

# **AC 2008-2740: THE VALUE OF VALUE STREAM MAPPING TO STUDENTS**

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# The value of Value Stream Mapping to students

## Abstract

This paper provides a discussion of the value of teaching the lean manufacturing topic of *Value Stream Mapping* to senior students in engineering. *Value Stream Mapping* is a technique that is used to view, on a broad level, a company's manufacturing of a part family. The technique is used to identify possible improvement areas within the manufacturing plant. Once identified, the appropriate Lean Manufacturing technique is used to meet specific improvement metrics. These techniques include visual systems, 5S, TPM, cellular layout, work balancing, JIT, etc. Engineering students in college typically do not have an extensive understanding, or the experience, in a manufacturing environment. Unless the topic of value stream mapping is presented correctly the student may not be able to properly use the technique in an actual applied situation. One method of re-enforcing the technique is to have the students working in teams to perform an actual analysis of a manufacturing system and present appropriate and realistic opportunities for improvement.

In order to organize this paper, an overview of Value Stream Mapping (VSM) technique will be discussed first. The primary section of the paper will be on the method of incorporating active learning in the presentation of VSM to engineering students.

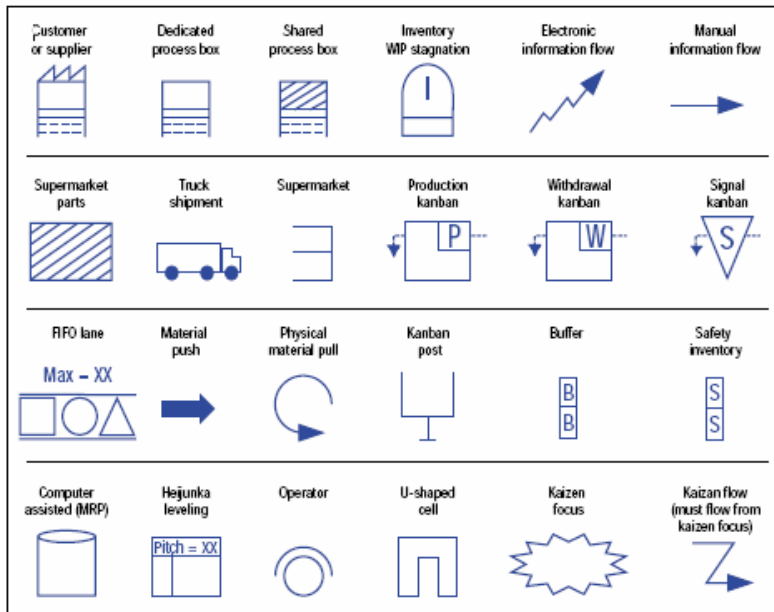
## Value Stream Mapping Overview

Value Stream Mapping is a visualization tool used in Lean Manufacturing (Toyota Production System). It helps to understand the processes and thereby streamline the individual process steps using the Lean Manufacturing tools. The goal of using the VSM technique is to identify the individual areas of waste in the process. Any activity that does not add value to the product is considered waste. Waste can be separated into 7 commonly accepted categories such as overproduction, waiting, transportation, poor processing, excess inventory, excess motion, and defective products.

VSM is the starting point in which engineers, management, production personnel, schedulers, customers, and suppliers can identify current and potential areas for process waste reduction. It is a method of graphically depicting the entire process from the initial customer's request to the final delivery of the product to the customer. The entire process includes areas such as order entry, customer service, scheduling, engineering, raw material ordering, component ordering, and most importantly, the individual process steps in manufacturing. Within the mapping, both the physical process flow and informational process flows are determined and graphically displayed.

VSM uses symbolic icons to represent certain activities such as the follow:

## Value Stream Mapping Icons



From “*Value Stream Management*” (Don Tapping)<sup>1</sup>

The process of Value Stream Mapping can be reduced to 6 general steps:

1. Determine the appropriate process to improve.
2. Create the current state map of the process.
3. Determine the appropriate metric for improvement.
4. Create the future state map of the process.
5. Determine improvement methods to go from the current state to the future state that achieve the correct metric.
6. Initiate the improvements.

