COMEC 2019

Relationship between lean philosophy and simulation modeling

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Abstract: Nowadays the application mode of the tool and rule systems of the lean philosophy plays a relevant role in the competitiveness of companies. Basically, the advantage is realized by reduction of logistics wastes. In our opinion integration of the more important lean tools (VSM, SMED, Kanban) with simulation modeling may be necessary in many cases in order to increase efficiency in manufacturing/production processes. The paper presents these possibilities. In addition, it outlines research directions in connection with the examined areas.

Keywords: simulation modeling, lean philosophy, process improvement

1. Introduction

Only companies can sustain or improve their competitiveness that endeavor to achieve satisfaction of unique customer needs with low specific cost. The complexity of logistics systems is increasing because of the increase in the number of product types. This results in several new challenges for companies. Basically, the lean philosophy's tool and rule was elaborated for manufacturing companies that manufacture few product types, and consequently the manufacturing processes are relatively simple. We have to improve the lean tools to increase the efficiency of waste reduction for complex logistics systems, as well. The lean philosophy basically distinguishes among the 3 MUs, namely fluctuation (mura), overload (muri) and the 8 essential wastes (muda). We can state that the muri and the muda can result in all cases in muda, therefore many experts speak only about the muda's elimination. The 8 wastes are the following: overproduction, unnecessary inventory, transport, motion, and waiting, unnecessary defects and overprocessing, and unused skills [1]. The elimination of waste is realized by the 5 steps of the lean process (1. determination of the value from the point of view of the customer, 2. mapping the value stream, 3. creation of the continuous flow, 4. creation of the pull-principled material flow system, 5. improvement of the examined process). Taichi Ohno said that the most important objective is the reduction in the lead time between the ordering and the payment by elimination of the wastes [1]. If it is necessary to use a lean tool that has a relevant effect on improvement of the logistics systems, then in many cases we need to select the best option from several alternatives (e. g. creation of the changeover process, pull principle, inter-operational storages and mode of the material supplies, etc.). It is possible to determine the Key Performance Indicators (KPI) of the simple processes easily, therefore we can prudently select anadequate alternative.

Several product lines are manufactured parallelly in complex material flow systems. These systems can contain [2]:

- different material flow processes,
- different technological equipment settings,
- different unit load forming devices,

in case of each product line. These product line material flow processes cross each other in many cases, consequently it is difficult to determine KPI indicators of different process improvement alternatives. Simulation modeling can be used in such cases to efficiently create reliable KPI data. A review of the literature shows that there are only some authors who have applied simulation modeling regarding the use of lean tools. [3-5]. This paper will give an overview about the integration possibilities between the lean philosophy and simulation modeling, as well as introducing new research directions in connection with this integration.

2. Realization process of the simulation examination

Simulation, as a term, is a method that enables the realistic modeling of processes and systems, therefore parameter changes can be evaluated [2]. There are two directions for simulation examination, namely using a commercial software (e.g. Plant Simulation, Arena, Simul8, etc.) or a self-designed application. The simulation modeling steps include the following [6]:

- Determining the aims of the simulation modeling, assignment of the examined logistics system: The investigational aims need to be defined clearly before making the simulation program. This is necessary in order to assign the examined system. The objectives of the simulation modeling can be summarized as follows:
  - Elaboration of the planning failures: The future state of an examined system can be examined to reveal the planning failures (e.g. selection of inadequate material handling equipment, technological equipment, inter-operational storage), therefore we can examine and eliminate the failures before putting the system into place.
  - Determining the operating characteristics of the examined system version(s): It may be necessary to extend the data to be examined in order to make the appropriate decision about the development (e. g.: effects of modifying one or more parameters on changes in KPI indicators). This data need can be satisfied by simulation of the current and future system versions.
  - Determining the limit of the performances and conditions: It may be necessary to determine the limit of the different performance factors (e. g.: maximum manufacturing capacity, stock-in, stock-out performance, etc.) and conditions (e. g.: in case of maximum performance the necessary storage capacities, number of the workers, amount of material handling equipment) in order to support

decisions regarding planning or development of a logistics system.

