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Modelling and Simulation the Value Stream Mapping – Case Study

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Abstract
Digitization in the production area represents the integrated planning and management of production and logistics systems and networks based on digital models, methods, and tools, which are built on a common flexible information and communication platform. Currently known and used Lean tools need to be dynamized and oriented to the creation of digital business, where digital models can be heterogeneous, respectively usable in several projects. One of these possibilities is the use of the Lean production method – Value Stream Mapping, the potential of which in the context of the above mentioned is great. The aim of the presented article is based on Gemba analysis of the production process to process the value stream in the environment of the software tool TX Plant Simulation for the needs of flexible reflection on changes in various parameters within the value stream. The case study carried out under this article aims, among other things, to highlight the importance of combining simple Lean Production tools with software in finding, testing, and designing alternative solutions. The potential of using the processed model was also processed for the needs of digitization of business processes in the future.

Keywords
Value stream mapping, Kanban, model, simulation.

Introduction

Value Stream Mapping (VSM) is a method known in the world for over 50 years when it appeared in Toyota, Japan, under the name "Material and Information Flow Mapping". This method of industrial engineering maps the value flow in all processes from material entry into production to the actual dispatch of the material to the customer. Using this method, processes that add or not add value are investigated and monitored in production, logistics, and administration but also service processes. By using the value flow mapping correctly, it is possible to record irregularities that arise during the implementation of the product or service (Ruano et al., 2019; Purba and Mukhlisin, 2018; Wicher et al., 2015). The aim is not only to monitor the material flow but also to the information flow in the representation of individual processes according to the given standard procedures. The actual goal of the value flow mapping is not only a map of the current state but also a map of the future state of the value flow. Optimizing the value flow is needed to successfully understand possible improvements and their benefits for the future value flow (Rajnoha et al., 2018; Chromjakova et al., 2017; Kuperova and Zatrochova, 2014; Micieta et al., 2018). All processes of changing the material to the final product form a flow of values. Value is a very important element for the customer. This value is calculated as the ratio between product performance and cost. When mapping the value flow and creating a map of the present and future state, it is appropriate to apply and make use of all changes in production plans as appropriate (Ruano et al., 2019; Fedorko et al., 2019):

- change a new product into production,
- change in the product manufacturing process,
- change in production layout,
- modifying processes or technologies.

The main output of the mapping is a visual representation of the state of the value flow and a comprehensive view of the production of the selected representative. Mapping provides a credible view of bottlenecks, the reasons for potential losses, and inefficient

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production or storage systems. The main outputs of the map are (Minh et al., 2019; Rosová, 2010):

- Value added index (VA index) – the ratio of the added value of a production process or product to the total production lead time. The index is given as a percentage.
- Process time – primarily depends on the cycle time.
- Information on completion – size, status.
- Information about the amount between warehouses.

Using the VSM method, it is possible to achieve several benefits for the systematization of production but also for the whole enterprise. Other benefits for the method are (Ruano et al., 2019; Purba and Mukhlisin, 2018; Wicher et al., 2015):

- optimization of material value flow,
- finding potentials for improvement,
- understanding process capacities,
- reduction of work in progress and warehouses,
- mapping of production status,
- data visualization,
- reduction of production lead time,
- view of bottlenecks.

Output indicators:

- Production Lead Time – (PLT) is a basic performance indicator and indicates the time interval from receiving a request from a customer to delivering a product to a customer. Shortening PLT increases the value-added index. The size of the PLT is primarily dependent on the dose size, the individual process and preparation times. In the case of series or parallel production, so-called total running time, considers the size of the required quantity. The total running time also includes transport times, waiting times by machine occupancy and more (Minh et al., 2019).
- Value Added Index – (VA_i) denotes the mapped value of the sum of all times adding value to the final product. Compared to the value-added index, it is also possible to observe the non-value-added index, which is the opposite and indicates a waste.

Fig. 1: Typical steps in VSM

- Inventory Turnover – is an annual figure indicating the number of annual orders/deliveries per year. This can also be calculated as the ratio between annual consumption and average consumption. It is one of the indicators of the efficiency of management systems (Minh et al., 2019)
- The number of process steps – (PPK) is the sum of the process steps adding value and not adding value. It is also used in conjunction with the percentage expressed process steps that add value in a nutshell ($PKVA_i$).