➤ *Step 1: Determine the appropriate process to improve.*

In any normal manufacturing environment there can exist many individual processes. Many individual products contain multiple processes, of which each process is further subdivided into multiple process steps (operations). An example of manufacturing a large aircraft may have one overall process for the final assembly of the components and testing but each component will have individual processes. Each of the components, such as a wing or fuselage, may also have multiple subcomponents resulting in multiple processes and

ultimately multiple process steps. The appropriate process must first be one in need of improvement and also be of a single process (with multiple process steps) that can readily be mapped. The selection of this process involves research and analysis by the management and engineering teams.

➤ *Step 2: Create the current state map of the process.*

Once a process has been selected, the detailed mapping can begin. The initial effort is to simply, and generally, determine process steps and map them in the order of the process flow. The mapping requires a vast amount of information on each and every step in the process. Examples of the required information may include (but not limited to):

Pre manufacturing:

Order entry time, Raw material delivery time, Incoming inspection time

Process steps:

Cycle time, Setup time, Number of operators required, Batch (lot) sizes, Equipment uptime, Quality rating (defect rate), Idle time, WIP (work in process)

Post manufacturing:

Final inspection time, Stocking time, Loading time, Delivery time

All of this information is gathered and displayed in order to get the ‘big picture’ of the process. The process of mapping starts with the customer and ends with the customer.

➤ *Step 3: Determine the appropriate metric for improvement.*

When a current state map is produced, it usually becomes evident that there are many opportunities for improvement. Unfortunately, there are times when multiple improvements can result in cancelling each other out; ending with an unimproved process. Metrics for manufacturing process improvements can generally be divided into 3 categories; those that reduce inventory, increase throughput, or reduce operational expenses.

Inventory metrics may include *quantity, quality, and obsolete product; turn over frequency, space, labor, location, etc.*

Typical metrics for throughput include *cycle times, order size, batch size, setup times, equipment uptime, material availability, available labor, labor skills, scheduling, etc.*

Operational expenses include *overhead costs, material costs, labor costs, transportation cost, quality costs*, or any other cost associated with production.

The selection of the proper metric will determine the improvement path taken for the process, so it is very important that the correct metric is selected and that a realistic metric value is also determined. An improvement metric of increasing throughput by reducing the cycle time by 95% is admirable, but may not be realistic nor obtainable. An unobtainable goal is a sure-fire way to sabotage the improvement effort. Why should an improvement team attempt the impossible knowing that they will fail to achieve an acceptable result?

➤ *Step 4: Create the future state map of the process.*

When a realistic metric and metric value (i.e. improve quality rate on part xyz by 15%) has been determined, the future state map can be created. During this exercise, the processes are redrawn in such a way as to include the metric improvement (i.e. quality rate).

➤ *Step 5: Determine improvement methods to go from the current state to the future state that achieve the correct metric.*

It is at this point that the engineering minds are challenged. Contemplating methods to improve a process from the current state to the future state can be difficult. Typical methods include brainstorming, and ‘fish-bone’ analysis in a group environment. Of the many possible solutions to the problem, several would be chosen and reviewed in depth until a single solution emerges. From this unique solution, the method of implementing it can be determined and detailed.

➤ *Step 6: Initiate the improvements.*

Finally the last step in the process; initiate the improvements. At this time the team/group can determine if the proposed solutions actually produced the desired effect and to what degree. Did the change/improvement result in the desired metric gain? If not, then the team/group must go back and reinvestigate the situation.

In an industrial setting, Lean Manufacturing and Value Stream Mapping are typically taught on-site by a consultant or at seminars, typically lasting two to five days. These are designed to give a detailed explanation of the technique and often include simulation examples and workshops using actual on-site manufacturing examples. For a company planning to train many employees, a seminar given by a consultant is a good method, although very expensive. If a company involved in lean manufacturing or planning to implement VSM, an engineering graduate possessing that information and experience would be very valuable and highly sought after.

