Component Based Modeling and Simulation of Value Stream Mapping for Lean Production Systems

Mohamed A. Shararah[1], Khaled S. El-Kilany, and Aziz E. El-Sayed

Department of Industrial and Management Engineering
College of Engineering and Technology
Arab Academy for Science, Technology, and Maritime Transport
Abou Keer Campus, P.O. Box1029, Alexandria, Egypt

Abstract

Value Stream Mapping is an important tool in the implementation of lean manufacturing. It identifies the waste in the system, paving the way for a successful lean implementation. VSM is a paper and pencil tool that captures the state of the system at the state it was drawn. Simulation can be combined with value stream mapping to give it power and flexibility in order to dynamically capture the state of the system. Component-based modeling divides a simulation model into a number of smaller simulation models each encapsulated in a component resulting in a set of simulation building blocks. These blocks can be used for the purpose of developing value stream maps as they are designed to be generic, reusable, and appear exactly like the traditional VSM icons. This paper introduces the Value Stream Map Simulator using ExtendSim (VSMSx) as a powerful tool designed to facilitate the implementation of lean manufacturing by simulating the value stream map. Compared to traditional value stream mapping, this tool outputs more quantitative information about the system under study and various scenarios allowing for better decision making, thus paving the way for successful lean implementation.

1. Introduction

Lean Manufacturing is a systematic approach for identifying and eliminating waste (non-value added activities) through continuous improvement by allowing flowing of the product at the pull of the customer in pursuit of perfection [1-3]. The goal of lean manufacturing is to reduce the waste in human effort, inventory, time to market and manufacturing space to become highly responsive to customer demand while producing world-class quality products in the most efficient and economical manner [4].

The basic principle of lean is responsiveness to change and waste minimization [5]. According to Womack [6] the five principles of lean are:

1- Correctly specify the value to the customer.

2- Identify the value stream for each product and remove waste.

3- Make the value flow without interruptions.

4- Let the customer pull value from the producer.

5- Pursue perfection by continuous improvement.

Hence, value stream mapping imposes itself as being the primary tool to apply lean manufacturing since it contributes to being one fifth of the principles followed to implement lean manufacturing.

The objective of this work is to develop a tool that combines the designing power of the value stream map with the analysis power of simulation; hence, better decision making in lean manufacturing implementation can be achieved. The paper starts with a brief introduction to value stream mapping followed by a description of reusable simulation and component based modeling as modeling methodology to develop the proposed tool. Afterwards, the VSMSx tool is presented along with a simple case study to show the modeling power of the tool. Finally, conclusions drawn from this work are pointed out.

[1] Corresponding author: Tel.: (+20) 10-6662288; Fax: (+203) 486-0484; E-mail: mshararah@aast.edu

2. Value Stream Mapping

A value stream is defined as all the value-added and non-value-added actions required to bring a specific product, service, or combination of products and services, to a customer, including those in the overall supply chain as well as those in internal operations [7].

VSM is an extremely valuable tool in lean manufacturing and the continuous improvement effort. Traditionally, it is a pencil-and-paper visualization tool that shows the flow of material and information as a product makes its way through the value stream; hence, waste and its sources can be identified [8, 9]. This initial map that identifies the sources of waste in a production process is referred to as the current state map. However, the purpose of value stream mapping is not only to identify the sources of waste, but also to eliminate the sources of waste by developing future state value stream that can be implemented in a short period and ultimately the production process is improved .

As regards to the real-world application of the technique, different practices have been developed and disseminated since VSM was created [10]. One of these practices that is highly used and has given power and flexibility to VSM is simulation as a tool for modeling the Value Stream.