By mapping process, it is necessary to adhere to the set rules of VSM creation, Fig. 1 (Bhat et al., 2009):

- All participants must be informed in advance about the mapping and principles of VSM.
- Mapping is not only based on management but also individual operators in processes are an important source of information.
- Do not rely on established standards and map everything in real, normal conditions.
- Avoid the use of subjective and informal information.
- If the process branches into more parts, the value flow is first drawn and then the most important components are logically connected to it.
- Completion of the entire VSM map, as an incomplete state has low information value.

The map of the current state has an opportunity for evaluation and control. From the customer's request to the handover of the finished product to the customer, space is created to increase the efficiency of individual non-value-added processes and thereby improve value flow. To exploit the potential for improvement, industrial engineers focus on basic types of waste. The decrease and saving of inventories positively influence the increase of the value-added index. If the solution uses all possibilities to reduce inventory in production, then the next step is to try to use the principle of pull when the requirements come from the following process. By implementing these two steps, it contributes to a smooth flow in production (Straka and Malindzak, 2009; Grznar et al., 2019; Krajcovic et al., 2019; Straka et al., 2018; Duplakova et al., 2017; Paulscrap, 2018; Bangsow, 2015):

Before drawing up a map of the future, it is necessary to focus on a range of questions:

- What is the tact for the product group?
- Where can a continuous flow of material be introduced?
- Where is it possible to use a thrust warehouse?
- Which point in the production chain is the step?
- What improvements must be made to meet all the recommendations?

VSM modeling using TX Plant simulation software

The main goal of implementing the above-mentioned methods Value Stream Mapping is to create a dynamic model of map of the value stream in the production of the reference product and optimize the current state using the TX Plant simulation software. The partial goal was to point out the possibilities that dynamic optimization through computer simulation allows. The reference product is steel codes, the main component used to reinforce an automobile tire, Fig. 2.

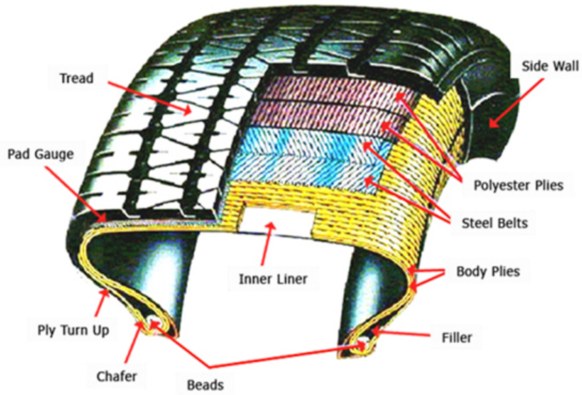


Fig. 2: Tire structure (Duplakova et al., 2017)

The production of cords consists of eight operations:

1) drumming (C/T = 1:15:00) – The input wire semi-finished on drums suitable for machines used in the production process.
2) crowding out (C/T = 4: 40: 00-4: 55: 00) – The blank wire is pulled to the desired fibre diameter and winded to the conveyor for the next process. Different diameters have different processing times, making the thinner the longer the processing time.
3) checking the diameter (C/T = 2:00) – Check the diameter with a high precision laser station. This check ensures the required quality of the entire length of the fibre.
4) cabling and splicing (C/T = 3: 10: 00-3: 20: 00/2: 15: 00-2: 25: 00) – production of cordless core, the fibres are machined by knitting on the machine to achieve the desired product.
5) coil packing (C/T = 6:00) – Coils should be wrapped tightly with a plastic foil to secure the cord against spontaneous rolling out
6) check Cords (C/T = 11:00) – Each coil comes to the final check where the specified length is cut

and tested their parameters.

7) pallet Packaging (C/T = 9:00) – Coils are stored on pallets and cardboard packaging is placed on top of the pallet.
8) shipping (C/T = 15:00) – The pallets are shipped to the customer according to the current orders.

The input information of manufacturing process is processed in Table 1. (cycle time, set-up time, availability and Mean Time To Repair). The input information was measured directly in the production plant used Gemba approach. View of the production hall is shown in Fig. 3.

