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ONLINE E-KANBAN SYSTEM IMPLEMENTATION IN A MANUFACTURING COMPANY

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Abstract
The article's goal was motivated by achieving the implementation of the continuous improvement process in the company in terms of establishing selected lean methods, techniques, and principles. The proposed methodology based on an expert approach makes it possible to find variant solutions and approach the optimization process according to the selected criteria and the implementation of such optimized solutions. The mentioned approach is based on modelling and analysis of Value Stream Mapping, detection, and optimization of the *OEE* indicator within the framework of specific projects taking place in the company, up to the introduction the online Kanban. This will ensure the achievement of the company's targeted goal in productivity and efficiency. The verification of the proposed methodology is processed in a case study of the project of the production of steel structures of car seats in a specific company. Part of the output is also an economic evaluation of the impact of implementing the online Kanban and the algorithmizing of this process for successful and quick application in practice.
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Key Words: VSM Analysis, e-Kanban, Algorithms, Process, Project

1. INTRODUCTION

The mentioned study presents a methodology that can be applied to companies that want to implement the Kanban system to ensure high production efficiency. Since Kanban only works with zero error tolerance of flows, processes, and production, it focuses on the issue of inventory management, storage, picking or. elimination of waste in this area, it is necessary to emphasize this side. The works [1, 2] are focused on a system of quality analysis about costs, which is intended to ensure high quality and efficiency of business processes from the point of view of ensuring the process of continuous improvement and making qualified managerial decisions in this context. Closely related to this is the work [3] focused on the production process with the support of modelling and simulation, which is currently one of the ways to quickly find and test variant solutions even in a virtual environment and direct implementation into reality without interventions and losses in production. Since Kanban, VSM/Value stream mapping, etc. belong to lean management techniques, it is necessary to consider the synergy of these simple tools in the context of digitization, or Industry 4.0, which is processed in the work, or simple modelling methodologies [4-6] are presented. The knowledge was used in the creation of the proposed methodology and is the knowledge base for finding managerial decisions. Weflen et al. in the study [7] mention another fact that increases the quality of managerial decisions, i.e., introducing decision-making and predictive expert systems to increase user confidence in such automated systems. It is necessary to understand the factors from the level of experts or managers, which influence forecasts or recommendations, and the ability to perform analysis of several scenarios and thus arrive at the optimum. When switching to the so-called smart production supported by smart logistics, it is first necessary to electronically record data, organize, complete, and create software information network using software support, which will create the ability to manage and coordinate all production and non-production operations – production, logistics, quality control, maintenance, etc. [8-11]. This information and communication system will make it possible to receive and process information in real time and solve the necessary measures. The aim is to create a computer-connected intelligent logistics network of the production process, which will create added value through communication between relatively autonomous entities, and thus achieve speed, flexibility, and quality of value stream. The convergence of the physical world with the digital world is currently a new paradigm of an autonomous and decentralized world of production [12-15].

2. MATERIALS AND METHODS

Each Kanban implementation project is generally a unique project that must be designed according to the exact requirements, production, and logistics potential of a particular company. It is necessary for the company to create a Kanban team that will fully devote itself to specific steps within the project, which is also proven in the article. In this sense, the design of a general model for the introduction of Kanban is challenging and needs to be tailored. Within the framework of implementing Kanban, it is necessary to carry out specific analyses, e.g., VSM, monitor equipment utilization through *OEE* (Overall Equipment Effectiveness) and use methods, or techniques that provide detailed planning with a time dimension, e.g., Gantt chart, etc. The proposed methodology (see Fig. 1) was built on these principles and successfully verified in a specific company, which is shown below. It is based on an expert approach, which makes it possible to arrive at variant solutions and then achieve the required optimum according to the chosen criteria and introduce it into corporate practice.