- Optimizing performance of the system alternatives: Simulation modeling can provide significant help for the optimization of the system parameters regarding a predefined system alternative (optimal number of the workers and amount of material handling equipment, production plan, ideal position of the objects, etc.), allowing us to increase the efficiency of the examined system.
- Malfunction and examination of potential solutions: Several problems can be encountered regarding operation of a system (material losses, equipment stoppages, product defects, etc.). The chosen solution has a significant effect on the system's productivity. Such protocols can be elaborated using simulation modeling that enables more efficient problem solving.

- Understanding the operation of the examined system: The person carrying out the examination has to understand the workings of the assigned logistics system in order to avoid mistakes during the simulation modeling.
- Determining the set of logistics indicators that are necessary to reach the investigational objective (utilization of the technological equipment, reduction of lead time, etc.).
- Determination of the input and output data: In this step, there is necessary to define the input and output data of the simulation model to be created. In many cases the requested data are not available; consequently, it is only possible to create these on the basis of estimation and/or on-site measurement.
- Creation of the simulation model: The simulation model has to be created on the basis of the input and output data and working principles.
- Control and adjustment of the elaborated model: The working of the simulation model has to be checked and it need to be adjusted the formation of the simulation model if some differences will be found between the real/planned system and the modelled system.

- Evaluating the investigational results, elaboration of the proposals: There is necessary to systematically modify the selected parameters and after running the simulation model it is possible to evaluate the results and make proposals.

3. Integration possibilities for lean philosophy and simulation modeling

Several lean tools and methods have to be introduced during realization of the 5 repetitive lean steps. The lean methods result in different degrees of transformation in the field of material and information flow, therefore the risk of the possible wrong decisions can be differed as well. The application of the simulation modeling can be advantageous in cases where simulation modeling provides a significant degree of transformation. Three kinds of lean tools in form of value stream mapping, Single Minute Exchange of Dies, and formation of a kanban system, were investigated in order to define the integration possibilities with simulation modeling.

3.1. Examining application of simulation modeling for the value stream mapping method [12]

The value stream mapping method was created on the basis of the Toyota's material- and information flow diagram. Firstly, this was published in Learning to See in 1999 by Mike Rother & John Shook [7]. This method's relevant aim is the reduction of the wastes through improvement of the logistics processes. This is a tool for continuous improvement of the created processes, which can be used regarding Steps 2-5 of the lean transformation. There is necessary a pencil and paper to improve our processes in case of each product line simultaneously.

The 5 steps of the method are as followed [7]:

1. Selection of the examined product line, nomination of the value stream manager: There is necessary to assign a product line to be examined (a product line contains those

product types where material flows are the same) and nominate the person responsible for process improvement.

2. Creation of the current state map: The value stream manager has to explore the assigned material and information flow in order to get to know the total value stream. After this activity the value stream manager will draw up the current state map. The examined logistics system will be transparent and the wastes will be definable in the current state map.

3. Marking of the problems on the current state map: Several questions can be defined regarding the current state (How can we guarantee continuous flow? What is the reason for the inventory?, etc.) On the basis of these questions we can mark the problems on the current state map.

4. Creation of the future state map: The future state map can be drawn without the marked problem. This map will define the target condition.

5. Realization of the future state map: There is necessary to create the implementation and annual value stream plan to achieve the future state map. Value stream mapping basically contains five sequential steps where feedback can occur between the steps in the following cases:

- if the current state map does not contain the information that will be necessary to create the future state map,
- if the future state has been realized, then it is possible to execute a new examination starting from the second step.

Simulation investigational possibilities:

- The present method does not take into consideration the interaction of logistics processes of different product families (utilization of the human and equipment, availability of the storage areas, etc.) because this method only analyzes one product line’s logistics process at a time. It is possible to make simulation models where the working of an assigned logistics system can be examined, therefore the interactions can be analyzed regarding other product families as well.