Table 1
Input information of manufacturing process [own processing]

Process	Cycle time (DDD:HH:MM:SS.XXX)	Set-up time (MM:SS.XXX)	Availability (%)	MTTR (MM:SS.XXX)
drumming	1:15:00	0:00.0000	100	0.0000
crowding out	4: 40: 00-4: 55: 00	10:00.0000	95	5:00.0000
checking the diameter	2:00	0:00.0000	100	0.0000
cabling	3: 10: 00-3: 20: 00	10:00.0000	95	5:00.0000
splicing	2: 15: 00-2: 25: 00	10:00.0000	95	5:00.0000
coil packing	6:00	0:00.0000	100	0.0000
check cords	11:00	0:00.0000	100	0.0000
pallet packaging	9:00	0:00.0000	100	0.0000
shipping	15:00	0:00.0000	100	0.0000

Fig. 3: Production hall

From applying the value flow mapping method, it is very important to have the current situation correctly described. To this end, the current state map is compiled, which will later serve as a basis for identifying the waste and compiling the future state map. To compile a map of the current state it is necessary to monitor the material flow directly in the production. It starts at the expedition where the stock levels were evaluated, and further information was collected between the stocks between processes towards the material input from the supplier. To build a map of the current state, it is important to work with the most up-to-date data. The production observed can be referred to as a series production using a pressure system. It is therefore a production where work according to the order from the customer. The current state map is shown in Fig. 4.

The created map of the current state describes the individual processes, their course in production and provides information about each process such as:

- name of the operation,
- number of pieces processed in the process,
- working time in percentage,
- waiting time in percentage,
- number of pieces in between warehouses.

The map was based on information provided by employees or measured directly in production. Other information was documents and information about the supplier, the method of delivery and exact dates, but also the order of the material, the method of production management and planning, or the form of ordering the finished products.

The selected product group was supported by ABC nalysis, which determines the closely monitored group of four products and their production in the value flow map. The group of products under review includes the products referred to below as A30-2 + 1×0.30 / B28-2 + 2×0.28 / C30-2×0.30 / D28-4×0.28. The current state of production analyzed shortcomings and it is, therefore, necessary to propose an adequate solution for these bottlenecks due to the wastage in the production process, which does not add value to the customers. To achieve an optimal future state, the Kanban system was designed and implemented in the Tecnomatix Plant Simulation environment. The introduction of Kanban would reduce stock levels and eliminate downtime. Kanban cards are based on the pull principle and to ensure a smooth material flow, it is necessary to identify the weakest link in the production process, which is the Extraction_1 and Extraction_2 processes. This is because if the processes in front of these cells are faster, they will be built up before the slowest process of inventory, thus increasing the storage costs of work in progress. It is therefore necessary to introduce the principle of a move based on Kanban cards, Fig. 5. In Fig. 6 are output information from the simulation run of the current

