Value Stream Map Simulator Using ExtendSim

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

***Abstract*—Value Stream Mapping 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 resulting in a set of simulation building blocks. 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. The VSMSx empowers the traditional value stream map by combining it with simulation and add the dimension of time making it a powerful analysis tool. The VSMSx is designed to have its own library of blocks that look identical to the icons of the traditional VSM. 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. Compared to traditional value stream mapping, this tool outputs more accurate quantitative performance measures of various scenarios that allow better decision making. Inputs to the VSMSx can be of a deterministic or a stochastic nature that would accurately represent the value stream map variables with any data distribution. A database is developed especially for manipulating the inputs/outputs to the VSMSx. As a conclusion, the VSMSx is a tool that can pave the way for successful lean manufacturing implementations.**

Index Terms*—Component-based Modeling, Lean Manufacturing, Simulation, Value Stream Mapping

I. Introduction

THE Toyota Production System is the starting point and basis for much of today's lean teachings and practice. Toyota is considered the leading lean example worldwide. Lean manufacturing strives to add value by removing the wastes available in a production system; it can be implemented by continually improving the system to make value flow through the identified value stream when the next customer pulls or demands.

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Value stream mapping is an enterprise improvement technique to visualize an entire production process by representing information and material flow to improve the production process by identifying waste and its sources [1]. Lately, a number of companies have utilized value stream mapping, the application crosses over different types of industries such as steel manufacturing [2], aerospace [3, 4], and the automotive sector [5].

The Value Stream Map serves as a starting point to help management, engineers, suppliers, and customers recognize waste and its sources [6]. It also creates a common language about a production process, enabling more purposeful decisions to improve the system [7].

Integrating the tools of simulation and value stream mapping appears to be an effective and more holistic approach to process management and improvement within the context of lean production [6], [8]-[12]. By combining lean thinking concepts and simulation, an organization can better determine where valuable resources should be applied [8].

Via the use of simulation managers can see the impact of lean transformation before the actual implementation. Combining VSM with simulation can strengthen the analysis and evaluation of the current and future states, documentation of the areas to improve, and the assessment of the impact of proposed improvements [6].This will increase confidence and surely enhance the rate of adoption of lean manufacturing, as it will provide a visual and dynamic illustration to management of how the new system would work [13].

What is needed is a tool to assist organizations considering lean manufacturing to quantify the benefits they can expect from applying lean principles to their system. An attempt is made in this manner, combining of simulation and value stream mapping to develop the Value Stream Map Simulator using ExtendSim® (VSMSx).

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 component-based modeling which is the modeling technique used to develop the tool and the concept used in its development. Afterwards, the VSMSx is presented along with its features and capabilities showing the power of the tool. Finally, conclusions drawn from this work are pointed out.

II. Component Based Modeling

Component based modelling is used because it supports building a number of reusable models, as it is not feasible to develop different simulation models for the VSM from scratch for each production system.

Component based modelling begins by identifying the major components required to model the system under study. Each of these components is modelled on its own, which is done by assembling a number of building blocks in a single component. Finally, the interaction and communication between the different components is established.

Components can be thought of as building blocks, 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.

III. VSMSx

A. *Conceptualization*

The concept behind the VSMSx is developing a generic tool that can be reused to model different systems; this tool should have a modular design to represent different entities of the system being modelled. Component-based modelling is the modelling procedure followed where the inputs and outputs within the components are manipulated remotely using a database.

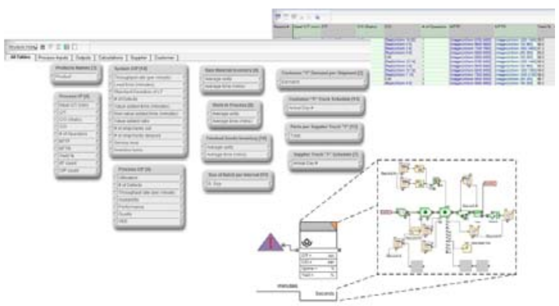

Fig. 1. Graphical concept of the VSMSx

Fig. 1 showed the graphical concept behind the VSMSx; where, each component built encapsulates in its internal structure a model on its own. Components can be connected to other components and its input/output data manipulation is done remotely through a database specifically developed for this purpose.

The VSMSx has been developed using the ExtendSim Suite version 7.0.5 simulation environment; it is a complicated tool in its structure yet very simple in terms of its usability.

A traditional value stream map is composed of material flow icons and information flow icons, all the material flow icons are modelled and some of the information flow icons. However, the remaining information flow is built-in the blocks so the VSMSx functions as it should.