### The value to Students

Engineering students, especially those pursuing a career in the manufacturing arena would greatly benefit by understanding the concepts and methods of Value Stream Mapping (VSM). Many engineering students do not have the background knowledge or experience necessary to fully understand the manufacturing processes and the process flows let alone the complexities associated with them. This inexperience that the students have can be improved by using the simple methods of VMS. After initial discussions on the types of manufacturing processes and discussions on the non-manufacturing processes involved the student would have the basic knowledge necessary to generate a map. Graphically depicting the process flow and having the students engage in the creation of the process help to enhance this information.

As many of the experienced manufacturing engineers are aware, there are many variables and contributors to a process that complicate and cause problems in the process flow. These complications are considered process variables and are inherent in all processes regardless of the product. By being able to view the process at a macroscopic level, rather than a microscopic level, the student can view the problem in context with other possible contributing process steps.

It is very important for students, especially those with little or no manufacturing background, to be able to see lean manufacturing actually being implemented and used. To that end, the lean manufacturing course taught at our college has each group of students (typically 4 to a team) assigned to a local plant facility for their project. The production facility is selected based on their need, ability to work with the students, and their willingness to participate. The plant tour gives the students the ability to see first-hand, why and how lean manufacturing is used, if at all, and the benefits derived from it. They are given the opportunity to ask questions that may not have been fully explored during class. The students are required to develop the VSM for the process selected by the company. The students create the current map and then discuss it with the company representative and a suitable metric is asked for. The students then create the future map and start brainstorming ideas on how to achieve the goal.

Engineers are problem solvers; that is what we are trained for. In order to solve any engineering problem, the engineer needs to have an understanding of the larger system and the effects that each step in the system has on it. The idea of problem solving is not limited to manufacturing systems, or manufacturing engineers; it is the basis for solving any engineering problem from research to analysis to design to production to distribution. In order to solve most engineering problems, engineers use analysis tools rather than guessing or past practices. VMS is one of these analysis tools that are very reliable when there are multiple contributors to the problem to be solved. In addition, this technique is not limited to the engineering field. VSM is also used for analysis of any process including the flow of information and paperwork (i.e. the office). Industries such as the medical field, food services, municipal services, and educational institutes use this tool to improve their separate processes.

Value Stream Mapping (VMS) is a method to think through a current situation, create an ideal situation, and determine the best way to get to that bridge the gap. VMS is not limited to only manufacturing environments; it is usable for many scenarios including the process of engineering design, sales, marketing, even the simple process of problem solving. Any process can be improved by applying the techniques of VSM.

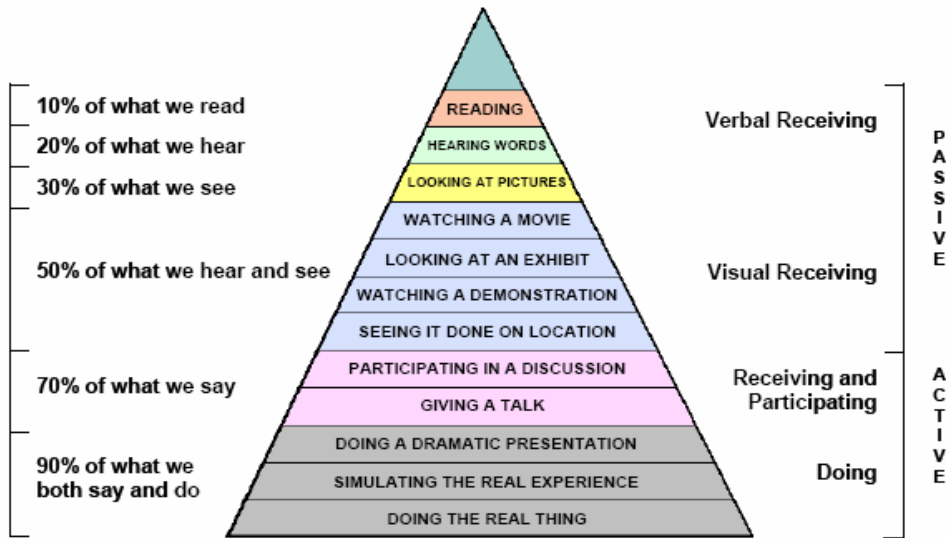
Lecturing is the common method of teaching Lean Manufacturing topics including VSM in an educational environment and the normal method of assessing the student is by a formal exam. This method is relatively easy to administer; however, the students will lack a true grasp of the advantages of lean manufacturing, and how to use lean manufacturing in an industrial setting if they are not directly involved in the process.