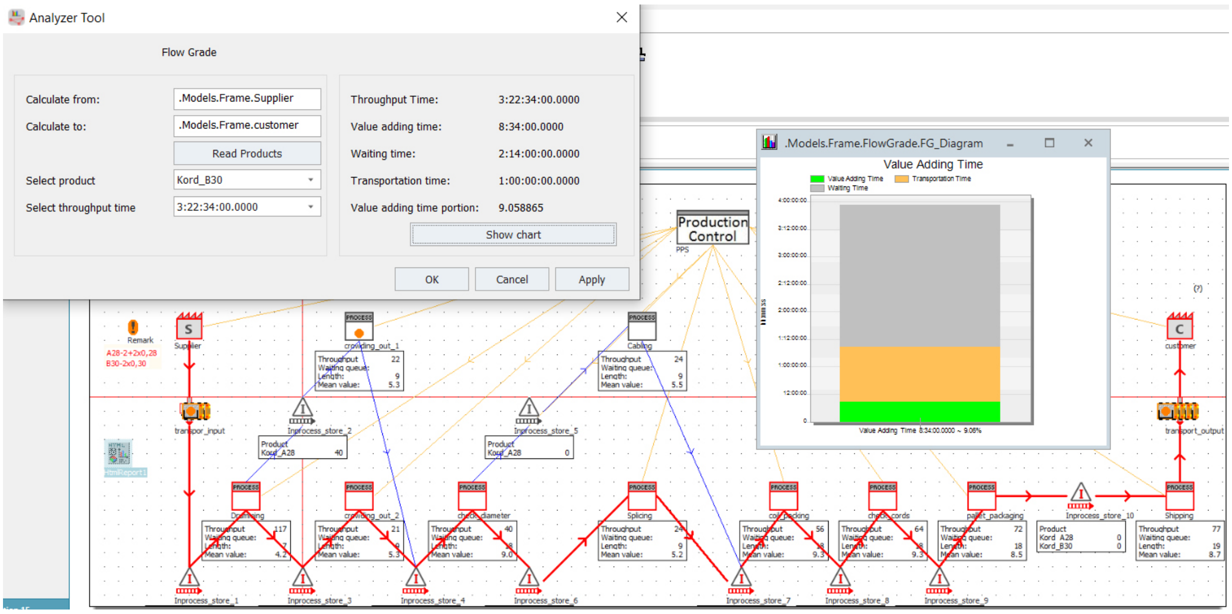


Fig. 4: Current state VSM map after simulation fun

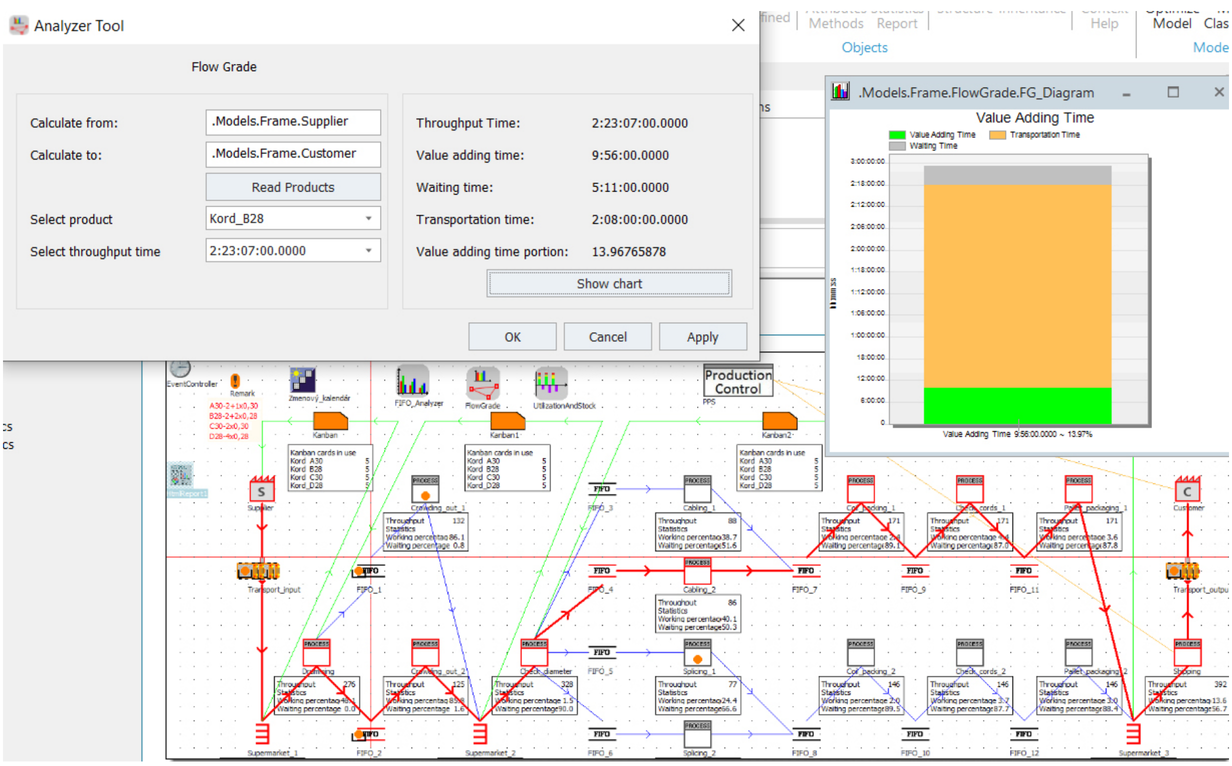
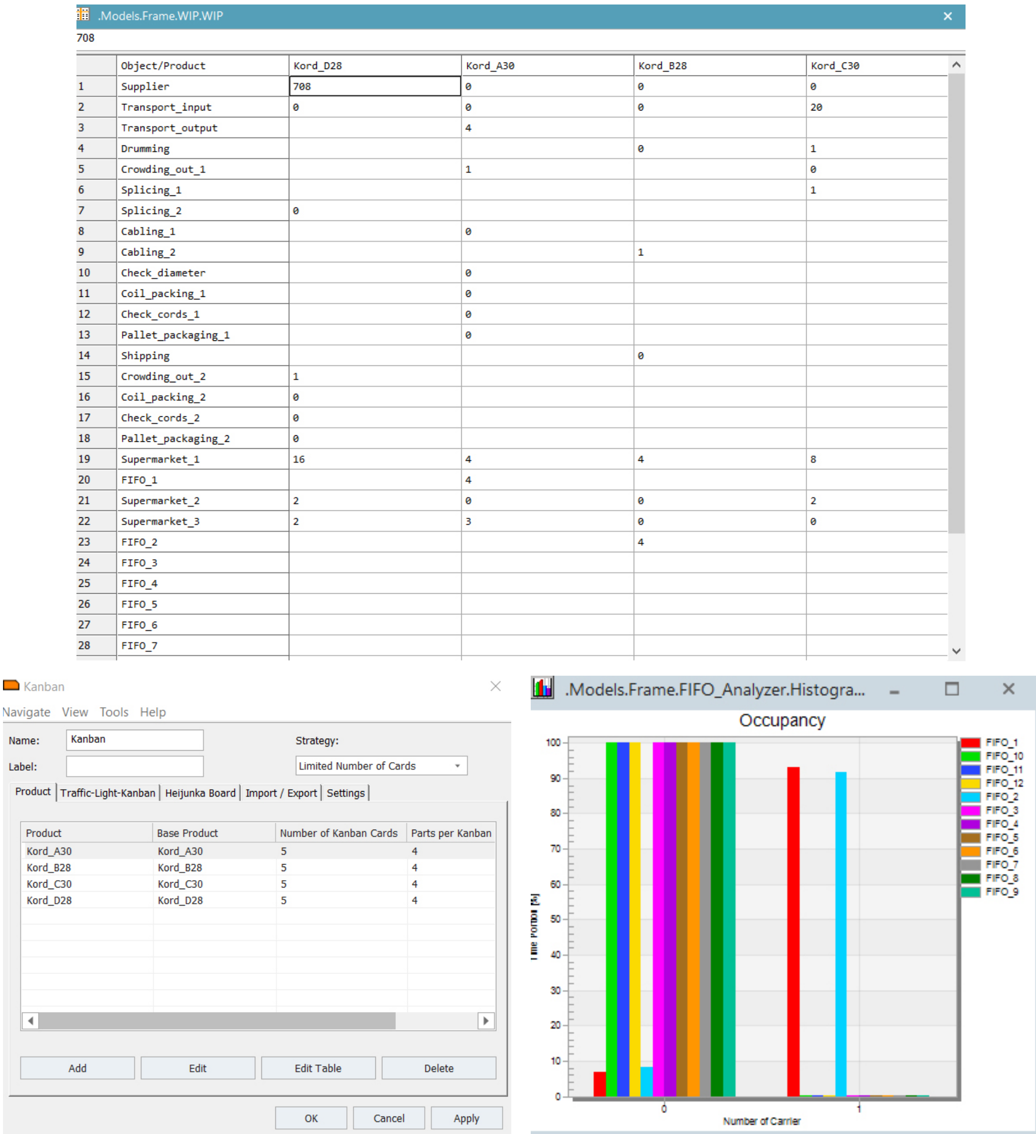


Fig. 5: Schema of the simulation model Value stream mapping process – proposal

and proposal model – WIP/Work in Progress, Kanban and FIFO analyzer. From the output statistics it is possible to subsequently suggest other possibilities for improving and increasing the productivity of the production process.

