learning to See, has great use, it is quite difficult to implemented in a High-Mix, Low-Volume environment. However, with the adaptations, it can bring the same, or greater benefits to the improvement of High-Mix, Low- Volume environments that the traditional methodology brings to repetitive processes. Should someone involved in the a manufacturing process which is high-mix, low-volume, there is much greater value that the person would extract from using the methodology in this book compared to the value that they would extract from Learning to See. That is because the methodology considers the special situations that arise in high-mix, low-volume manufacturing, and addresses them specifically.

From an academic point of view, the methodology proposed in this master paper also provides some innovative tools to improve High-Mix, Low-Volume processes:

Electronic Work Order Board**:** By taking the Work Order Board concept proposed by Greg Lane in his book Learning to See, and adapting it to an excel macro VBA sheet, there has been an easy and effective way to bring visibility to production floors. The electronic work order board is superior to a work order board because it provides an easier process to update, scanning the order, and it is also easier to visualize the data than a regular work order board. In addition, since the information is contained electronically, it allows for the automatic recollection of information about the process which provides an automated time study. All of this can also be done with expensive IT systems which rely on updating licenses, consultants, and expensive technical maintenance.

Product Variety Funnel in the Value Stream Map: In addition, the use of the product variety funnel inside the value stream map adds another dimension of visibility and analysis into the use of Value Stream Mapping. The tool simplifies the decision of where to implement supermarket pull systems.

Demand-Proportionate Process Boxes: By having different size process boxes, it makes it possible to map all of the possible flows in a high-mix, low-volume manufacturing process, yet it does seem to crowded. In addition, it makes it easier for the user to prioritize where waste is being created. It adds to the visual aspect of value stream mapping.

Prioritization Unit Numbers: No other proposed literature had touched on the subject of the FIFO problem in High-Mix, Low-Volume manufacturing environments.

CONCLUSION

The proposed methodology of Value Stream Mapping adapted to High-Mix, Low-Volume manufacturing environments can help lean enthusiasts worldwide improve on manufacturing process technique. Although Value Stream Mapping as describe in Learning to See, has great use, it is quite difficult to implement in a High-Mix, Low-Volume environment. However, with the adaptations, it can bring the same or greater benefits to the improvement of High-Mix, Low-Volume environments that the traditional methodology brings to repetitive processes. Should someone involved in the a manufacturing process which is high-mix, low-volume, there is much greater value that the person would extract from using the methodology compared to the value that they would extract from Learning to See. That is because the methodology considers the special situations that arise in high-mix, low-volume manufacturing, and addresses them specifically. From an academic point of view, the methodology proposed in this paper will greatly expand the potential in which value stream mapping can add value to processes. In traditional Value Stream Mapping, value streams are only considered for product families. This methodology looks at a holistic view of the manufacturing process to include the entire product manufactured inside the value stream. Not only does that bring value to high-mix, low-volume processes, yet it also gives insight into improving processes considering more than one family, even if the process exhibits a medium product mix.

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