Simulation adds the fourth dimension, time, to a value stream map. After being simulated, the VSM is no longer just a snapshot; it is a moving picture, which offers insights that may have been missed if VSM alone had been used. In addition, both VSM and simulation take a holistic look at the system; VSM is an efficient design tool, while simulation is an efficient analysis tool. VSM creates the model and provides the vision, whereas simulation is used to evaluate the model and substantiate the vision. Thus, combining VSM with simulation can strengthen the following [11]:

- Analysis and evaluation of the current and future states
- Documentation of the areas to improve
- Assessment of the impact of proposed improvements

Simulation has the capability of demonstrating the benefits of lean manufacturing throughout the entire manufacturing system, from raw material arrival to finished goods delivery, and from order receiving to order replenishment. Adding simulation capabilities to value stream mapping is discussed in the next section.

3. Simulation

Discrete-event simulation is a tool used to assist organizations with the decision to implement lean manufacturing by quantifying the benefits that result from applying lean principles in their specific situation. To this end, simulation models are developed to replicate the operation of an existing system, as well as that of a proposed new system that modifies the existing design to incorporate lean manufacturing shop-floor principles. In addition to the manufacturing operations and processes, simulation models can include the warehousing, inventory control, transportation, and production scheduling systems [12].

3.1. Reusable Models

In order to develop a simulation tool for value stream mapping, a number of reusable models are needed to represent the different symbols of value stream mapping. It is not feasible to develop different simulation models of VSM from scratch for each production system. An alternative to unique model creation is the reuse of an existing generic model. If correctly developed, the generic model can be reused, thereby reducing model-building time as well as increasing simulation accuracy.

Figure 1 shows a spectrum of different types of model reuse [13]. It shows types (or levels) of model reuse with two different axes. The first, frequency, indicates that reuse is much more frequent at the right-hand end of the spectrum, where all modellers engage in code reuse provided with a simulator. The second axis, complexity, runs in the vertical direction, making the point that code reuse is relatively easy, whereas successful reuse of entire simulation models can be very difficult indeed.

It should be noted that if the full model is reused in application domains with widely ranging objectives, making it what is called an "all-purpose" model, the complexity of such will increase dramatically. Hence, such type of reuse is practically impossible to achieve [14]. In addition, function reuse refers to the reuse of functions provided with a simulator like random number generators. Finally, component reuse is of particular interest to this work.

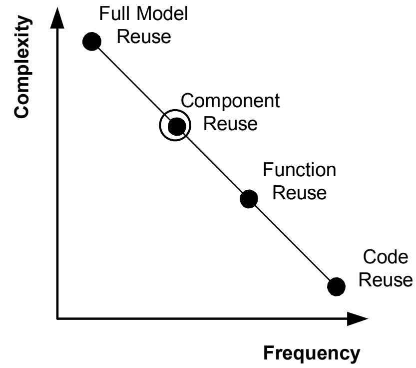

Figure 1: Model reuse spectrum.

Component-based modeling allows users to quickly and efficiently create high fidelity simulation models by linking independent model objects. The result of linking these models is a model network that can be used to evaluate the aggregate performance of the system as well as investigate the interactions and performance of the individual component models. Model users should be able to assemble the model component parts in a plug-in manner, thus minimizing the time, cost and expertise required to construct comprehensive models within the context of their organization [15].

3.2. Simulation Building Blocks

The Component-oriented worldview sees a simulation as being composed of a set of components. It takes a divide-and-conquer approach in which the whole simulation is partitioned into a number of smaller simulation tasks, which are modeled individually as components.

Component-based or simulation building blocks are given the definition of [16]: *"A building block is a self-contained, interoperable, reusable and replaceable unit, encapsulating its internal structure and providing useful services or functionality to its environment through precisely defined interfaces"*.

Meaning that once the building block receives an external event to perform a function, it can execute this function with the information and process description that represents the state of the building block, the building block must cooperate with other building blocks.

It also should be instantiated more than once in a simulation model or other simulation studies, the building block could be removed from the system and another building block takes its place. It should also add something to the model otherwise it should be left out and whatever intelligent or secret mechanism is inside the user does not need to know about. Finally, a building block should contain visualization and animation.

