MILK RUN TESTING THROUGH TECNOMATIX PLANT SIMULATION SOFTWARE

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Abstract

The article focuses on the testing of Lean tools on a created simulation model in the TX Plant Simulation software environment. Lean manufacturing tools and techniques are a progressive means of increasing the efficiency of production and logistics processes in an economically optimal way. It involves eliminating various types of waste, which requires good analysis and knowledge in the field. The article deals with the selected Lean production tools such as Value Stream Mapping, Milk run and Kanban to improve logistics flows processed in a case study. The output of the implemented case study was the optimization of logistics flows related to the supply of workplaces in the reduction of work in progress. (Received in November 2021, accepted in February 2022. This paper was with the authors 2 weeks for 1 revision.)

Key Words: Milk Run, Logistics, Model, Simulation, Lean Production

1. INTRODUCTION

It is possible to see the significant potential that is created by the introduction of information and communication technologies Industry 4.0. It is suitable for companies that work based on Lean Manufacturing principles. Proper usability is the key to integrating information and communication technologies into lean methods and techniques. Intensification of technology increases the usability and flexibility of Lean Production principles. It can be stated that it is faster, smoother, more stable, and more accurate. The authors in the study [1] published a research that focused on PD (Product Development) with an emphasis on lean principles. The different approach to lean manufacturing and PD is emphasized due to the different economies and value creation mechanisms. Significant in connection with the implemented study is the importance of the use of Value Stream Mapping analysis, which was also applied in this paper. In the article [2], the authors elaborated an algorithm that can be applied to the Inventory Routing Problem. They point to the importance of introducing a vendor-managed inventory (VMI) system, which is one of the latest examples of added value through logistics services. They emphasize the importance for both the supplier and the customer, thanks to which the customer is freed from high investments in inventory and the complexity of inventory control.

The case study can be cited as an example of using PLM software TX Plant Simulation in combination with the use of the Milk run method. It is focused on optimizing the supply of workplaces at the mentioned production layout. Importance of using Industry 4.0 technologies in connection with Lean Production methods [3, 4], Table I:

- allows much faster one-piece flow,
- allows introducing more efficient e-Kanban,
- streamlines the implementation of VSM value stream mapping,
- increases the transparency and visibility of data in real-time,
- potential to radically reduce stocks in the supply chain and produce less waste – DDMRP/Demand Driven MRP.

Table I: Matrix of impact Industry 4.0 on Lean Manufacturing [5].

Lean tools	Data collection and processing				Communication machine - machine		Interaction man - machine	
	Sensors and regulators	Cloud computing	Big data	Data analysis	Integration		Virtual reality	Augmented reality
					vertical	horizontal		
5S	+	+	+	+	+	+	++	+++
Kaizen	+	++	+++	+++	+++	+++	+++	+++
JIT	++	++	+++	+++	+++	++	+	++
Jidoka	+	+++	+++	+++	++	++	+	+
Heijunka	++	++	+++	+++	+++	++	++	+
Standardization	++	+++	+++	+++	++	++	+++	+++
Tact	+	+	+++	+++	+++	+++	+	+
Pull	++	+	+	+	+++	+++	+	+
Man - machine	+	+	+	+	+	+	+++	+++
People and teamwork	+	+	+	+	+	+	+++	+++
Reducing of waste	+	+	++	+++	+++	+++	+	+

The impact / synergy of Industry 4.0 with lean tools is + (+ / weak, ++ / higher, +++ / highest possible impact).

The main reason for using the Lean Manufacturing concept is to maximize resource utilization by minimizing waste. Lean Manufacturing principles define the value of a product, resp. service as perceived by the customer through waste and loss elimination and by sorting activities into value-added (VA) and non-value-added activities (NVA). Advanced technologies related to Industry 4.0's: IoT, IoS, big data, cloud computing, 3D printing, AI, etc. may seem at odds with lean principles. However the manufacturing companies which operate on lean manufacturing principles are more standardized, more transparent, and limited to the necessary work. Therefore lean principles become more important, as efficient and processes are a prerequisite for the deployment of Industry 4.0 technologies.

2. MATERIALS AND METHODS

Lean manufacturing tools and techniques operate as an important management tool, especially in manufacturing companies. Mapping the entire production chain is the first step in implementing a lean concept. It is advisable that VSM / Value Stream Mapping take place with the intentions of the PDCA / Plan-Do-Check-Act cycle. According to [5], these are the following steps in the context of VSM:

1. Plan: Define strategic goals and KPIs of improvement – Make staff of every level understand the importance of Lean.
2. Do: Identify a Value Stream Manager for VSM Map out processes/products/services according to VSM – Implement redesigned VSM (future-state).
3. Check: Measure the results obtained through KPIs and Lean Metrics – Monitor economic and financial results according to Lean Accounting.
4. Act: Communicate results to everyone in the organization – New targets and goals, new VSM.