The major types of components that are modelled for the VSMSx are:

- Process
- RM/WIP/FG Inventory
- Supermarket with Push/Pull production system
- Customer/Supplier
- Customer trucks/Supplier trucks
- FIFO lanes

B. *Components*

Tool building is concerned with transforming the tool conceptualization, presented in the previous step, into a computer recognizable form. This form is the operational components forming the VSMSx library of blocks and constructed using ExtendSim® item blocks and value blocks. MS Visio® is used to design the shapes of the hierarchical blocks to look exactly the same as the symbols used in the traditional paper and pencil VSM, a comparison between the main components built is shown in Fig. 2.

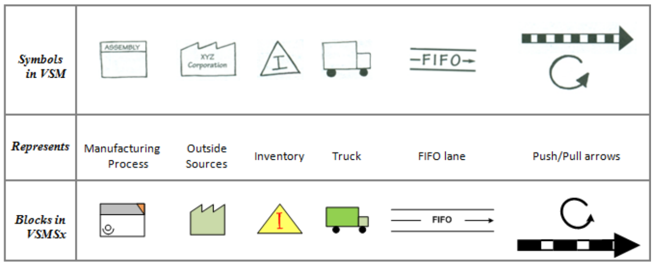

Fig. 2. Comparison between symbols of VSM & icons in VSMSx

It is clearly noticed how both the traditional VSM and the VSMSx icons perfectly match, thus making sure that any user that understands how the VSM translates will definitely understand the model built using the VSMSx.

VSMSx Library

The components built for the VSMSx are stored in the VSMSx library for easy access; this library was developed specifically to integrate with the functions of the tool. It was built to be user friendly, it only requires dragging-and-dropping of components from the library to the simulation environment in order to build a map Fig. **3**.

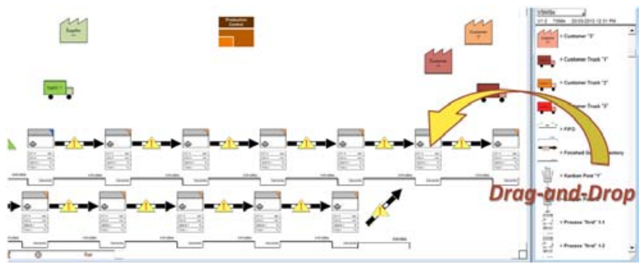

Fig. 3 Dragging & Dropping of components from Library to the Model

C. *VSMSx Inputs/Outputs*

The VSMSx uses different variable types when running developed models. Fixed variables are those that have a value that remains constant over the whole simulation run, such as number of operators, input/output count, and size of batch per interval. Other variables change values as the simulation run progresses according to a defined data distribution, such as process cycle time, changeover time,

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yield percentage, MTTR, and MTTF, the method of converting a variable into a random number is shown in Fig. 4. Stochastic variables are also used in the tool to represent the randomness of some variables that are specified a known data distribution.

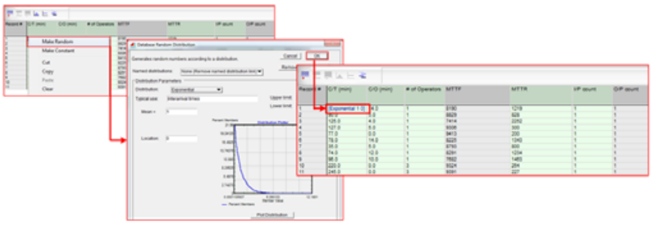

Fig. 4 Transforming a data cell into a random distribution

Inputs required to run the VSMSx

Process cycle time (P/T), Changeover time (C/O), Mean time to failure (MTTF), Mean time to repair (MTTR), Yield Percentage, Number of Operators, Input count, Output count, Size of batch per interval, Supplier trucks interval, Quantity per supplier truck, Customer trucks interval, Quantity per customer truck.

Performance measures reported by the VSMSx are more than what is reported by the traditional VSM. Simulation allowed predicting the state of the system at any instant in the future. The performance measures are output to the VSMSx database automatically after the simulation run is complete. They can either be read from the database directly or exported to an MS Excel® file for further analysis. Outputs to the database are classified into categories such as systems outputs or process outputs. Fig. 5 show a sample of the systems output database.

Throughput rate (per minute)	Lead time (minutes)	# of Defects	Value-added time (minutes)	Non value-added time (minutes)	Value-added ratio	# of shipments out	# of shipments delayed	Service level	Inventory turns
0.42	525	2487	21.41	503	0.0408	32	2.02	93.68%	9

Fig. 5. Sample from the VSMSx output database

Outputs measured by the VSMSx

Value added time, Non-Value added time, Lead time, TAKT time, Raw material inventory, Work-in-process inventory, Finished goods inventory, Time spent queuing, Utilization, Inventory turns, Throughput rate, OEE, Shipments delivered, Shipments delayed, Service level, Number of defects/process.

D. Verification

Animation plays a key role in the verification and validation process for models of existing and non-existing systems. It has been built into the tool to provide the user with an understanding about the system behaviour. Verification of a tool is a continuous process and is carried out in parallel to the model building process. Every component modelled, and even part of a component in some cases, is verified. Verification in this case is by testing a variety of settings of the input parameters and checking that the output is reasonable. Display value blocks, provided by ExtendSim® are used to read the output value of every block in the component to ensure that those blocks are functioning in the intended manner.