4. Value Stream Mapping Simulator using ExtendSim (VSMSx)

The VSMSx has been developed using the ExtendSim Suite version 7.0.5; it is a complicated tool in its structure yet very simple in terms of its usability and generic nature. Icons are built as simulation building blocks for their high advantage in its use as described. The icons are simply dragged from a library onto the model and connected to look exactly how the traditional VSM looks like. Each Process or Inventory is given a number by the user, this number is the record number where the user will input all the information required for the block to function as required. i.e. the supplier block requires the quantity that is shipped and the days that the shipments should arrive in, the process block requires the cycle time, changeover time, uptime and yield percentage and so on.

As shown in Figure 2 that the simulation building blocks look identical to the VSM icons so that any value stream map reader can understand what the simulation model represents. They are simply dragged and dropped on to the model.

A simulation building block was described in a previous section of this paper. As such, the process icon of the VSM was built in the same manner. It is *self-contained* by receiving its external events (parts) and information (Cycle time, Changeover time, etc.) remotely from a database built and linked to each block in the simulation model. A screenshot and a brief description of the database is shown in the next section. It is *interoperable* since it cooperates with other building blocks in the simulation model, i.e. it receives raw material from the supplier, processes it and then supplies it to the inventory block.

The process block is reusable as shown in the model built using the VSMSx; the blocks are *reused* by simply dragging and dropping it from the library formed to facilitate the building of value stream maps in a simulation model. Any other block can be connected in place of it using the same connection method thus making it *replaceable*. However, the other block won't perform the same function as the process block, thus maintain its *functionality*.

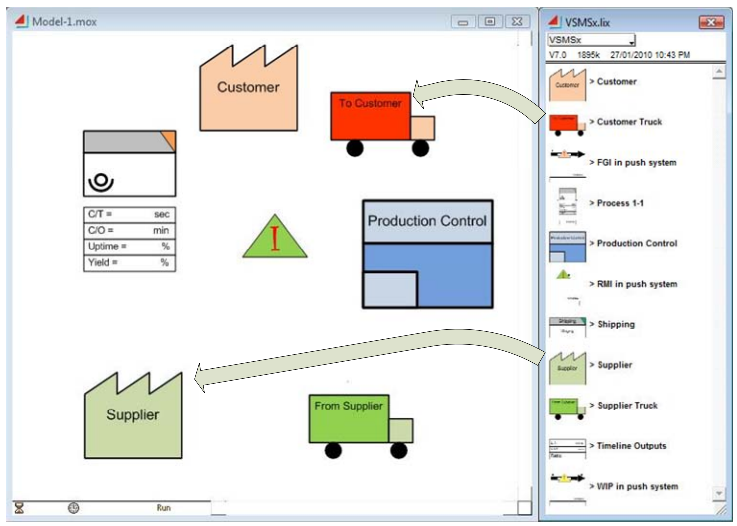

Figure 2: The blocks in the Library are easily dragged and dropped to the model

The block encapsulates its internal structure and a simple representation of what its components are, is shown for demonstration purpose only for the paper in Figure 3. The block has precisely defined interfaces such as the visualization of its inputs and the animation of products flowing. It also exchanges entities and information with other building blocks.

