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CONCEPTS FOR SIMULATION BASED VALUE STREAM MAPPING

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ABSTRACT

Traditionally Value Stream Mapping (VSM) is used for quick analyses of product flows through a manufacturing system, from raw material to delivery. Discrete Event Simulation (DES) is often used for analyses of complex manufacturing systems with several products and a complex planning. These two methods have similarities but also differences. This paper presents a concept for creating dynamic value stream maps of a system using simulation. Creating dynamic value stream maps makes it possible to analyze more complex systems than traditional VSMs are able to and still visualize the results in a language the Lean coordinators recognize. The value stream map is presented in an spread sheet that can be altered in the way the team wants. Some standard icons are predefined, based on traditional VSM icons. One or more products can be visualized at the same time and simulation runs and results compared immediately, helping choosing the best solution.

1 INTRODUCTION

With the increased customer demand within most manufacturing industries today it has become increasingly important to continuously analyse and improve the manufacturing system and the corresponding planning system. The most widely known approach for improvement work is Lean Manufacturing. The Lean concept was defined by Americans (Womack, Jones, and Roos 1990) (Liker 2004), even though the concept has evolved from TPS (Toyota Production System) in Japan. The TPS has developed continuously at Toyota's production facilities from the early 1930s. TPS and Lean Manufacturing have developed into several variants and every company adapting, or trying to adapt, to these working methods develops its own variant of it, such as Honda Production System (Freyssenet et al. 1999) and General Motors Production System (Dinero 2005). Within Lean there are a vast amount of working methods that are used for various purposes. One of them is VSM (Value Stream Mapping). VSM is traditionally used for quick analyses of product flow through a manufacturing system, from raw material to delivery.

Simulation has played an important role in the industrial development in recent years, at least within companies in the Western part of the world. New ways to use simulation and improved technologies are continuously being developed which improves the usefulness of simulation. Discrete Event Simulation (DES), which is used in this research, is traditionally mostly used for analysing advanced manufacturing systems. The use of simulation contradicts, to some extent, the use of Lean tools since Lean tools per se should be of more simple character. On the other hand does simulation add value to the use of Lean tools, as described by Standridge and Marvel (2006). This issue is addressed in this research where a simulation method is developed to enhance the use of VSM.

2 VALUE STREAM MAPPING

Value Stream Mapping (VSM) is one of the many tools, working methods and concepts in the Lean environment (Liker 2004, Bicheno 2004). Other familiar tools are Just-in-Time (JIT), Single Minute Exchange of Die (SMED), 5S and Kanban. VSM can be and is used in all different kinds of manufacturing and can easily be learned and then used by just about everyone. In a VSM a team walks through the manufacturing system and documents facts such as cycle times, buffer sizes and personnel requirements. The facts are then turned into a map which describes the system with standardized icons. When a map of the current situation is documented a parallel map is developed within the team which instead describes the ideal future state. This future state is used as a base for prioritizing improvement activities, so called kaizen events.

2.1 Strengths with VSM

VSM is a valuable tool for analyzing value flows and the most obvious strengths are:

- Fast and easy to carry out.
- Cheap, since no special tools or computer programs are needed. Only man hours are spent during initial work.
- Simple – Easy to learn and understand.
- All tools needed are pen and paper
- Gives a good basis for discussions and decisions.
- Increases the understanding for the customer, the product and information flow and losses.
- Can often be performed with people directly involved in the system with aid from a VSM experienced person.

2.2 Weaknesses with VSM

There are also some weaknesses with VSM as it is normally used:

- Only the flow of one product or product type is analysed per VSM analysis.
- The VSM gives only a snapshot of the situation on the shop floor at one specific moment.
- The VSM map is a rough simplification of the real situation.
- It is difficult to experiment with suggested new systems and layouts.

3 SIMULATION

Computer simulation is today being used for various applications. It is already in common use in a wide range of areas including the military, logistics and manufacturing. Simulation is an emerging technology, and a growing tool also in non-engineering areas such as health care, finance, agriculture and ergonomics, but in the application described in this research the focus is on production systems. Simulation is defined as "*…the process of designing a model of a real system and conducting experiments…"* (Pegden, Shannon, and Sadowski 1995) and *"A simulation is a model that mimics reality."*(Robinsson 1994). The key point of all definitions of simulation is that in a system is imitated to generate a better understanding of it and to find answers to questions about it.