Using Edgar Dale's "Cone of Learning" example<sup>2</sup> we can see that a student attending only the lectures on a subject will only retain approximately 20% of the material and is considered "passive" learning. In order for our engineering students to grasp and retain the material, the course must be organized as an "active" learning experience.

# CONE OF LEARNING

## WE TEND TO REMEMBER OUR LEVEL OF INVOLVEMENT

(developed and revised by Bruce Hyland from material by Edgar Dale)



Edgar Dale, *Audio-Visual Methods in Teaching* (3<sup>rd</sup> Edition). Holt, Rinehart, and Winston (1969).

A unique way of teaching lean manufacturing has been developed at Penn State Erie - The Behrend College, and has been taught for the past 5 years. The course is offered as a technical elective in the fall semester to seniors and graduates engineering students. In order to promote and encourage open participation within the class, the normal teaching methods had to be altered to allow for an easy exchange of manufacturing experience between class members. By providing an environment where lectures, open discussions, simulations, and industrial sponsored projects are encouraged, it is believed that the students have a better understanding of the concepts and uses of lean manufacturing in industry<sup>3</sup>.

The class semester begins with an overview of lean manufacturing starting with the Toyota Production System (TPS); including the importance of Lean Manufacturing in the industry. The roles that each individual within a corporation plays from the CEO to the hourly workers is also discussed and explored. Since Lean Manufacturing can be considered a mixture of many techniques and methods, it is important to display to the students how the lean system may be structured such that the information presented in class will follow a logical path. The course starts with Value Stream Mapping (VSM) and continues to enhance the concept as each of the different lean manufacturing techniques is discussed. The other topics included in the course, directly related to VSM, are Visual controls, 5S, Kanban, Just In Time (JIT), Fast Setup

(SMED), Cellular Layout, Total Productive Maintenance (TPM), Process Control/Improvement, and Quality Improvements.

The VSM material is presented as a combination of lectures (low passive learning), examples (high passive learning), open discussion (low active learning), and application of the technique in an actual manufacturing situation (high active learning). During the material presentation on VSM, the 6 steps outlined at the beginning of this paper are followed through using a simple manufacturing example such as the production of wire coat hangers. This example is used because the product is known by all students and the individual production operations can be easily understood.

The 6 VSM steps created as a class area as follows

- Step 1: Determine the appropriate process to improve.  
Example is the manufacturing of wire coat hangers
- Step 2: Create the current state map of the process  
The class is given the following information:  
Pre manufacturing  
Order entry time = 1 day  
Raw material ordering = 1 hour  
Raw material delivery time = 2 days  
Incoming inspection time = 0 hours