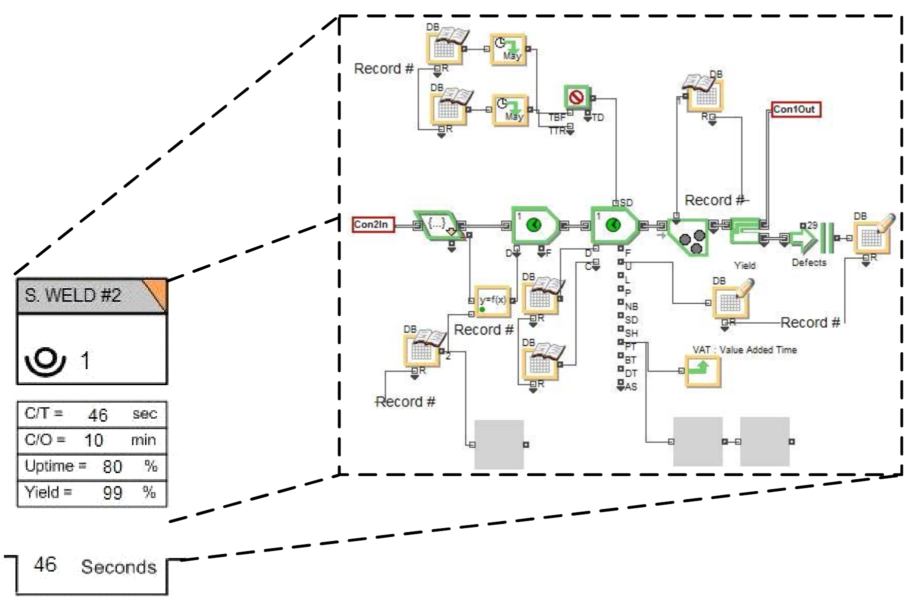

Figure 3: The "Process" block and its internal components

A screenshot of the database is shown in Figure 4, through the database, input parameters to the whole model are identified by the user by simply entering the data collected in a user friendly database interface, such data will also be transmitted to the interface of the blocks to look more like the VSM icon. Data can be altered to review different scenarios and different outputs. The outputs from the model such as statistical data are reported back to the database with no interference from the user.

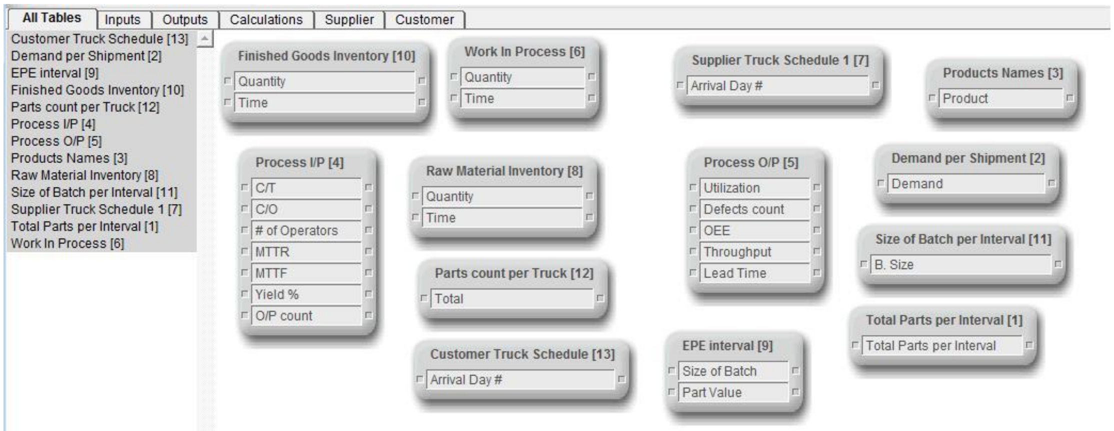

Figure 4: Database used for input and output

5. MODELLING THE ACME STAMPING FACTORY

The simulated model is for a factory called Acme Stamping found in [17]. Acme produces stamped-steel steering brackets in two versions: Left-hand drive and Right-hand drive. All the parts are done in batches by making every part every 2 weeks. Acme are supplied with coils twice a week, it requires five processes to produce the steering bracket, either Left-hand drive or Right-hand drive. Inventory is located prior to each process and although orders are delivered to the customer daily, there is finished goods inventory located in large quantities.

The current state of the Acme factory using traditional value stream mapping is shown in Figure 5. As a comparison to how the VSMSx builds models that look the same as the real-world pencil-and-paper value stream maps, the same map was built as a model as shown in Figure 6.