- The stochastic behavior of the logistics parameters (e.g.: operation time, material handling time, etc.) is not taken into consideration in standard VSM, and consequently it is not possible to make the best decision. The mentioned parameters can be applied if the simulation modeling is used.

3.2. Examining application possibilities of simulation modeling for the SMED method [12]

Reduction in the lead time of the changeover processes results in reductions in the inter-operational stock, production lead time, and the required floor area, in addition to increases in production flexibility and productivity. An increasing number of companies use the Single Minute Exchange of Die (SMED) method in order to reach these advantageous effects.

Steps of SMED application [8,9]:

Step 1. Measurement of the total changeover process: The total changeover time is made up of several operations, which in many cases can be executed in parallel mode. The lead time have to be measured for each step of the changeover process; the best method is often to make a video recording. After this the identified activities have to be recorded, their lead times, and any notes on a changeover measuring sheet.

Step 2. Rearrangement of the internal and external changeover steps: The activities revealed have to be sorted in the previous step, categorizing them as internal activities (can be executed during the production's stoppage) or external activities (can be executed during the production's run). We can support the rearrangement by making control lists (their aim is the control of the parts, tools and settings which are necessary for the changeover activity) and operability checks (checking the parts and tools before the changeover in order to eliminate later problems) as well as the optimized transport of the parts and tools.

Step 3. Transformation of internal steps into external steps: There is necessary to examine what kinds of internal activities can be transformed into external activities through technological improvement. This can be done through preparation of the working conditions (for example pre-heating or pre-positioning) and standardisation of the basic functions (for example standardisation of tools or fixed support of tools), as well as use of intermediate elements (for example: the next part to be manufactured can be put on an intermediate element and therefore the next machine can be adjusted within a shorter lead time).

Step 4. Improvement of the internal and external steps: The kaizen activities have to be executed in internal and external changeover operations. Basically kaizen is an endless process which consists of a number of improvement steps without major investments. The aim of the improvements is the increase of productivity through the reduction of the operations' lead time. The application of 4 principles can be examined as follows [10]:

- Contraction: the closer placement of the motion's object to the working place and/or skipping an unnecessary operation,
- Coupling: the execution of two or more operations in parallel and/or transformation of two or more tools into one,
- Rearrangement: the rearrangement of the objects in the interest of more efficient work,
- Simplification: the simplification of the methods and tools (for example: wing nut fixing or spring fixing).

Simulation investigational possibilities:

- It may be necessary to significantly transform the changeover process in cases of Steps 2 and 3. This transformation can result in additional costs (employment of more workers, purchasing material handling equipment and new technologies, creation and application of new software, etc.), as well as cost reduction (lower stock level, smaller required floor area, etc.) and/or an increase in the amount of the manufactured product. Usually there is necessary to create several changeover process alternatives when we examine these steps. In these cases, simulation modeling can be useful because it is possible to analyze the selected alternatives more prudent as than before.

3.3. Examining application possibilities of simulation modeling for formation of the kanban system [12]

The transformation from push system into pull system and the improvement of the transformed processes have a significant effect on companies' compatitiveness. Basically the pull system is realized by the kanban system. The kanban can be explained as an information system that enables the control of the material- and production process on the basis of the pull system. It is possible to avoid overproduction or missing stock, and realize the production balancing, as well as improve our system using the kanban system [10]. The transformation process's most important steps are as followed:

1. Fulfillment of the prerequisites [10]: The following lean devices have to be implemented before creation of the pull-principled production control system:

- visual management,
- proposals system,
- 5S,
- standardization,
- creation of the company culture for more efficient process improvement,
- kaizen.

2. Creation of the group: There is necessary to create a group that will plan and coordinate the pull-principled production control system's realization. There is important to choose different company areas representatives for this group who will be

touched by the transformation. It is very important to include at least one person who has experience in the pull system's realization.

