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Procedia CIRP 67 (2018) 30 – 35

www.elsevier.com/locate/procedia

11th CIRP Conference on Intelligent Computation in Manufacturing Engineering, CIRP ICME '17

Combining factory simulation with value stream mapping: a critical discussion

Dario Antonelli[a,*], Dorota Stadnicka[b]

[a]Politecnico di Torino, Corso Duca degli Abruzzi 24, I 10129 Torino, Italy
[b]Rzeszow University of Technology, Al. Powstancow Warszawy 12, Rzeszow 35-959, Poland

* Corresponding author. Tel.: +39-011-090-7288; fax: +39-011-090-7299. *E-mail address:* dario.antonelli@polito.it

Abstract

Value Stream Mapping (VSM) is employed for the analysis of manufacturing processes. The VSM analysis leads to improve the process through the reduction of non-value added steps. The optimization is often verified by computer simulation (CS) before actual implementation in the factory. The two approaches imply a different underlying conceptual model of production: a deterministic flow of material against a stochastic queuing network. The authors discuss the critical issues, but show, with the help of an automotive case study, that they could produce positive outcomes if the goals are carefully chosen and if some rules of use are respected.

Peer-review under responsibility of the scientific committee of the 11th CIRP Conference on Intelligent Computation in Manufacturing Engineering

Keywords: Value stream mapping; Discrete events simulation; Just in time

1. Introduction

Value Stream Mapping (VSM) is widely established in industry (Rother and Shook, 2003; Womack and Jones, 2002; Stadnicka and Antosz, 2013), particularly in the mass production sectors, like the automotive industry (Belokar at al., 2012; Palak and Sheth, 2014).

There are occurrences of the method in manufacturing processes (Rahani and al-Ashraf, 2012; Jeyaray et al., 2013; Grewal 2008; Singh and Sharma, 2009), in business processes (Teichgräber and de Bucourt, 2012) and in administrative ones (Joseph and Ronald, 2012).

The method helps to improve manufacturing processes (Gunaki and Teli, 2015), assembly processes (Kadam et al., 2012; Álvarez aet al., 2009), processes concerning product development (McManus and Millard, 2002; Hugh et al., 2002) etc.

Analyzing a value stream map it is possible to discover problems whose solutions can let the company achieve better results. Even if the solutions for the problems, which were discovered in Value Stream Analysis (VSA) is apparent, there is still the necessity to verify it against the actual production in the factory. It is a risky and expensive task that could be shortened by having recourse to computer simulation (CS). CS saves time and gives the possibility of having a deeper insight on the process performances. Examples of simulations implementation together with value stream analysis we can find in literature (Abdulmalek and Rajgopalb, 2007; Chukukere et al., 2014). However, the preparation of a model of a manufacturing system (MS), which will be analyzed in CS is also time consuming. That is why some authors question when we really need to simulate and if it is necessary.

An overlooked question is if the input data and the results of VSM and CS could be the same. In the following it is shown why the answer to the question is no and what should be done to make comparable both the inputs and the outputs.

The paper presents a case study in which a production flow of vulcanized sleeves is analyzed with the use of VSA and existing problems are identified. The improved MS was modelled by CS and the proposed modifications to the process are validated to make a deeper insight in the process on the base of results obtained from the simulations.

Peer-review under responsibility of the scientific committee of the 11th CIRP Conference on Intelligent Computation in Manufacturing Engineering
doi:10.1016/j.procir.2017.12.171

Nomenclature

M_{CD} monthly client demand [pcs/month]
T_W working time a day [s/day]
T_B break time [s/day]
IQ inventory quantity [pcs]
D_{CD} daily client demand [pcs/day]
R_{ON} required number of operators

2. Building the VSM

VSM starts from mapping of the present state of MS, then improvements are proposed in order to eliminate non-value added activities and the results are presented in the future state map (FS). To develop the current state map it is necessary to gather information concerning client orders, shipment frequency and quantity, processes involved in products manufacturing, processes' cycle times (CTs), changeover times (COs), number of operators, materials deliveries' frequency and quantity, inventories' quantity and places, working time, problems existing in MS. Table 1 presents and discuss the necessary data to build VSM.

Table 1. Definition of the variables necessary to build the VSM model (par=parameter, in=input, out=output).

Variable	Unit	Type	Definition
Sequence of processes		par	material flow, can be in parallel or in series.
Size of batch	[pcs]	In	Number of pieces which go through a process together
Operators per process		In	Number of operators performing each process
Average Cycle Time (CT) for each process	[s]	In	Time elapsed for one product from the entry to the exit, see Table 2
Average Changeover time (CO) for each process	[s]	In	time needed to make a workstation ready to perform another manufacturing process.
Available working time (A_{WT}) on each workstation	[s]	In	normal working time minus planned breaks
Availability of a workstation (a machine)	[s]	In	percentage of time in which a workstation can be utilized for manufacturing
Number of working days in a month (N_{WDM})		In	Average number of working days in a month
Number of shifts for each workstation		In	Number of shifts for each workstation can be different
Number of products ordered by customers		In	Average number
Number of products in a shipment		Par	Average number, product dependent
Frequency of shipments	[1/s]	Out	Average number
Frequency of deliveries	[1/s]	Par	Needed for each supplier
Processing time (*PT*)	[s]	Out	Time needed to perform a process
Inventory lead time (*ILT*)	[s]	Out	How long a product has to wait in inventory before being processed.
Lead time (*LT*)	[s]	Out	time from entry to exit into MS.
Takt time (*TT*)	[s]	Out	Average time between unit productions, when production starts are set to match the rate of customer demand.

The calculation of the VSM variables is performed by using the following relations:

$$D_{CD} = \frac{M_{CD}}{N_{WDM}}, \quad (1)$$

$$A_{WT} = T_W - T_B, \quad (2)$$

$$PT = \sum_{i=1}^{n} CT_i, \quad (3)$$

$$ILT = \frac{IQ}{D_{CD}}, \quad (4)$$

$$LT = PT + \sum_{j=1}^{n} ILT_j, \quad (5)$$

$$TT = \frac{A_{WT}}{C_D} \quad (6)$$

$$R_{ON} = \frac{PT}{TT} \quad (7)$$

The analysis highlights bottleneck workstations, excessive inventory levels and unnecessary frequent shipments.

Then, it should be analysed whether the MS is balanced. If possible, the flow should be improved, otherwise Just in Time with supermarkets and Kanban cards can be introduced to decrease the size of inventories.

3. Building the CS

Computer simulation of the product flow is a common design strategy used before launching a new production line (Gershwin, 1989). The most frequent simulation method, used to describe production processes, is Discrete Event Simulation (DES), that is numerical solution of queueing networks. The main benefits of DES are the understanding of the system behavior before building it, the discovery of unexpected nonconformities, the possibility of investigating different uses of case scenarios (Kellner et al., 1999). The main drawback is related to the extent to which the simulation can be made compatible with the current system.

This drawback is particularly significant when DES is applied to a process model described by VSM. The goals of the two methods are different, and that is reflected in the kind of data collected by VSM which are different from the data needed by DES. The main difference is the use of stochastic variables. In order to build a DES the variables described in Table 2 are necessary.