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September 25th — 26th, 2017 | Darmstadt, Germany
Interdisciplinary Conference on Production, Logistics and Traffic

Application of simulations and LEAN management in designing material flows in production systems

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Abstract. Simulations are a proven tool for planning, designing and optimization of production systems. In the planning or redesigning stage of a production system, simulations represent an effective way to show how the system will work and thereby encourage thinking how to improve it. LEAN proved to be very effective approach to streaming material flows. Within this paper the idea was to use simulations and LEAN management to design and optimize a new material flow in an existing production system. The concept was applied on the example of a production company that produces several different products and currently considers extending the production program with a new product. The simulation model of the new product's material flow was developed based on the existing technology, current production site layout and production cycle times measured during the production of the prototype. Simulation results pointed out following waists: long waiting times, high inventory and non-adequately exploitation of resources. LEAN tools: Value Stream Mapping, 5S and heijunka, have been applied, pointing out the changes that should be done in order to improve the system. The new simulation model including the suggested changes has been developed and tested. In that way, anticipating effects of the suggested improvements have been measured and validated providing the valuable inputs in the early stage of production planning and material flow designing.

1 Introduction

In today's competitive market the companies are required to continuously optimize and improve the material flows along the entire supply chain, and particularly within the production system. For these purposes LEAN management can be applied. LEAN represents an approach to planning and organization of a system, which considers eliminating all wastes - activities that do not add value to the final product. In this way, significant savings of resources and increase of customer satisfaction can be achieved.[1][2] Measuring the LEAN management effectiveness in the existing system is every day practice; however, measuring the LEAN management effectiveness at designing new material flows is not possible without application of simulations.

Simulations are a proven tool for planning, designing and optimization of production and logistics processes. They enable creating simulation models that credibly replicate the real system providing the possibility for detecting eventual malfunctioning of the system, bottlenecks and obstacles for its further development, options for their removal, as well as the visualization of the effects of the proposed changes. Using simulation is an effective way to show how the system works and thereby encourage thinking how to improve it, providing the opportunity to test the proposed improvements on the simulation model, and only in the case of the verified effectiveness to implement changes in the real system.[3][4]

Within this paper, the idea was to design a material flow of a new product in the existing production of a metalworking industry using the LEAN management principles and tools.

Considering that only one prototype of the new product has been produced and that there was no empirical evidence of its production, simulations were used to replicate potential material flow design and to evaluate its effectiveness. Based on the layout of the existing production system and measurements done during the production of a prototype, a simulation model of the "new product" material flow in the existing production system has been developed. Based on the simulation results, the system was redesigned using the LEAN tools.

2 Material and method

In order to design the new material flow in an existing production system, two simulation models have been developed. The first model was used to analyse the effectiveness of the system and to reveal potential bottlenecks of the new material flow. The second model was used for testing of the possible solutions and suggested improvements. The models were developed and tested in the simulation software Enterprise Dynamics. For both models, simulations were carried out for the time frame of one year.

Suggested improvements of the system were based on the implementation of LEAN principles and tools: Long-Term Thinking, Value Stream Mapping, Continuous flow, Pull instead of push, 5S, Production levelling – heijunka, Standardization of work tasks as the basis for continual improvement, Implementation of visual control, etc.

3 Case study

The concept was tested on the example of a production company that produces several different products and currently considers extending the production program with a new product. As a potential product, trailers with capacity of 8 t are considered. In order to reduce the risks, in the early production stage, the company considers acquiring most components from local and foreign suppliers and producing only selected smaller sub-assemblies and final product assembly. The production should be organized in three phases. The first phase should comprehend production of the sub-assemblies, the second stage the sandblasting and painting of trailer parts, while the final stage should represent assembly of the final product.

3.1. Simulation of the prototype production

In order to examine the possibility and effectiveness of the new product introduction to the existing production system a simulation model was developed. The model was developed based on the existing technology, current production site layout and process cycle times measured during the production of the prototype.

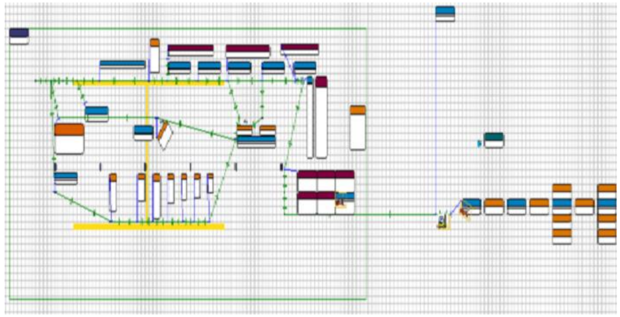

Figure 1. Simulation model of the prototype production material flow

Simulation results of the prototype production model point out two major bottlenecks:

- Processes of sandblasting and painting;
- Process of electrical wires installation.