Process steps

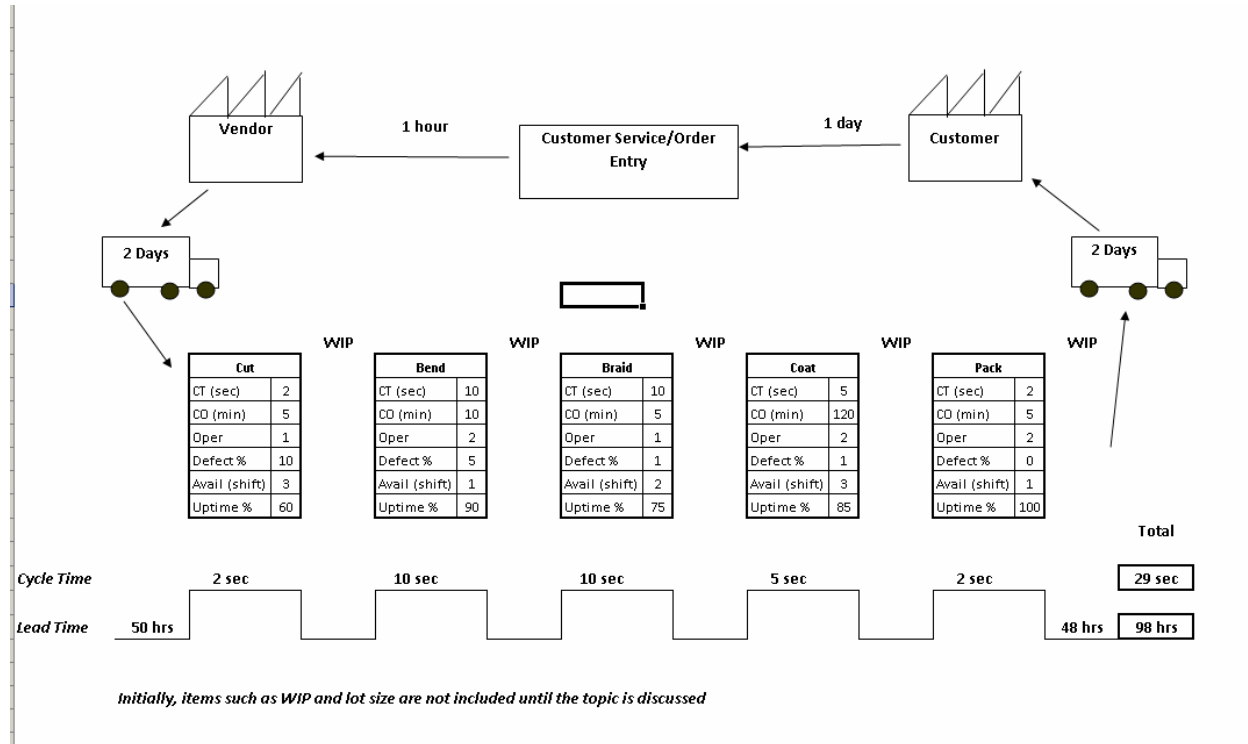
	Cutting	Bending	Braiding	Coating	Packing
Cycle Time (sec)	2	10	10	5	2
Changeover Time (min)	5	10	5	120	5
# Operators	1	2	1	2	2
Defect rate %	10	5	1	1	0
Available (shifts)	3	1	2	3	1
Uptime %	60	90	80	85	100

Post manufacturing

Delivery time = 2 days



From this information, the class creates the current map on the blackboard using the common VSM icons.



During the initial stages, the WIP, incoming inspection, final inspection, lot/batch sizes are ignored in order to keep the example as simple as possible. The students in the class, at this point, can clearly see that the manufacturing time (cycle time) is far less than the lead time. If the issue was delivery time, without seeing the big picture, an engineer may mistakenly attempt to reduce a particular operation's cycle time rather than attempt to reduce the larger contributor; the vendor's delivery time or the customer's delivery time.

- Step 3: Determine the appropriate metric for improvement.

Once the current map is displayed, the class (as a group) discusses the different metrics available for improvement. Three primary metrics are used; Throughput, Inventory, and Operational Expense. Each of the waste types (cycle time, changeover time, etc) are listed for each metric and for each waste type the operation that contributes most is listed. This is accomplished via the brainstorming technique and using a simple spreadsheet:

Metric type	Waste Type (CT, CO, etc)	‘Tall Bar’ (operation)
Throughput	Cycle Time	Bending or Braiding
	Changeover Time	Coating
	Defect Rate	Cutting
	Availability	Bending or Packing
	Uptime	Cutting
Inventory	Changeover Time	Coating
	Defect Rate	Cutting
	Uptime	Cutting
Operational Expense	Cycle Time	Bending or Braiding
	Changeover Time	Coating
	Defect Rate	Cutting

Based on the spreadsheet, the class decides on a single metric to pursue such as “increase throughput by 5%”, or “decrease operational expense by 10%”. For the next step in this example we will choose the latter (operational expense).