In addition, verification of the input parameters, especially the randomly generated ones, is needed to ensure the model is using valid values for the different input parameters.

E. Validation

To validate the VSMSx tool, simulation models need to be built by the VSMSx. These models are face validated using different procedures. A current-state map of the system under study is built after verifying that the components functions as they are supposed, opinions of experts of the system was taken to validate the results reported from the VSMSx, such as lead time and inventory levels. To increase the confidence in the validity of the tool, the response of the model is tested to extreme conditions by radically increasing the amount of work-in-process in the system and noticing how this has affected both the lead time of the parts and the throughput from the system.

F. Application on the VSMSx

The models built using the VSMSx have very clear identicalness with the traditional VSM built with pencil and paper as shown in Fig. 6 and Fig. 7. This allows the models built via the VSMSx to be read by anyone who understands a traditional VSM. The built models also have animation features to give the user a sense of the state of the system at a specific instant. Animation is visible when the system is running or shutdown or when changeover is in progress.

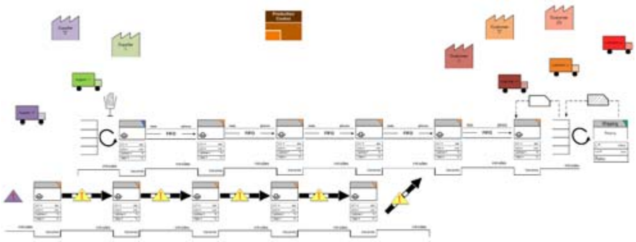

Fig. 6. Model built using the VSMSx

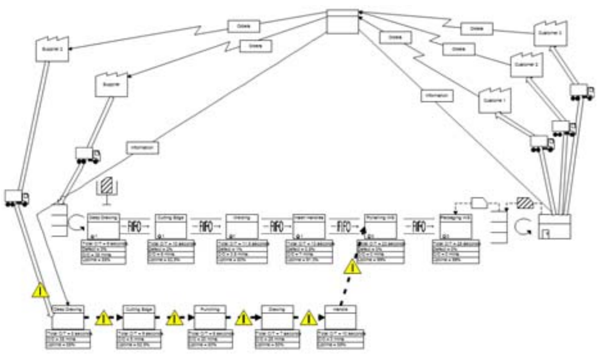

Fig. 7. Map drawn as traditional VSM

The components are simply dragged to the simulation environment and dropped; they are then connected together by a few mouse clicks. A pre-saved model is available for usage to overcome some limitations in the use of the ExtendSim®.

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Inputs to the model are done via the inputs database in the specified fields. When the model is run according to the desired simulation parameters, it reports the performance measures that are calculated by the VSMSx to the outputs database. The database is supplied with a number of blocks for writing/extracting data to/from the different components of the tool. Thus, almost any part of any component can read data from the database and can report results as well to the database which is a very useful feature.

The database categorizes the different data into groups (Fig. 8); this helps the end-user in finding the data that he/she is looking for easily. This is especially important because of the large amount of data that the tool is dealing with; for example, grouping the different outputs of the model under 'Outputs' assists the user to locate the output of a simulation run quickly.

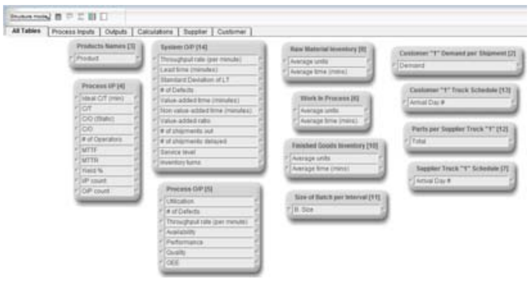

Fig. 8. Categories in the VSMSx database

IV. 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. Using simulation building blocks to model VSM icons gives great flexibility and power to the simulation model. Simulation added another dimension to VSM which is time, and VSM showed the importance of simulation in modelling production systems. It is now easy to know the state of the system under different circumstances allowing for better decision making.

Experiments can easily be done varying setup times and 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.

The VSMSx is a user-friendly tool requiring 6 simple steps to build a model, those are:

- Draw the traditional VSM
- Collect the required data inputs for the VSMSx
- Open the pre-saved VSMSx model using ExtendSim simulation environment
- Drag & Drop the blocks from the VSMSx library and connect them together corresponding to the VSM previously drawn
- Run the model for the required time and number of replications
- Open the VSMSx output database to view the results automatically submitted

V. Recommendations for future work

Coding of components to overcome the limitations experienced in using ExtendSim® to reduce simulation execution time and enhance reporting.

To improve the VSMSx to have the capability in handling additional products and diverse production routes.

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