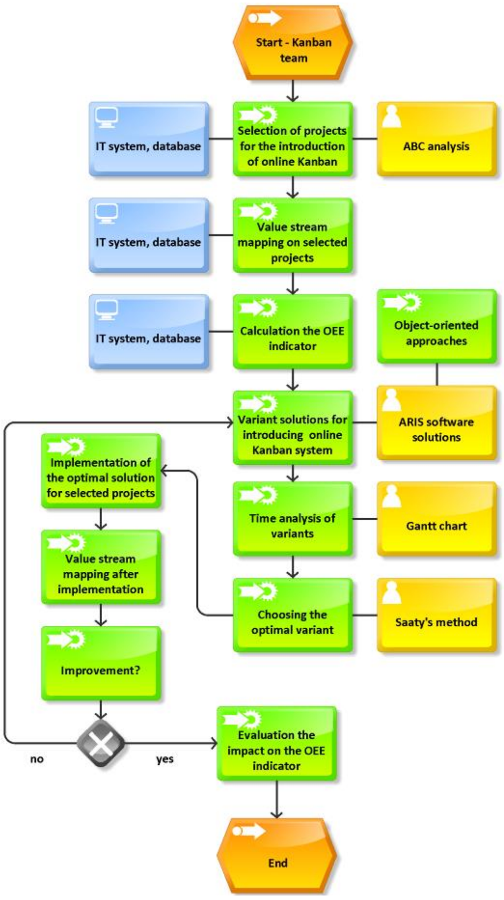

Figure 1: Methodology proposal for the implementation of the online Kanban system in production practice.

Kanban is strictly oriented towards the demand of relatively small production/transport batches, it mitigates the impact of the so-called Bullwhip effect, which is one of the major challenges in supply chain management. Kanban is suitable for slight fluctuations in demand and ensures high quality products and delivery times. Flexible modifications of working hours are appropriate, as labour capacity should be coordinated according to actual production needs. In the traditional Kanban system, replenishment is oriented through the state of the tanks, the introduction of information and communication technologies will enable the monitoring of the state of the stocks in real time. Instead of signalling material requirements via cards, resp. containers, these can be digitized using CPS/Cyber Physical Systems. This is the introduction of the so-called smart storage tanks (iBin), which increase the flexibility of the supply system. Necessity for the implementation of online Kanban/JIT/Just in Time is transparency of information, accuracy of planning and coordination of transport processes [16-20]. The case study used the VSM which is effective in analysing processes and identifying all types of losses that need to be subsequently eliminated by applying appropriate methods and techniques. The authors point out the potential of this methodology in their works and to the overlap of several methods that can be used in the analysis and detection of losses and bottlenecks (*OEE*), ecological effect, etc., which were also used in the case study [21-24]. The implemented case study used the VSM, which is effective in analysing processes and identifying all types of losses that need to be subsequently eliminated by applying appropriate methods and techniques. The authors [25, 26] made opinion that the computer simulation using a hierarchy structure is a fundamental approach for current trend, leading to the design of "digital twins". A "digital twin" represents a virtual copy of a real production, while the real system is continuously monitored and observed with its output, running and input data. A similar approach is used within every simulation, but the data are not transferred in real time but with some delay, meaning lag in verifying the data in practice. Process flow diagrams in case study are processed using the ARIS methodology [27].

3. CASE STUDY

3.1 Identification of strategic company projects for the needs of online Kanban system design using ABC analysis

The introduction of the online Kanban system is implemented on selected strategic projects of the company, focusing primarily on the projects that are most profitable and where increasing efficiency and reducing costs will have a significant impact on profits. ABC analysis, based on the Pareto principle, is used to identify relevant projects. The evaluation criterion is defined as the amount of turnover for a specific year, which represents the value equivalent of sales. The total turnover of the company for the monitored year represents a value of over € 1.500.000 (due to the sensitivity of the data, it is not possible to state their fair values).

Table I: Distribution of projects according to ABC analysis based on the criterion of annual turnover.

Project	**Annual turnover** [%]	**Cumulative annual turnover** [%]	**Group**
L405	27.99 %	27.99 %	**A**
X61	24.80 %	52.79 %	**A**
D7	22.13 %	74.93 %	**A**
C520	7.28 %	82.21 %	**B**
B515	4.63 %	86.84 %	**B**
X152	3.48 %	90.32 %	**B**
B3B4	2.83 %	93.15 %	**B**
9X1	2.31 %	95.46 %	**B**
EVO	2.07 %	97.54 %	**B**
A9	1.27 %	98.81 %	**C**
C8	1.19 %	100.00 %	**C**
∑	**100.00 %**		

The order of projects is given in Table I in descending order based on annual volumes; the cumulative annual turnover is also given. The annual turnover of projects L405, X61 and D7 represent approximately 70 % of the total turnover of the analysed company. These projects are classified in group A. With approximately 20 % of annual turnover, project C520, B515, X152, B3B4, 9X1 and EVO are classified in group B. Group C, where the annual turnover represents less than 10 % of the company's total turnover, consists of projects A9 and C8 (see Fig. 2). The current status of the identified projects was analysed using the VSM.