In connection with the introduction of digitization elements into the management of business processes, it is necessary to implement elements of standardization. It is therefore necessary to extend the classic PDCA in the following repetitions by the so-called SDCA/Standardization-Do-Check-Act cycle (see Fig. 1). This is a way to stabilize production, improve products as well as increase the efficiency of implemented tools and digital technologies. Part of the SDCA cycle is an audit to check the level of compliance with standardization processes. The result of the audit is then a set of countermeasures to restore the normal state of the process after determining the reason for its failure, resp. non-compliance.

Figure 1: PDCA and SDCA combination (own processing).

Milk run is generally a cyclical transport system ensuring the distribution of raw materials, finished products, semi-finished products, respectively, in general, stocks of individual collection points in the required quantity, which ensures consumption until further distribution. The origin of this system is in the supply of milk, according to which the name Milk run came from. The introduction of the Milk run aims to minimize transport and inventory costs regarding the capacity of the transport system as well as the storage areas of the collection points. In the context of the above Lean production, the use of Milk run is common. Within in-house logistics, the supply of workplaces means a small amount of inventory from one central warehouse within the operation. Part of the material flow is transport units (crates, pallets, boxes, ...), which limit the amount of stock in circulation. Source [5, 6] lists the characteristics that most represent the definition of Milk run from the perspective of logistics practice:

- Milk runs are fixed routes with fixed pick-up and delivery time slots (and fixed volumes), which are executed according to a fixed cycle.
- On Milk runs, LTL of more than one supplier are consolidated to be able to increase the individual shipping frequency compared to executing a direct point-to-point transport for each of them.
- Milk runs are round tours on which full and empty returnable containers are exchanged in a ratio of 1:1.
- Milk runs are planned by the consignee.

3. CASE STUDY

3.1 Analysis and creation of the current state simulation model in TX Plant Simulation

The case study below deals with the product group to be mapped, namely door locks. These components are manufactured in three variants: front doors, rear doors, and trunk locks. The researched company focuses mainly on the production of components for the automotive industry (see Table II, Fig. 2). The overall principle of production lies in the size of customer demand. The company works for one 12-hour shift (scheduling of working hours for each employee is the so-called carousel, that is shift 1, shift 2, 2 days off). The customer requires 800 pieces of components for one shift.

Table II: Input data from production process.

Workplace	Process time	Number of employees	Availability
Riveting	10 s	1	85 %
Lubrication	7 s	1	85 %
Screwing	8 s	1	85 %
Sticking	7 s	1	85 %
Control	10 s	1	95 %
Packing	8 s	1	90 %

Figure 2: Production sequence diagram.

The VSM method for material flow mapping was used to analyse the current state (see Fig. 3). Microsoft Excel was used for display. The value-added index, which is used to examine the efficiency of processes, can be expressed as follows, in the solved case study, this means:

$$\text{Value added index} = \frac{0.0005787 \text{ days}}{10 \text{ days}} \times 100 \% = 0.0058 \% \quad (1)$$

Figure 3: VSM realized for the analysis in case study – current state.

The model consists of the introduction of the Milk run system for supplying workplaces with production parts and materials. The design of the assembly line consists of six workplaces. At each workplace, there is a workplace for one production operator. The case study includes:

Usable time pool: 43,200 (12 hours) – 3,600 (1 hour break) = 39,600 seconds per shift

$$Takt\ time = \frac{39\ 600\ seconds}{800\ pieces} = 49.5\ seconds \quad (2)$$

The formula that was used is from the basic literature. As a result, customer requirements will be met if the site produces one component in 49.5 seconds.

Figure 4: Production and logistics flow – current state simulation 3D model.

The transport time between the supermarket and the assembly workplaces was 7 minutes, which means that each transport circuit should contain 7 minutes of transport time plus variable working time. For 4 production cells, 10 containers are needed every 30 minutes, and this requires 5 minutes and 40 seconds of added work to the 7 minute transport time between the supermarket and the assembly sites. Summary, this meant 12 minutes and 40 seconds. Each time the transport Kanban was lifted from the work-place, the material was replenished in the next supply cycle. Holding the stock of material is 60 minutes (see Figs. 4 and 5, Table III).

Table III: Activities and individual times for the supply circuit.

