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Mobile Value Stream Simulation –Potentials and Requirements of a new Optimization Technology

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ABSTRACT

The use of mobile devices like smartphones and tablets as well as mobile apps continues to experience exponential growth. For some time apps are gaining more and more attention in producing companies as enabler for process optimization. Advances in wireless technologies and an increasing maturity of mobile devices foster a wider spread of apps for industrial purposes. In the field of industrial engineering value stream mapping is one of the most common methods for material and information flow optimization. In combination with discrete event simulation it is a powerful tool for improving volatile and complex production systems. In this paper the potentials and the requirements of mobile value stream simulation as a new-type optimization technology for industrial engineering are discussed.

INTRODUCTION

In industrial engineering the methods of lean manufacturing add decisively to the success of producing companies. The goal of these methods is to strengthen the competitiveness of production systems by eliminating waste in the internal and external value chain (Holweg 2007). The background is to develop systems with minimal inventory, maximal productivity and thus efficiently used resources (Caridi and Cavalieri 2004).

Value stream mapping (VSM) in this context has been established as the preferred way to implement the principles of lean manufacturing (Grewal 2008). Its focus is not set on the improvement of individual processes, but of entire process chains from receipt to delivery of goods. (Rother and Shook 1999) About 60% of German producing companies use VSM and many of them already achieved significant improvements (Haemmerle and Rally 2010). Despite its popularity, VSM has some significant shortcomings: The result is only a snapshot of the system under consideration. Here, misperceptions of the analysis results are possible as there may be other system properties at any other time. Furthermore, the optimal degree of implementation of the principles of value stream design is difficult to determine. Improvements cannot be quantified before physical implementation (McDonald, van Aken and Rentes 2002). Usually, the conversion of a value stream follows to the principle of "trial and error" (Marvel and Standridge 2009).

Thus, decision makers have to trust the benefits of the method, especially when investments have to be made. Determining the optimal degree of conversion and convincing decision makers of the favorability of suggested improvements is not an easy task even for experienced experts in the field of lean manufacturing. In improvement projects therefore much time and effort is invested and still a suboptimal solution is achieved.

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Through material flow simulation, the limitations of VSM can be partially extended. Another benefit of simulation is its effectiveness in systems with increased material flow complexity where analytical approaches reach their limits. (Fink *et al*. 2014; Huber 2009) Hence, the prior quantification of possible production system designs, using material flow simulation, is gaining more and more importance.

Using simulation, highly complex processes can be analyzed and optimized during the whole life cycle from planning to operation (VereinDeutscherIngenieure 2010). Currently the technology of discrete event simulation (DES) is widespread especially for the simulation and analysis of material flows (Daniluk and Chisu 2010; Al-Aomar 2011; Maerz *et al*. 2011). Further, the technologies of system dynamics and agent based simulation allow the simulation of material flows (Negahban and Smith 2014). In a series of preparatory work it could already be demonstrated that it can be purposeful to combine VSM and material flow simulation (Roessler, Riemer and Mueller 2015).

In 2012 nearly 70% of all internet users accessed the internet using mobile devices like smartphones and tablet PCs (Accenture 2012). Apps on these devices are becoming the core of the digital life of consumers and are used for communication in social networks as well as mobile banking and shopping (Groeger *et al*. 2013). For some time apps are gaining more and more attention in producing companies as enabler for process optimization. In this paper the potentials and the requirements of mobile value stream simulation as a new-type optimization technology for industrial engineering is discussed.

Current Limitations:

Because of existing deficits VSM and material flow simulation currently can only be combined with huge effort. Thus, it is necessary to start with a value stream analysis of the production environment to find out and map the current system status. Such an analysis is usually made by hand with pen and paper and afterwards evaluated outside of the production environment. In conjunction with a downstream material flow simulation, it is necessary to implement this paper-based model in simulation software. When creating a simulation model, several analyzes in the production environment are usually required because the data demand of a simulation exceeds the information content of a conventional value stream analysis (Wolff 2013). The phase of value stream design is following a similar manner: First a paper-based model of a potentially more performant state has to be developed and afterwards to be implemented in a simulation model by a simulation expert.