The processes of sandblasting and painting cause a lot of waiting of the material flow, which can be seen by the buffer status in front and behind of these processes (Buffer 7 and Buffer 8 – see table 1) and blocking and low utilization of other processes (see figure 2). This is a consequence of long cycle times of these processes.

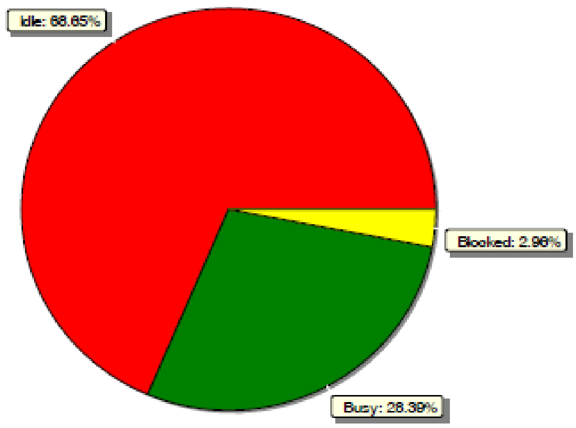

Figure 2. Utilization of the CNC lathe

The same problem of long cycle time occurs with the electrical wires installation blocking the other processes and causing their low exploitation level and high level of inventories along the production (see figure 3).

After the simulation model was developed, it was used as a basis for the Value Stream Mapping of the new product material flow within the production system.

Unfortunately, due to the size of the Value Stream Map of the production system, it is not possible to insert them in this paper. Reducing the map size to any format smaller than A3 makes them unreadable.

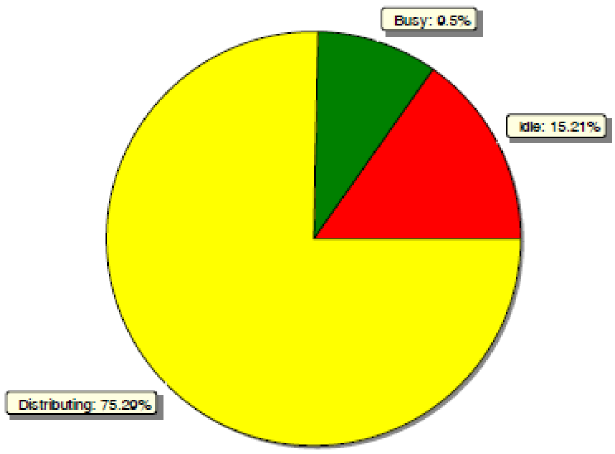

Figure 3. Utilization of the final assembly processes before the electrical wires installation

The bottlenecks are also apparent at the production Value Stream Map. The production lead time is too long mostly due to the material flow waiting times. The Map of the Prototype production points out the need for the implementation of the Pull system, reduction of production inventories and material flow waiting times at the above mentioned processes.

3.2 Simulation of the LEAN material flow

Based on the simulation results, in order to stream the material flows and to prevent the bottlenecks and resources wastes in the real production, the following LEAN tools were applied and implemented in an improved simulation model: 5S, Value Stream Mapping of the targeted production efficiency and Heijunka.

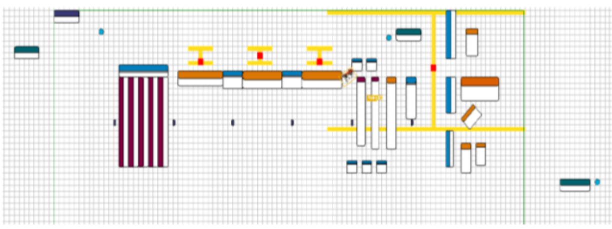

Figure 4. Simulation model of the LEAN material flow

The model improvement considered changing of the production site layout, taking into account the requirements of the existing production and applying the LEAN 5S tool. Additionally, real production cycle times for every process were measured individually after application of 5S and further considered for the application of heijunka in the first phase of the production – production of the selected sub-assemblies.