The simulation variant used in this research is Discrete Event Simulation (DES) which deals with flow of parts in a system. Parts can be for example casted products and the system will then be built up with for example machines and buffers. The events will trigger what happens in the flow.

3.1 Strengths with simulation

Simulation is a valuable tool for analyzing complex systems and the most obvious strengths are:

- The flow of all products can be included in the model.
- Not only a rough simplification.
- Can analyse a time span and not only a snapshot.
- Dynamic course of events,
  - Complex planning/control logic.
  - Variations and breakdowns can be included.
- Advanced analyses,
  - Bottlenecks, utilisation etc.
  - Mean sizes of buffers, standard deviations.
- Possible to experiment with system changes and parameters.

3.2 Weaknesses with simulation

There are also some weaknesses with simulation as it is normally used:

- Demands a large investment in time and money.
- A good knowledge of simulation methods and programs are needed.
- Difficulty of getting right amount of data in right format.
- Often a simulation expert running a simulation project is not otherwise directly involved in the studied system.

A comparison of VSM and simulation can be found in figure 1.

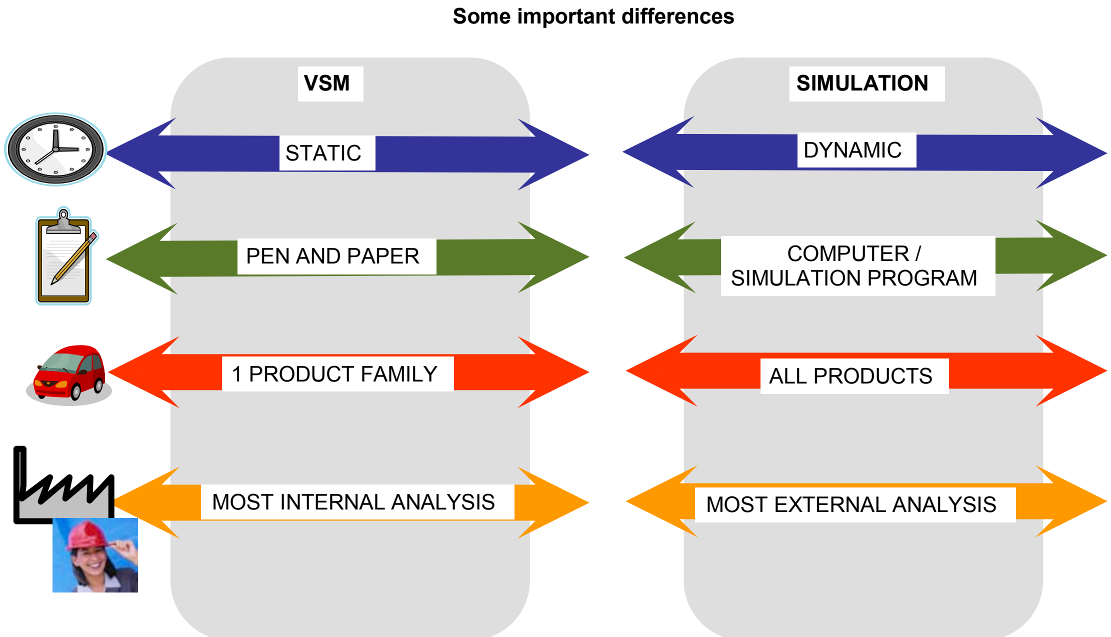

Figure 1: Some important differences between VSM and simulation.

4 SIMULATION BASED VALUE STREAM MAPPING

During the course of this research a tool for Simulation Based Value Stream Mapping (SBVSM) has been developed. The tool is aimed at being able to construct dynamic values stream maps that could represent the snapshot picture at any time during a time period and not only at one specific time, as normal VSM's do.

4.1 The SBVSM concept and the issues it addresses

As described earlier there are some weaknesses with using VSM and simulation alone. We believe that many of these can be avoided by integrating VSM analysis in a simulation model. At the same time the goal is to keep all the strengths of simulation and VSM as they appear when applying the methods separately.