Following such an approach, significant media disruptions occur because the information collected in the analysis must be partially digitalized. This is characterized by a strong information redundancy and a high error rate; this vulnerability increases with rising complexity of the system to be imaged and the number of involved, but necessary individuals.

Such projects require interdisciplinary teams of participants, mostly composed of production managers with knowledge of VSM and simulation experts or programmers. If existing software is used for material flow simulation due to high degrees of freedom always expertise with respect to simulation modeling is necessary. This represents an enormous financial burden, especially for SMEs, because competence usually must be purchased.

Another limitation of this manual approach is that the involvement of production staff is often neglected in the improvement process. Value stream maps are often displayed away from the shop floor due to the high space requirement. Also discussions and decisions regarding future designs are often made without involving the operative staff. If further an external simulation expert is consulted, the transparency of the procedure and the acceptance by the production employees decreases even further. The ability to initiate and quantify improvements in a transparent manner directly at the scene currently is not given in practice:

- Media disruptions exist during data collection in the production environment and the conversion into simulation models, which entails high costs and transmission errors,
- Extensive expertise on the one hand in terms of material flow simulation, on the other hand with respect to design guidelines for lean material flows is necessary,
- There is a relatively low level of transparency and thus acceptance by the workers, as evaluations and decisions are made away from the production environment.

Objective And Innovative Approach:

The review of the mentioned shortcomings makes it evident that a mobile solution for value stream simulation is advantageous. Having an easy-to-use mapping device and thus all the information needed in the palm of the hands in this case can be a true business enabler.

Thus, this paper aims at addressing the above-mentioned shortcomings, in order to enable an effective connection of VSM and material flow simulation. The focus of this research is therefore the development of an integrated approach and a mobile tool for value stream simulation. The tool for the use directly in production environments includes a software application which enables a preliminary quantification of planned changes in the production process. To address the media disruptions described above, it is purposeful to record all the necessary data directly in the production environment with a mobile tool in collaboration with the production staff and build simulation models right on the shop floor. The mobility aspect also addresses the factor of worker acceptance.

Thus, a more efficient and effective value stream optimization is enabled, which leads to more competitive production systems. This applies to redesigns of existing value streams as well as to completely new value streams still in the planning phase.

To accomplish the stated goal, the workflow when using the tool follows an extended process model for value stream mapping, see figure 1.

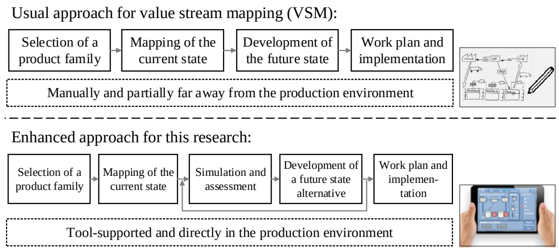

Fig. 1: Comparison of the work flows of VSM following the usual analytical approach and mobile value stream simulation.

State Of The Art:

Introduction of value stream mapping:

Value stream mapping is a holistic approach to achieve improvements on a production system level. Thus, the entire value stream of a product family between incoming and shipping of goods can be analyzed, see (Rother and Shook 1999; Erlach 2010). VSM conventionally consists of the four phases*selection of a product family, analysis / mapping of the current state, design / development of the future state and work plan / implementation*. In the following a distinction between analysis and design will be made (VereinDeutscherIngenieure 2012).

Value stream analysis provides a practical way to identify and assess the current state of the material flow within a production system (Rother and Shook 1999). Value stream analysis involves a form of modeling in which knowledge is gained, that can then be transferred back to reality with a suitable interpretation (Arnold and Furmans 2006). The result of a value stream analysis is an analyzable model (current state) of the selected value stream of a physical production system. Both, value-added and non-value-added activities are considered.

After the analysis phase is finished, the derivation of improvement potential can be started. This phase of so called *value stream design* leads to an improved model of the value stream, the future or target state. The future state indicates an ideal state of the system and can be gradually converted (Marvel and Standridge 2009). Here, only a single target state is derived following the original literature. However, in science and practice the possibility of multiple target states is mentioned (Wolff 2013; Roessler, Metternich and Abele 2014). To derive potential for improvement out of the current state Rother and Shook defined a set of practical design guidelines (Rother and Shook 1999).