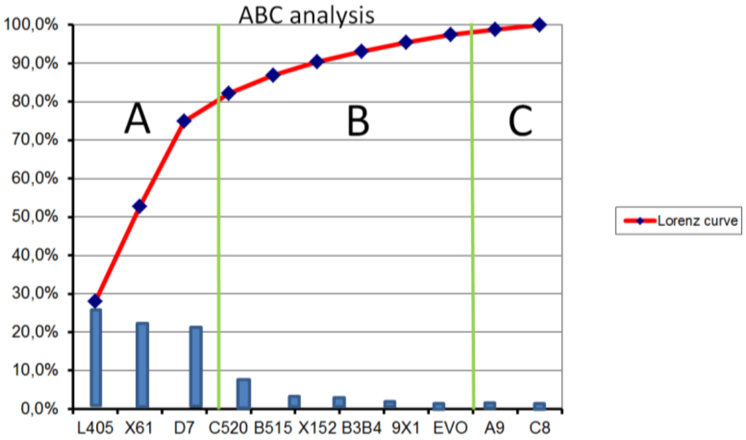

Figure 2: Graphical representation of ABC analysis.

3.2 Analysis of selected project D7

Project D7 represents the production of rear structures of steel structures of car seats. In the JIT plant, the final assembly of the car seat takes place, i.e. the assembly of plastic components, foam and upholstery parts and the eventual electrification of the car seat, depending on the variant and the requirements of the end customer. The D7 project identifies several types of car seats. The structures differ conceptually depending on the design of the car, the so-called car body. The first step in the implementation of the VSM method is the identification of the product representative of the product group, which in this case is represented by the supports of the D7 project. For the needs of identification of a suitable representative, a process/product matrix is created (see Table II).The current status of the identified projects was analyzed using the VSM (Value Stream Mapping) method, focusing on the production flow to define total product production times and times that contribute to value creation, to identify opportunities to improve supply flow production lines.

Table II: Process/product D7 matrix.

		PROCESS				
		Pressing	Bending	Welding	Painting	Assembly
PRODUCT	X260 40 RH		X	X	X	X
	X260 40 LH		X	X	X	X
	X760 40 RH		X	X	X	X
	X760 20			X	X	X
	X760 40 LH		X	X	X	X
	X760 100	X	X	X		X
	X260 100	X	X	X		X
	X761 40 RH			X	X	X
	X761 20			X	X	X
	X761 40 LH			X	X	X
	L560 20			X	X	X
	L560 40 LH		X	X	X	X
	X260 SB		X	X		X

From the process point of view, the X760 100 type backrest appears to be a suitable representative, as the production of this variant goes through more than 80 % of all process steps. Attention will be focused on the specific input material from its order from the supplier to the shipping process, where this input material is already part of the finished product. In this case, it will be a seamless cold-rolled tube which is one of the first components entering the production process of the X760 100 backrest. Product representative, the cold rolled tube is shortened to the required size at the supplier. Deliveries are made weekly, using returnable stackable packaging. The production process itself consists of seven processes, between which stocks of work in progress are created. The first process is the pressing process. Specifically, it is a reduction in the diameter of the pipe at its ends at a specific production facility. Between the pressing process and the next pipe bending process, stocks of pressed pipes of 330 pieces are accumulated. The process of bending pipes using CNC bending follows. During this process, the pipes are removed from the hopper using a robotic arm and the pipes are automatically fed into a CNC bending machine, where the required bends are realized. Subsequently, the pipes are automatically removed from the bending machine and transported and stored in transport boxes used for internal logistics. Since the CNC bending machine bends the pipes for several projects, the machine is sorted, while the production batch of the product representative for the D7 project is 180 pieces. The bending process is followed by the process of pressing the pipes in a specific production facility. After pressing, the tubes are stored in the supermarket. From the supermarket, the pipes are transported to the welding machines via internal logistics. Bent pipes as well as other components are joined into structures by robotic MAG welding. The robotic welding workplace also has two associated workplaces. First, a visual inspection of the support is performed and, in the case of identification of the NOK weld, its manual repair. This is followed by the inspection workplace, where a visual inspection of each weld is performed as well as a physical measurement of the support using a jig designed for this purpose. gauge. After welding, the supports are transported for assembly.