3. Creation of the schedule: Determination of the implementation process' most important milestones and those deadlines.

4. Education [10]: In this step, there is necessary to provide some training for members of the group in connection with the creation and actuation of the push-principled production control systems.

5. Drawing, analysis, evaluation of the current state: The value stream mapping's method [7] is suggested for mapping of the current state of process to be transformed. This method enables the current state's understanding and objective evaluation.

6. Planning of the future state: Actually, the planning of the future state means creation of the future state mapping [7], which is realized on the basis of evaluating several variations and selecting the optimal one. The map defines the principles of system operation, namely where and what kinds of devices there are necessaries to locate, and how the flow of material and information will work.

7. Planning of the system introduction: A table has to be created that contains the tasks to be realized, period of the implementations (Gantt diagram), and performance indicators to be reached, as well as the people concerned (RASIC chart).

8. Determination of the system working regulation [7]: In this step, there is necessary to determine the workers' work instructions for different conditions (e. g. mode of the process improvement, regulation of the stock level in the case of different customer needs).

9. Planning of the system's device: There is necessary to determine the standard and the special kanban cards (pool kanban, express kanban, etc.), the heijunka boards, the supermarkets and/or FIFO lanes, the kanban storage areas, milkrun trains, etc.

10. Realization of the system: The pull-principled production control system has to be realized on the basis of the system's implementation plan.

11. Education of the system's working: In this step, there is necessary to provide some training for the workers regarding the elaborated work instruction and the total system working. After training the appropriate skills have to be checked at the production area.
12. Actuation and improvement of the system: The system has to be actuated after the realization of the system and the workers' training, which will result in several failures in the beginning. The continuous process improvements (kaizen events) have to be carried out during the actuation of the system.

Simulation investigational possibilities:

- It is possible to create some system versions of the future state map within a short time using the simulation modeling, and therefore we can take into consideration all necessary parameters (required floor area, lead time, number of kanban cards, number of workers) regarding selection of the appropriate version.
- The operation rules of the kanban system can be determined with more efficiency regarding different customer needs using simulation modeling. The kanban stock levels can be calculated with more precision using simulation modeling because the stochastic effects can be considered as well. The production process work instructions can be better defined and therefore the utilization of the human and machine resources can improve.
- The type and number of the milkrun trailers, kanban cards, kanban card places, as well as the inter-operational storage areas can be determined more precisely using simulation modeling. This can result in relevant savings.
- The continuous improvement of the created kanban system is necessary to sustain or improve the company's competitiveness. The improvement decision can refer to more than one value stream simultaneously; in such cases we can use simulation modeling in order to avoid the wrong decisions (e. g. purchasing the smaller performance technological equipment).

We can improve the quality of the training and reduce the lead time of the training in case of processes that have been or are to be implemented regarding all three introduced methods using simulation modeling and new training methods (e. g.: gamification) [11-12]. Integration of the introduced methods and simulation modeling defines new research directions because it is possible to elaborate the exact realization of the integration using investigational and decision- making methods.

Summary

Basically, the methods for waste reduction, as well as ways to satisfy unique customer needs, plays a significant role in the competitiveness of companies. More and more companies are using the lean philosophy in order to sustain/increase their competitiveness. This paper introduced lean tools (VSM, SMED, Kanban transformation) where the application of the lean tool has a significant effect on the transformation of the logistics processes. The integration possibilities of the mentioned tools and simulation modelling were examined in the article, as well as possible advantages of integration. These integration possibilities induce new research areas through exact elaboration of the integration models and methods. Finally, we can forecast that the efficiency of the process improvement will increase in the future due to the integration of lean tools and simulation modeling.

Acknowledgement

The described article was carried out as part of the EFOP-3.6.1-16-00011 "Younger and Renewing University – Innovative Knowledge City – institutional development of the University of Miskolc aiming at intelligent specialisation" project implemented in the framework of the Széchenyi 2020 program. The realization of this project is supported by the European Union, co-financed by the European Social Fund.

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