Introduction of material flow simulation:

Material flow simulation provides the opportunity to assess design alternatives and improvements to systems prior to physical implementation by modeling and dynamic examination. Simulation models are predictive models for complex systems, in which cause and effect relationship cannot be modeled analytically (Domschke and Drexel 2007). In the area of production and logistics usually the technology of discrete event simulation is applied (Maerz *et al*. 2011).

In discrete event simulation (DES) the dynamic and stochastic behavior of systems is modeled by time variant state variables. Events occur at a limited number of instants of time (Domschke and Drexel 2007). Typical events in production systems are the finishing of a task or the arrival of an order at a work station (Maerz *et al*. 2011). DES has long been the most common simulation technology in the sector of operational research. This also holds true for the special case of material flow simulation. (Siebers *et al*. 2010)

By quantifying the intended benefits of improvements e. g. their financial effects can be assessed in advance. Various authors suggest a connection of material flow simulation and value stream mapping (McDonald, van Aken and Rentes 2002; Marvel and Standridge 2009; Wolff 2013).

Tool Requirements And Studies:

This section contains a definition of target criteria for the tool development, shows the results of a market study and an expert survey. The novelty of the approach addressed in this paper is based on the fact that so far there is no simulation software, which supports VSM in the aforementioned form that the restrictions can be overcome. In the following, target criteria for the tool development are defined and discussed. In addition, for these criteria different characteristics are described ((+), (0) and (-)) to enable a direct comparison of the planned development with the prior state of the art and the tools available on the market.

For the purpose of this research a market study was performed to analyze existing IT tools in the field of value stream mapping and assess them according to the following target criteria (cf. tables 1 and 2):

Dynamic assessment of value streams: (+) With the tool it is possible to model, analyze and assess value streams dynamically using DES. The attribute (-) is given in the assessment, if this is not possible.

Extension flexibility: (+) The tool allows the definition, the parameterization and the programming of new value stream modules. (0) The tool allows it to expand individual modules (processes, inventories, transports, external entities, ...) by new parameters. (-) The tool allows only the use of predefined modules and existing parameters.

Work flow animation: (+) During simulation the material flow is graphically visualized to check the plausibility of the models. (-) A graphical display of the material flow to the running time of the simulation is not possible.

Usable without simulation experience: (+) The tool can be used by people with knowledge of value stream mapping. Programming skills are not necessary. (0) It is possible to create executable models without any knowledge of a programming language. More complex models require programming. (-) It is rather possible to create models without any knowledge of a programming language. Realistic models require the programming of methods.

Ergonomic use on mobile devices: (+) The tool has been specifically designed for the use on mobile devices (display of about 8" to 10") and their usual usage context and is compatible with one of the three newest operating systems for mobile devices (Windows Phone 10, Android 6.X or Apple iOS8.X). (-) The tool can't be used on any of these operating systems or devices ergonomically.

Automatic suggestion of recommendations: (+) After modeling and assessment of a value stream the tool recalls guidelines of value stream design and shows fields of opportunity. (-) The tool does not refer to design guidelines.

Mobile and cooperative working: (+) It is supported to work with more than one person from different locations on one value stream model. (-) The function of cooperative or distributed working is not supported.

There are a number of software tools that pick up on the topic, which are listed below in the tables 1 and 2. The market study shows that the aspects of ergonomics and mobility in the area of material flow simulation were not considered yet. Also the suggestion of recommendations is not mentioned before.

Table 1: Software for digital modeling of value streams, their properties and description of the new development (1).