The SBVSM consists of two parts, a simulation model and a spreadsheet. The specific programs used in this case are AutoMod and MS Excel. However the method described in this paper can be used together with any other programs with similar capabilities.

4.1.1 The simulated manufacturing system

The simulation model built represents a conceptual model of a possible Pressure Die Casting (PDC) plant. It includes 5 die casting machines, 2 fettling machines and 2 painting boxes. After each machine there is a supermarket buffer and each product is stored separately so that each product can be followed throughout the simulation run. There are 13 different products, named A-M. Initially, each product has one or more dedicated die casting machine that the product can be produced in, which often is the case in plants like these. After that each product can be used in both fettling and painting stations. However all products does not need painting and these are transported directly to the out buffer. A layout of the simulation model can be found in figure 6.

4.1.2 Information that builds up the model

The main information and data that is used in the model concerns the products and the flow. The Products are named A-M and have different cycle times, setup times and batch sizes. The order procedure also follows the one normally used in VSM studies, namely an order size and time between orders. All this can be found in figure 2. In the die casting machines there is, for each product, a minimum number of products that should be produced after each tool change. This is a typical parameter that is used for experimenting when showing that SMED activities play an important role for the flexibility of the plant even in high volume production systems like this. An example table can be found in figure 3.

To be able to initiate the order procedures in the simulation model in a good way an initial storage volume is defined. This can be found in figure 4 together with the minimum and maximum storage levels decided in the finished goods storage. Min/max levels is also a parameter interesting to study when experimenting and suggesting changes to the system.

Name	Setup PDC	Cycle PDC	Nrs/batch fettling	Cycle fettling	Setup painting	Cycle painting	Purchase interval	Time between purchases
A	135	2	15	4	15	5	3	144
B	180	2	15	4	0	0	3	72
C	135	2	15	3	0	0	3	36
D	120	2	15	5	0	0	3	72
E	150	2	15	4	0	0	3	36
F	165	2	15	2	15	5	3	72
G	115	2	15	3	0	0	3	144
H	195	2	15	4	0	0	3	72
I	145	2	15	3	0	0	3	48
J	180	2	15	2	15	5	3	36
K	120	2	15	3	15	5	3	28,8
L	220	2	15	4	0	0	5	28,8
M	135	2	15	5	0	0	5	144

Figure 2: List of articles, cycle times, setup times, batch sizes, order size and order interval.

PDC machine 1		PDC machine 2		PDC machine 3		PDC machine 4		PDC machine 5	
Name	Nr	Name	Nr	Name	Nr	Name	Nr	Name	Nr
A	1800	C	3000	F	1600	J	800	L	1000
B	3600	E	3000	G	800	K	1000	M	200
D	3600			H	1600				
				I	2400				

Figure 3: Example of initial production sequence.

Product	Articles at start			Finished goods	
	After PDC	After fettling	After painting	Max	Min
A	0	200	600	950	400
B	0	0	200	500	200
C	0	0	500	950	400
D	1500	0	400	950	400
E	0	0	700	950	400
F	0	0	200	200	100
G	0	700	300	950	400
H	1800	0	400	950	400
I	0	0	500	950	400
J	0	0	100	500	200
K	0	1500	500	950	400
L	1600	0	400	950	400
M	0	0	600	950	400

After painting:
When minimum value is reached an order is triggered in a PDC. When the maximum level is reached the production is stopped

Figure 4: Initial storage in buffers and min/max storage sizes in finished goods storage.

4.1.3 The VSM representation

The goal when developing the VSM representation was to make it look as much like a standard VSM map as possible. The same type of icons and data should be visualized. Data that is shown are cycle times, setup times, mean storage sizes and value adding time compared to total lead time. One big difference from a standard VSM representation is that the spreadsheet shows all products in the system and not only one.

All the information in the VSM map is based on results, and sometimes input data, from the simulation model. Using the simulation results as a base means that data can also be described in other ways in addition to this. In figure 6 there are pictures showing graphs of how storage develops over time, utilization of different resources and utilization divided into time periods.

Currently the focus when developing the visualization representation of the VSM map has been on the flow of material. The flow of information is still to be developed further. The information flow concerning the flow within the simulation model is logically built into the model. However it is not described fully in the VSM representation.