When Kanban cards are introduced, the workstations are more connected, because the Kanban system works by sending a Kanban signal from the last workstation and always sends a signal that the workstation can receive the stock. Kanban cards improved



	Object/Product	Kord_D28	Kord_A30	Kord_B28	Kord_C30
1	Supplier	708	0	0	0
2	Transport_input	0	0	0	20
3	Transport_output		4		
4	Drumming			0	1
5	Crowding_out_1		1		0
6	Splicing_1				1
7	Splicing_2	0			
8	Cabling_1		0		
9	Cabling_2			1	
10	Check_diameter		0		
11	Coil_packing_1		0		
12	Check_cords_1		0		
13	Pallet_packaging_1		0		
14	Shipping			0	
15	Crowding_out_2	1			
16	Coil_packing_2	0			
17	Check_cords_2	0			
18	Pallet_packaging_2	0			
19	Supermarket_1	16	4	4	8
20	FIFO_1		4		
21	Supermarket_2	2	0	0	2
22	Supermarket_3	2	3	0	0
23	FIFO_2			4	
24	FIFO_3				
25	FIFO_4				
26	FIFO_5				
27	FIFO_6				
28	FIFO_7				

Fig. 6: Output from the simulation run of the current and proposal model – WIP, Kanban and FIFO analyzer

the feedback and communication between production and management, improving the quality and speed of the information flow. They have also fallen in stock for work in progress and finished products, as semi-finished and finished products often remain in stock for a long time. The products thus bind capital, increase storage costs, and reduce inventory turnover. The production time is prolonged, which does not add value to the customer and wastes. With the introduction of Kanban, there was a reduction in stored stocks and the elimination of downtime. Thus, material and information flow have become smoother by application of the kanban system and the waiting time in stock has been shortened. This aligns processes and resources between supplier and customer.

Conclusions

The overall planning and organization of the future state simulation were very prolegomenous because it was necessary to carefully set up and interconnect all processes to show a situation that might occur in the future so that these processes have sufficient informative value. It is important that the simulation must be useful to the company and sufficiently evident for subsequent application.

Traditional static value flow analysis is expanded to include a critical time element of stock availability. Modelling and simulation of value flow allows create the dynamic fluctuations in daily production due to batch size, setting procedure, product changes, or other faults. It takes some important differences between traditionally made VSM and VSM made with software support, Table 2. Simulation software Tecnomatix Plant Simulation (Duplakova et al., 2017), discrete event simulation tool helps to create digital models of production and logistics systems and allows testing system performance and optimizing them.

Table 2
Differences between traditionally made VSM and VSM made with software support

Aspectr	Traditionally VSM	Software support VSM
time	static	dynamic
costs	low	higher
means	pencil and paper	computer and simulation software
product family	1 product	all products
analysis	most internal	most external
advanced analyses	no	yes
skills	analytical	analytical and computer
usable of model	once	reusable
clarity of model	low	high
rate of creation map	fast	slow
system and parameters changes	no possible	possible

VSM – Value Stream Mapping

With initializing the VSM Library in the frame area of TX Plant Simulation it is possible to creating and testing the value flow of all product families. Created digital models make it possible to create experiments and scenarios without disturbing existing production systems. Extensive analysis tools, such as the analysis of barriers, statistics and graphs allow evaluating different manufacturing scenarios.

At first glance, there may seem to be a great contrast between the implementation of lean principles and the introduction of industry 4.0 technology. Manufacturing processes within Lean Manufacturing are more standardized, more transparent and limited to the necessary work compared to other types of organizations. As a result, they are less complex and support the implementation of Industry 4.0 solutions (Fig. 7).

It is interesting, that the principle of Lean production is a relatively new practice for Russian companies. According to the source (Plakhin et al., 2019),

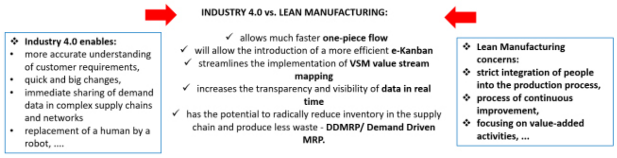


Fig. 7: Industry 4.0 vs Lean

the introduction of Lean production systems into Russian reality began in 2000. The main reason given is that domestic companies, starting with the state of the economy and mentality, cannot use foreign experience without change. Industry 4.0 technology intensification are tools that increase the flexibility, efficiency, and performance of manufacturers. Just simply convert paperwork instructions to digital, increasing the speed, accuracy, and addressability of information. However, the impact of Industry 4.0 on companies using Lean production principles has not yet been sufficiently explored. Nevertheless, it can be stated that the combination of principles, methods, and tools of lean manufacturing with information and communication technologies from Industry 4.0 already has a high potential in the present and soon.

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