- Step 4: Create the future state map of the process.

The future map created, by the class; as an open discussion, and must include the reduction of the operational expenses by 10%. This can be done by reducing the cycle times of the bending and/or braiding operations, reducing the changeover time for the coating operation, and/or reducing the defect rate of the cutting operation. We would first have to determine a manufacturing rate and a changeover rate for each operation. In addition, the value of a scrapped component would be required.

- Step 5: Determine improvement methods to go from the current state to the future state that achieve the correct metric.

This is the step that requires some engineering thought and problem solving. There can be many methods to improve a manufacturing situation from simplistic to complex. By working as a group (teaming), the ideas are brainstormed and the top 5 ideas are voted on for further discussion. In order to fully analyze each idea’s validity, more information would be necessary such as annual volume, profit margin, etc. in order to justify any changes/improvements.

➤ Step 6: Initiate the improvements.

Since this is a fictional example of a process, the actual improvements cannot be performed. Since the students only have one semester to complete the project, the initiation is in the form of a professional report. The company can then decide if the project warrants doing and can follow through on the completion of the project.

The class size is currently limited to 16 student and four teams are created consisting of 4 students each. Each team is assigned an industry sponsor to work with outside of class. The teams complete the industrial portion of the project as each of the subjects is discussed in class concerning the VSM. The project outline for each team is to as follows:

- Visit the industry sponsor and take a plant tour of the facility.
- Discuss the different processes viewed during the tour and decide on a single process to investigate. (*VSM Step 1*)
- As a team, investigate and document the process steps necessary to receive and deliver an order of the product to a customer. This includes raw material ordering time, delivery times, production times, operations, etc.
- Create the current Value Stream Map (*VSM Step 2*)
- Present the current map to the sponsor and discuss possible metrics to pursue. (*VSM Step 3*)
- Create the future Value Stream Map based on the improvement metric. (*VSM Step 4*)
- Present the future map to the sponsor and discuss improvement limitation (i.e. moving equipment, budget, floor space, time, labor, etc)
- Brainstorm on improvement ideas and research costs to implement the improvements. Improvements are very specific and include drawings, layouts, ordering information, etc. (*VSM Step 5*)
- Create a professional report on the project including the return on investment (ROI) for the improvements. (*VSM Step 6*)

As stated earlier, the benefit to the student is not only learning the VSM and using it in an actual manufacturing situation, but the student also obtains the ability to use the general technique for any problem solving. The core of the VSM technique is to view the situation as a big picture, then systematically break the components down to manageable sizes and solve the smaller items. Many of our students that have passed the course have taken jobs directly involving lean manufacturing.. The course is a very important addition to a student's resume' if that student is trying to obtain a position in manufacturing.

To date, the course has been taught for 5 years at Behrend College. During this time interval, over 100 engineering students have enrolled in the class consisting of 20 student teams involved with 15 different local companies. Of the 15 companies involved, all have been very satisfied with the students work and results. Many of these companies request to be included as a project sponsor each year for different processes. We currently do not charge for our student's involvement so long as the sponsor is willing to spend the time necessary for the students to complete the project.

In the past, the enrollment limit for the class has been reached within 5 minutes of being offered. The students self enroll on-line based on the number of accumulated credits they have. Each year there is a waiting list of students wishing to over enroll in the course. During the next fall term (F08), the course will again be offered to only 16 students but each will have to have the instructor's approval. This change is due to the desire to obtain only the best students, and those who also have a desire to continue with lean manufacturing when they graduate. It is our vision to provide the industrial companies with highly trained engineers capable to solving complex lean manufacturing problems from the first day of hiring.

## Bibliography

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