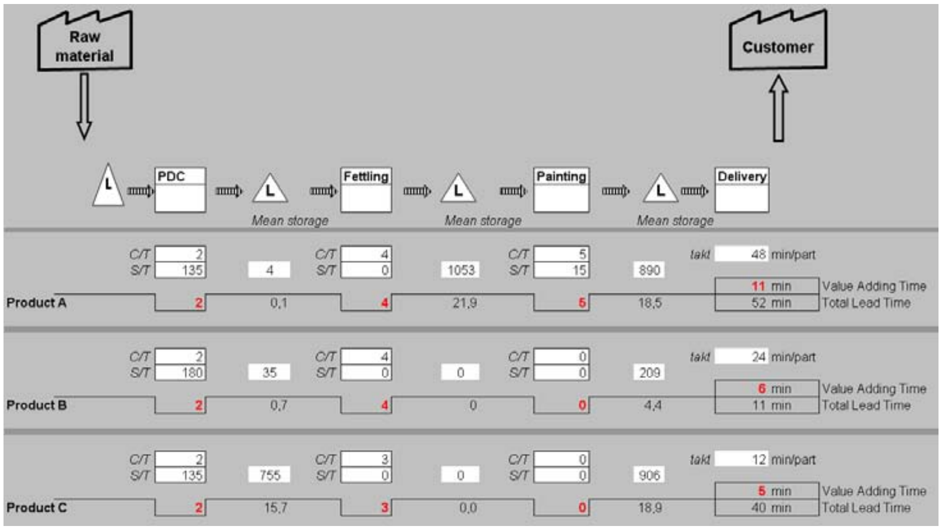

Figure 5: The VSM representation with the first 3 products shown.

5 ANALYSES OF THE USE OF SBVSM AND CONCLUSIONS

The primary goal of the development described in this paper was to present a concept for creating dynamic value stream maps of a system using simulation. The aim with this was to enable analyses of more complex systems than standard VSM analyses does and present it in a way a Lean coordinator recognizes.

It was described earlier that there are some weaknesses with using VSM and simulation alone. Many of these can be avoided by integrating VSM analysis in a simulation model. The simulation model can handle several products at the same time and can give more than only a snapshot at one specific time which help eliminate the first two weaknesses (the problem with only one product or product family and that VSM only gives a snapshot of the situation on the shop floor). The problem that the VSM map only is a rough simplification of the real situation is however only partially solved since all simulation models to some degree also are simplifications of the real system. However most of the time simulation models are much more detailed than corresponding VSM maps. Correctly built, simulation models are easy to experiment with so that problem is eliminated.

When it comes to the weaknesses of simulation not much of this is eliminated with the SBVSM approach. A program is still needed as well as the knowledge of it and simulation in general. With the increased complexity that SBVSM creates comes a need for extra information and data which obviously demands a bit more time for model building.

At the same time the strengths that simulation gives are the same in the SBVSM since this approach uses the simulation model as a base for the whole concept. However, all the strengths of VSM alone are not possible to retain. The simplicity of VSM is lost due to the complexity the simulation model brings as described earlier. But the simplicity of the visualization is still maintained. The tool becomes more difficult to understand, even though the VSM representation is still approximately the same. SBVSM also still increases the understanding for customer, products, product flow and losses and is a good, or even better, basis for discussions and decisions.

As a consequence of the above mentioned issues, the use of SBVSM demands that the model builder is skilled within both simulation and VSM.

Experimenting with a SBVSM 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 the effect of proposed future kaizen events will be. Also buffer sizes and batch sizes can be altered to see how it affects the system. One example can be that analyses shows that it is necessary to buy more tools for one or more products or to switch machines for products. Doing that will enable the production of a product in more machines, leveling the utilization. Another example is the visualization of which machines will give you the best and fastest effect when initiating SMED work. The possibilities are many with SBVSM, helping to avoid sub-optimization when working with improvements of the manufacturing system. It is our belief that many of the users of VSM would indeed benefit the use of simulation, but are seldom introduced or motivated for using simulation. Yet another benefit of SBVSM would be that it gently introduces to end-users the tool and method of simulation and presents its capabilities.