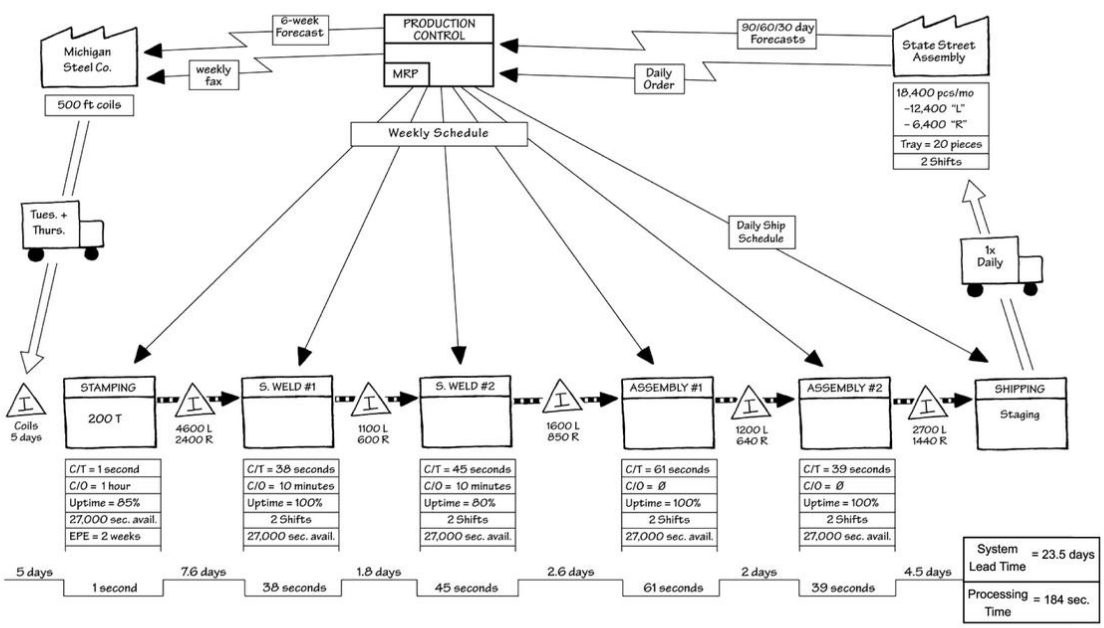

Figure 5: The current state of Acme with traditional value stream mapping

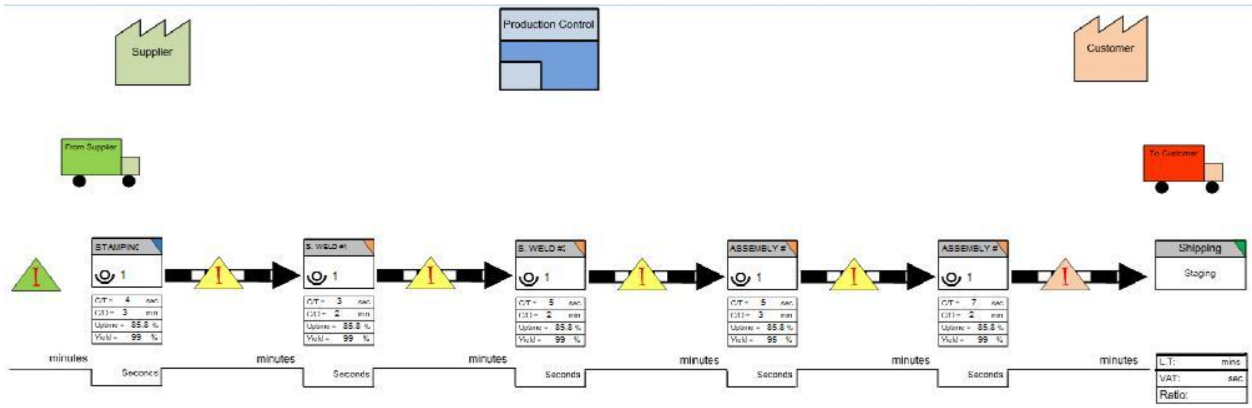

Figure 6: The current state map of Acme with VSMSx

5.1 VSMSx versus traditional VSM

The information flow in the VSMSx is not visible as in the VSM, but that is because the information flow concerning the flow within the simulation model is logically built into the model.