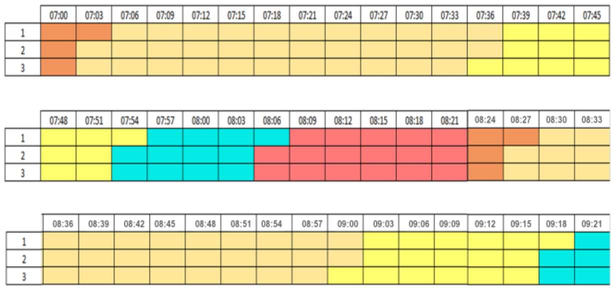

Figure 4. Section of heijunka of subassembly process of 5 different parts (represented with different colours, three work stations and process cycle time 3 minutes per part)

The improvement also comprehended some technological upgrades through implementation of plastification instead of sandblasting and painting and introduction of robotic instead of manual welding.

All mentioned improvements removed obstacles in the material flow that were causing waiting times and increased utilization of the other processes (see figures 5 and 6).

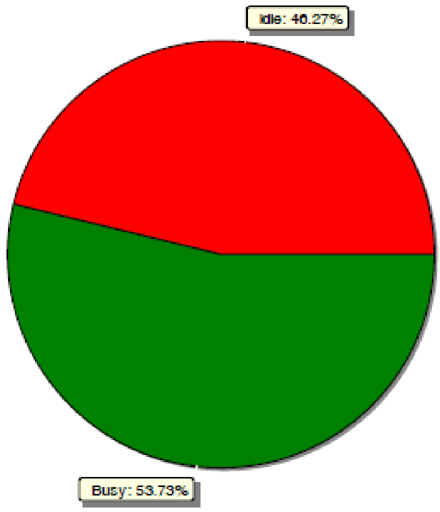

Figure 5. Utilization of the CNC lathe after system improvement

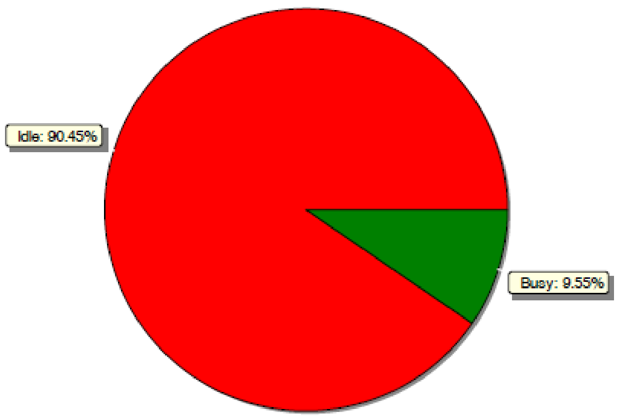

Figure 6. Utilization of the final assembly processes before the electrical wires installation after system improvement

Besides the abovementioned improvements, an organizational change is suggested – cooperation with new local suppliers instead of foreign ones. The change is recommended because the waiting times of the delivery and the costs of holding inventory of the parts supplied from abroad are greater than the costs difference for the more expensive locally supplied parts that have satisfying quality and significantly shorter delivery times.

3.3 Discussion

Results of Lean implementation in the company are primarily measured in the following three ways:

- By comparing the average inventory retention time at the selected buffers in the production in both models simulations;
- By comparing the lead time in the two developed Value Stream Maps;
- By comparing the required number of workers in the two developed Value Stream Maps.

According to the simulation results, in the LEAN implemented simulation model, the average inventory retention time at the selected check points in the production is significantly shorter than in the prototype production simulation (see table 1).

Table 1. Simulation results - average inventory retention time in the production, in seconds

Inventory at	Prototype production simulation	LEAN implemented simulation
Buffer 1	3221	896
Buffer 2	1005595	280
Buffer 3	575667	345
Buffer 4	537364	450
Buffer 5	582947	458
Buffer 6	519627	458
Buffer 7	1262582	0
Buffer 8	1810987	0

The lead time of the production is reduced from 411 to 93 hours with the "LEAN material flow".

The required number of workers is reduced from 29 to 19 in the production with the "LEAN material flow".

Additionally, the required production area is significantly reduced.

4 Conclusions

Within this paper, combination of LEAN management and simulations were used as a tool in designing the new material flow in the existing production system. The case study has shown that, although production still does not exist, simulations can model and test it in early stages of production planning in order to identify potential problems and solve them. By applying the LEAN concept, production optimization was made so that it became more economical and cost-effective. Combination of application of simulations and LEAN concepts in the material flows designing stage gave very good results. Considering that it is not a common approach, results of this research are significant and valuable in pointing out the possibilities for the future applications.

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