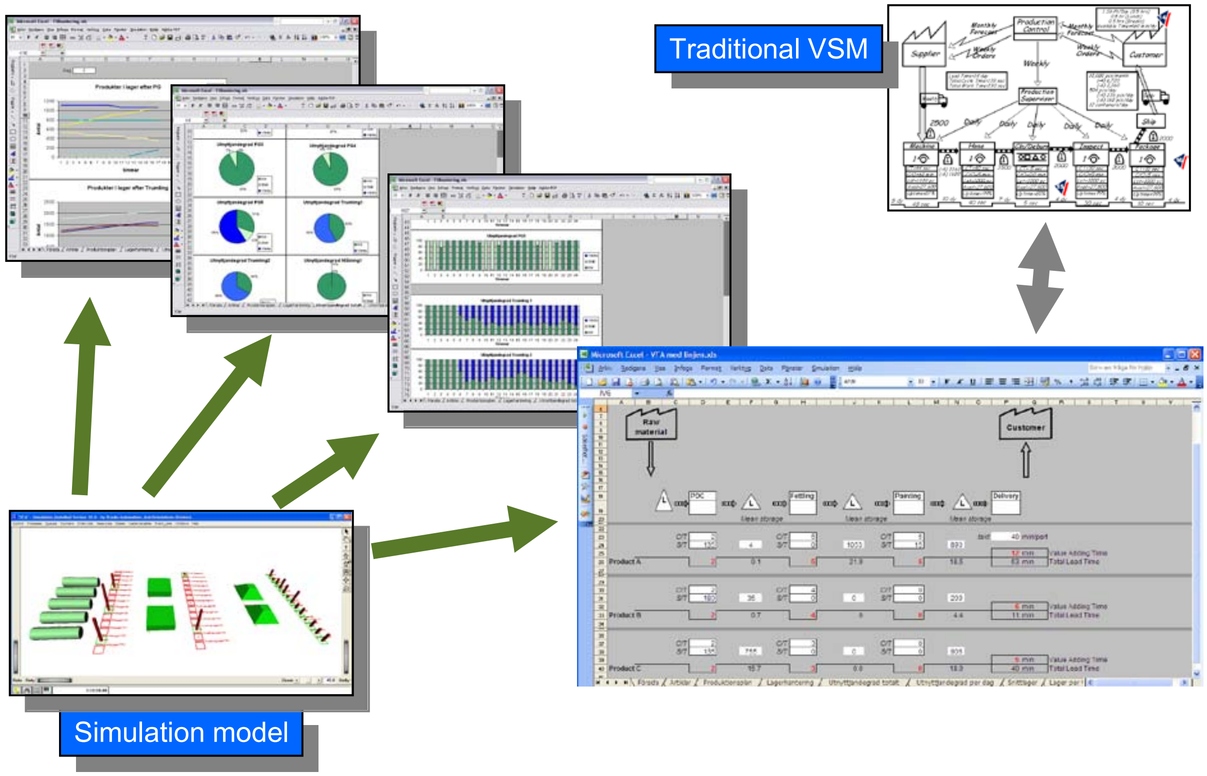

Figure 6: Simulation Based Value Stream Mapping (SBVSM)

The SBVSM uses the best from both simulation traditional VSM. In the bottom left the simulation model is shown. In the bottom right the spreadsheet visualization of the VSM map is shown. The map is based on the information and data which comes from the simulation model, of which some is shown in the three pictures in the top left.

6 FUTURE WORK

The concept described here is built on a conceptual plant. To enhance the SBVSM method, the spreadsheet template, the VSM representation in the spreadsheet and how the simulation model interacts with the VSM analyses more development is needed. There are still weaknesses with the individual methods that should be eliminated or diminished as much as possible and strengths that could be brought forward in an even better way. The conceptual model is generic for many industries with pressure die casting process. Also in cases the conceptual model is not capable of modeling the plant's process, system behaviors and Lean principles can still be simulated for educational purpose. A development of a more generic conceptual model is planned. Currently an industrial case study is carried out. This study will help improving the SBVSM method. It will also try to show that the method is usable on a real plant and that the benefits from using the method exceed the extra effort when building the model.

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