Step	Working activities	Estimated time
1.	The transporter passes from the central supermarket and arrives at the individual workplaces	2 min
2.	The operator picks up all the transport Kanbans at each station and also picks up empty crates and delivers parts to the workplace and returns to the central supermarket.	7 min
3.	Classification of collected cards in the supermarket	20 s
4.	Placing empty crates in a reserved place	1 min
5.	Parts (nuts, bolts and caps) are located on the conveyor	2 min
6.	Transport Kanban cards are placed on individual containers with parts	20 s
TOTAL CIRCUIT TIME		12 min 40 s

Figure 5: Production and logistics flow – proposal 2D model and Milk run supply circuit.

To tune the line and a properly functioning production process, it is necessary to calculate the individual important parameters that are related to the smooth material flow. The increment is calculated by multiplying the cycle time and the number of pieces in the package. If the manufactured locks are packaged and are ready for shipment to the customer, they are packed in crates of 10 pieces. In this case, it will be prepared every 10 minutes (see Table IV).

Table IV: Production increment calculation.

Takt time	×	Quantity in package	=	Increment
49.5 s	×	10 pc	=	495 s

The number of available incremental intervals was calculated by the following calculation to meet the demand and smooth the production mix (see Table V).

Table V: Incremental interval calculation.

Available time	/	Increment	=	Number of intervals
39 600 s	/	495 s	=	80 intervals

Production mix (see Table VI):

- Item A – front lock,
- Item B – rear lock,
- Item C – trunk lock.

Table VI: Time intervals for individual items of type A, B, C.

Total interval	×	% production mix	=	Intervals per item	(Corresponding time)
80 intervals	×	40 %	=	32 reserved for A	$(495 \text{ s} \times 32 = 15840 \text{ s})$
80 intervals	×	40 %	=	32 reserved for B	$(495 \text{ s} \times 32 = 15840 \text{ s})$
80 intervals	×	20 %	=	16 reserved for C	$(495 \text{ s} \times 16 = 7920 \text{ s})$

Multiplying the packaging quantity and the number of intervals shows that the company needs to produce 320 pieces of front locks, as well as 320 pieces of rear locks and 160 pieces of trunk locks. Furthermore, in order to achieve a suitable supply method, it was necessary to determine the natural supply circuit between the cells and the supermarket. The enterprise transport circuit for production components is shown in Fig. 3 and included 10 different parts of one to three containers placed on the line, which meant an hourly supply per item.

4. RESULTS AND DISCUSSION

Based on the simulation settings for the required amount of production and according to the average daily customer demand for 12-hour shift, the following statistical data were from simulation, shown in Fig. 6 and Table VII.

Figure 6: Resource statistics and occupancy of storage areas – after simulation run.

Table VII: Resulting statistics after simulation run.

Object	Working	Waiting	Blocked	Failed
buffer	0.00 %	100.00 %	0.00 %	0.00 %
lubrication	41.16 %	6.98 %	35.51 %	16.35 %
screwing	46.83 %	13.83 %	27.11 %	12.23 %
sticking_foam	40.80 %	16.90 %	26.76 %	15.54 %
control	58.05 %	22.72 %	2.70 %	16.53 %
riveting	59.05 %	0.00 %	26.67 %	14.28 %
packing	48.47 %	36.56 %	0.00 %	14.97 %

The utilization of the finished products warehouse, waste, and smaller storage areas at individual workplaces, which are supplied by the Milk run concept are shown in Fig. 6. The benefit of this concept is in reduction of the inter-operational stocks and the regular replenishment of material in the workplace. To achieve a suitable supply method, it was necessary to establish a natural supply circuit between the cells and the supermarket.

Table VIII: Material flow in buffers.

Object	Number of entries	Number of exits	Minimum contents	Maximum contents	Relative empty	Relative full	Relative occupation without interruptions	Relative occupation with interruptions
buffer_lubrication	82	76	0	6	1.82 %	0.00 %	49.06 %	49.06 %
buffer_screwing	123	117	0	6	1.91 %	0.00 %	49.44 %	49.44 %
buffer_sticking	82	76	0	6	1.99 %	0.00 %	48.93 %	48.93 %
buffer_riveting	123	117	0	7	1.70 %	0.00 %	49.61 %	49.61 %
waste	376	366	0	10	13.34 %	0.00 %	15.62 %	15.62 %

As shown the Table VIII a maximum intermediate storage capacity of 10 pieces, there is no overfilling and they are regularly replenished by the transporter after 2 or 3 pieces every 60 minutes, which is also the time of holding stocks in the warehouse. It is also possible to see the percentage of interruptions. After the introduction of the Milk run concept, the distance of the transporter in the supply circuit during a 12-hour change is 5617 meters (output from the simulation). Based on the data on the movement of the transporter, it is possible to modify the route and minimize transport costs. It is also possible to monitor and display bottlenecks in production and prevent unexpected delays or losses (simulation output). By monitoring and subsequently eliminating such deficiencies that slow down or limit production, a smooth flow of production can be achieved. It is also important to record data for regular maintenance and repairs. As an output, the analysis of VSM after the introduction of Kanban and Milk run was processed. The results are shown in Fig. 7.