A brief comparison of outputs and inputs between the traditional VSM and the VSMSx was performed to show the power of the simulating tool over the pencil-and-paper method.

5.1.1 Outputs

As much as it is a powerful tool in identifying the waste in a system through drawing the whole plant from raw material to finished goods on a sheet of paper paving the way towards lean implementation. However, the pencil-and-paper method lacks the output of much quantitative data to facilitate in assessing the system under study.

The only outputs of the pencil-and-paper VSM are what is shown in Figure 5 . However, in the VSMSx the output to the database is very rich. A comparison between both methods is done in Table 1. Moreover, VSMSx allows for multiple scenarios to be performed according to different "what if" situations to give more flexibility to the user.

Table 1: Comaprison of outputs between VSM and VSMSx

OUTPUT	***Traditional VSM***	***VSMSx***
Value added time	✓	✓
Non-Value added time	*Current-state only*	✓
Lead time	*Current-state only*	✓
Total changeover time	✓	✓
TAKT time	✓	✓
Raw material inventory	*Current-state only*	✓
Work-in-process inventory	*Current-state only*	✓
Finished goods inventory	*Current-state only*	✓
Time spent queuing	*Current-state only*	✓
Utilization	*N/A*	✓
Inventory turns	*N/A*	✓
Throughput	*N/A*	✓
OEE	*N/A*	✓
Uptime/Downtime	*N/A*	✓
Service level	*N/A*	✓
Number of defects/process	*N/A*	✓

5.1.2 Inputs

The inputs of the traditional VSM and the VSMSx are almost the same. However, the VSM requires constant values as those inputs do not need further processing and will not affect the output. On the other hand, VSMSx can process stochastic data inputs in order to give more reality to the system modeled allowing for outputs to be closer to the real system. A snapshot of the inputs database is shown in Figure 7. The database has a user friendly interface allowing any user to input the data and use the tool.

Record #	C/T	C/O	# of Operators	MTTR	MTTF	Yield %
1	3.0	2.0	1	55	500	97.0
2	4.0	3.0	1	40	440	98.0
3	5.0	15.0	3	48	333	90.0
4	5.0	0.0	1	30	650	95.0
5	7.0	16.0	1	120	720	96.0
6	8.0	3.0	4	15	1000	99.9

Figure 7: Process input database

6. CONCLUSION

This work presented the combining of value stream mapping and simulation, and how such a combination gave much power and strength to both tools. Simulation added another dimension to VSM which is time, and VSM showed the importance of simulation in modeling production systems.

Using simulation building blocks to model VSM icons gives great flexibility and power to the simulation model. Simulation itself gives another dimension to the VSM which is time, thus making it easy to know the state of the system under different circumstances allowing for better decision making.

Experimenting with a VSMSx model will give information about the system that can be very useful. As when doing a more standard simulation analysis it gives a very good overview of the interaction of the products with each other in the system over time. It also gives some additional information and possibilities. The results can give information on how differences in lead times appear and how lead times relate to value adding times. Experiments can easily be done varying setup times and even some cycle times to see what effects that has on inventory. Also buffer sizes and batch sizes can be altered to see how it affects the system. Another example is the visualization of which machines will give you the best and fastest effect when initiating Single minute exchange of dies (SMED) work. The possibilities are many with VSMSx paving the way towards better lean understanding by decision takers and faster lean implementation.

7. REFERENCES

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