Product	**Distributor**	**Dynamic assessment of value streams**	**Extension flexibility**	**Work flow animation**	**Usable without simulation experience**
MS Visio	Microsoft	-	+	-	+
iGrafix Process	iGrafix	-	-	-	+
Simulator Process Analyser	Sigma Flow	+	-	-	+
IMApp	iFAKT	-	-	-	+
Value stream designer	Imatech	+	**0**	-	+
Dosimis 3	SDZ	+	**0**	+	**0**
Plant Simulation	Siemens Tecnomatix PLM	+	+	+	-
Value Stream Mapping	C2 lean Ltd.	-	-	-	+
Simboli VSM	Giotroni	-	-	-	+
Process Simulator	GBU	+	-	+	+
visTABLE® touch	plavis GmbH	-	+	-	+
New development		+	+	+	+

Until today, none of the available tools on the market is able to fulfill all criteria listed before. The desired properties therefore stand out from the current state of the art and require a new development.

In addition to the market study further tool requirements could be raised by an expert survey with eleven experts. These experts work in the field of industrial engineering and are from producing companies out of mechanical engineering and drives / controls industries. They cover the production ranges of high-variance-low-volume and low-variance-high-volume. Selected results of the expert survey are consolidated in figure 2.

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Table 2: Software for digital modeling of value streams, their properties and description of the new development (2).

Product	Distributor	Ergonomic use on mobile devices	Automatic suggestion of recom-mendations	Mobile and cooperative working
MS Visio	Microsoft	-	-	-
iGrafix Process	iGrafix	-	-	-
Simulator Pro-cess Analyser	Sigma Flow	-	-	-
IM App	iFAKT	+	-	-
Value stream designer	Imatech	-	-	-
Dosimis 3	SDZ	-	-	-
Plant Simulation	Siemens Tec-nomatix PLM	-	-	-
Value Stream Mapping	C2 lean Ltd.	+	-	-
Simboli VSM	Giotroni	+	-	-
Process Simulator	GBU	-	-	-
visTABLE® touch	plavis GmbH	+	-	-
New development		+	+	+

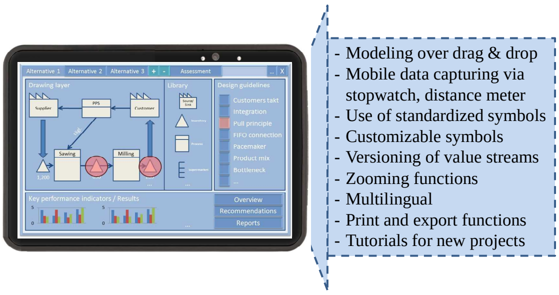

Fig. 2: Sketch of a possible user interface of a mobile value stream simulation tool and selected expert requirements.

Potentials Due To Smart Factory:

In future production systems the acquisition, processing and intelligent linking of all data, which is created during a production process, might play a significant role for industrial engineers. A vision of a smart factory is the fusion of the physical and virtual world leading to Cyber-Physical-Systems (CPS). Both, the data collection and the communication between all involved IT systems and resources in production environments must work without any media breaks, via standardized interfaces and fully automated in the background.

As a direct association and link between the real and the digital world is created on product and manufacturing equipment level, historical and real-time data of a facility can be used for optimization projects. Therefore a user-oriented processing and aggregation of data is essential. The above sketched mobile value stream simulation tool would benefit of a direct database connection resulting in a more realistic picture of the issues in production.

In the course of simulation modelling in the majority of cases deviations and average cycle times are determined on an individual basis due to expert surveys. This approach serves if there is no adequate data basis or results are needed rapidly. Thus the inaccuracy of simulation models increases and the validity of simulation results declines.

If cycle times are taken automatically out of historical data to generate more precise probability distributions the quality of simulation models can be significantly improved. Also during drafting processes for different future states of value streams a data driven approach would increase the credibility of the mobile value stream simulator and support more objective discussions on the shop floor.

Conclusions:

In combination with material flow simulation value stream mapping is a powerful tool for improving volatile and complex production systems. In this paper we discussed the potentials and the requirements of mobile value stream simulation as a new-type optimization technology for industrial engineering. The aspect of mobility can foster the transparency and credibility of planned improvements, minimizes media disruptions and thus can increase the reliability of results. With this new technology a more effective and efficient value stream simulation is potentially enabled.

In future work the mentioned requirements as well as the results of the expert survey will be used further. Thus a prototype of the mentioned software tool will be developed and tested in laboratory and industrial applications to assure the internal and external effectiveness of the technology.

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