In contrast to the original model (see Fig. 3), the change can be seen in the Value Added Index. This index has increased its value from 0.0058 % to 0.23 %. It was caused primarily due to the reduction of WIP and the implementation of the Milk run set according to the requirements of a specific process.

The output value from the solved case study:

$$\text{Value added index} = \frac{0.83333 \text{ min}}{360 \text{ min}} \times 100 \% = 0.23 \% \quad (3)$$

Figure 7: VSM realized for the analysis in case study – final state.

The case study focuses on the automotive industry, specifically on a company producing car components. With the help of lean manufacturing methods, a stable operation of the simulation model was achieved. Based on the analysis of processes using value stream mapping, the basic parameters of processes and individual material flows were determined. These eventually contributed to the proper debugging of the line. The implementation of the Milk run concept into production has eliminated bottlenecks and highlighted the stability and flexibility of lean thinking. By saving mainly the time of supply of workplaces and storage space in supermarkets and warehouses, the potential profitability of the company increases. The use of simulation to implement new production or supply elements into the process is a powerful tool in testing. By combining modern technologies and methods, it is possible to achieve targeted results that help increase the competitiveness of the company.

5. CONCLUSION AND OUTLOOK

The case study is aimed to point out the potential of simulation software in the implementation and testing of modern technologies with the Lean production concept Milk run. Lean production or even lean thinking is a very utilizing and practical philosophy of the company. It is constantly improving and expanding with modern technological elements. The potential of Lean is significant if is done right. This can be seen in reduced delivery times, improved quality and increased efficiency [6-10]. From the case study was made a scheme of the procedure for solving the implementation of Milk-run into real practice was elaborated (see Fig. 8). It is a procedure that reflects the use of several methods that cooperate and the outputs from them follow each other to achieve synergy in the form of quality supply flow. These are well-known and practically usable methods of Lean production, such as Value Stream Mapping, Design for Flow, push and pull systems, PDCA / PDCS cycle. It is also an application of software for modelling and simulation of processes, in the case study it is TX Plant Simulation from the Siemens portfolio. The flow consists of 9 dimensions: challenge/skill balance, clear goals, immediate feedback, merging of action and awareness, ability to concentrate on the task at hand, ability to control the means to achieve the task's outcome, loss of self-consciousness, transformation of time, and autotelic (self-rewarding) experience. These criteria may not be

used in full, but their combination represents a set of necessary specifications for defining the flow.

Figure 8: Proposed Milk run solution procedure.

Applying lean concepts at the supply chain level, manufacturers can become more agile and increase customer service levels while reducing the cost of custom manufacturing. Currently, very frequented Industry 4.0 enables a much richer understanding of customer demand and allows immediate sharing of current demand data in complex supply chains and networks. Smart factories can produce faster and less waste. The Industry 4.0 technology enables a much faster one-piece flow of customized products. It holds the potential to radically reduce stocks in the supply chain as a whole. It will lead to personalized production, with the associated achievement of a high level of customer service, optimization of production capacity utilization, but not in terms of maximizing its utilization, but ensuring maximum flexibility and speed and efficiency and reducing storage costs [11-19]. Such an approach will open a value chain for specific participants, i.e. priority also for customers, which thus becomes part of it. For the customer to be able to hold such a position, a certain level of customer erudition is also required, resp. use of artificial intelligence to transform the exact requirements of the customer into a product. The value chain constructed in this way enables real-time communication with each other, sharing, processing, analyzing data, designing, and communicating suggestions for improvement, etc. [20-25]. The provision of such a dimensioned value chain must be seen in quality logistics in terms of information and material flows. This means that inbound and outbound logistics will have to work on the decentralization and implementation of self-regulation of individual elements of production systems. Optimised manufacturing processes must minimise negative environmental impacts. The main aim of sustainable manufacturing is to introduce a new holistic presence product cycle and optimise the lifecycle of manufacturing systems, products and services [26, 27]. The potential for further research can be seen in the authors' work [28], in which they propose the methodology for designing the manufacturing lines using the reconfiguration principles. The methodology is interesting in the context of using a mathematical model to create algorithm particular applications in the MS Excel and Tecnomatix Plant Simulation environments.

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