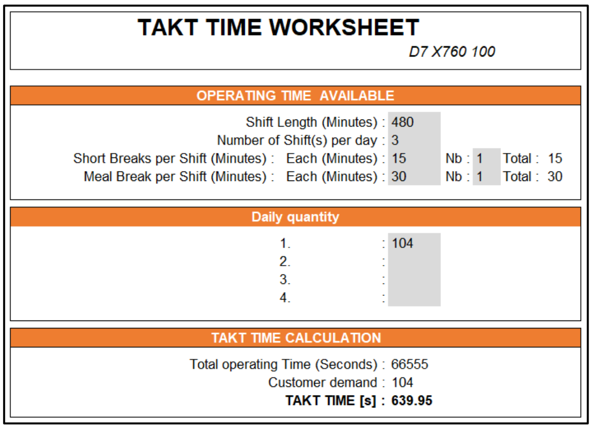
TAKT TIME WORKSHEET
D7 X760 100
OPERATING TIME AVAILABLE
Shift Length (Minutes) : 480
Number of Shift(s) per day : 3
Short Breaks per Shift (Minutes) : Each (Minutes) : 15 Nb : 1 Total : 15
Meal Break per Shift (Minutes) : Each (Minutes) : 30 Nb : 1 Total : 30
Daily quantity
1. : 104
2. :
3. :
4. :
TAKT TIME CALCULATION
Total operating Time (Seconds) : 66555
Customer demand : 104
TAKT TIME [s] : 639.95

Figure 3: Calculation of takt time D7 X760 10.

Table III: VSM analysis output for the project D7.

Comparison	Hours	Days
Production Lead Time	379.35	17.4
Value Added Time	0.42	0.0193
Ratio between Value Added Time and Production Lead Time	0.11 %	

As in previous analyzes, the first step of the VSM method is to calculate the takt time. Based on the calculation, the takt time for project D7 X760 100 is 640 s (see Fig. 3). Mapped flow of values for project D7 X760 100 is shown in Fig. 4. It follows that the total production time of one piece of the backrest is 379.11 hours, while the activities generating the values are only

0.42 hours (see Table III). The ratio of the total time to the time during which the product representative becomes a part of the finished support is 0.11 %.

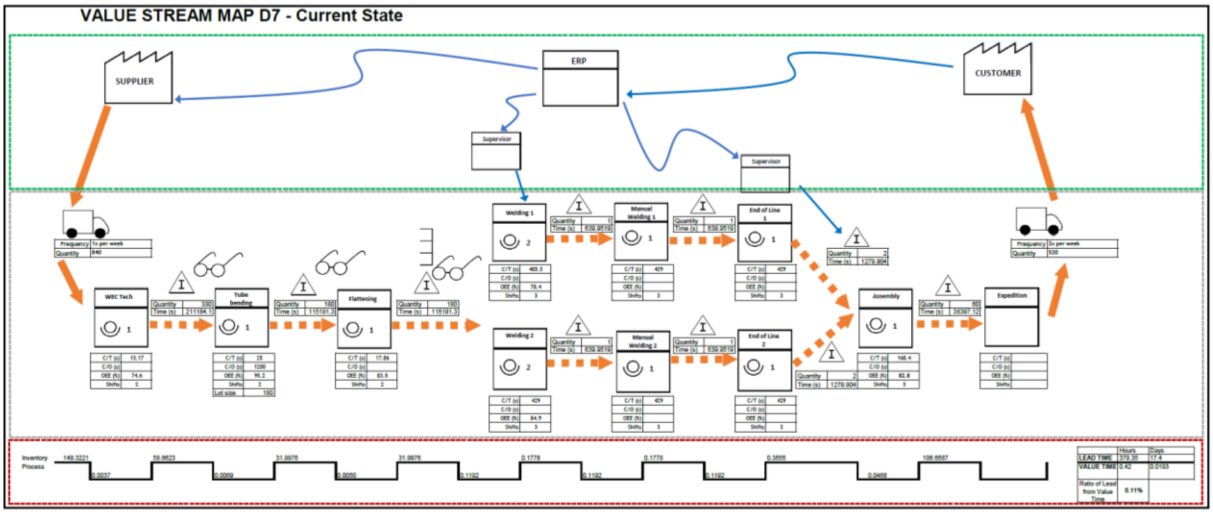

Figure 4: Value stream map for project D7 – current state – schematic representation.

The welding station represents a bottleneck in the process due to the longest production time. In addition, in this process, production equipment failures and various qualitative downtimes often occur. Because no safety stock is created between the assembly site and the welding site, these downtimes also affect the *OEE* of the assembly station. *OEE* model is given in Fig. 5. Based on the graph in Fig. 5 it can be stated that the assembly workplace achieves the required performance and quality, but the problem is the availability of equipment due to the frequent lack of inputs from the previous welding station.

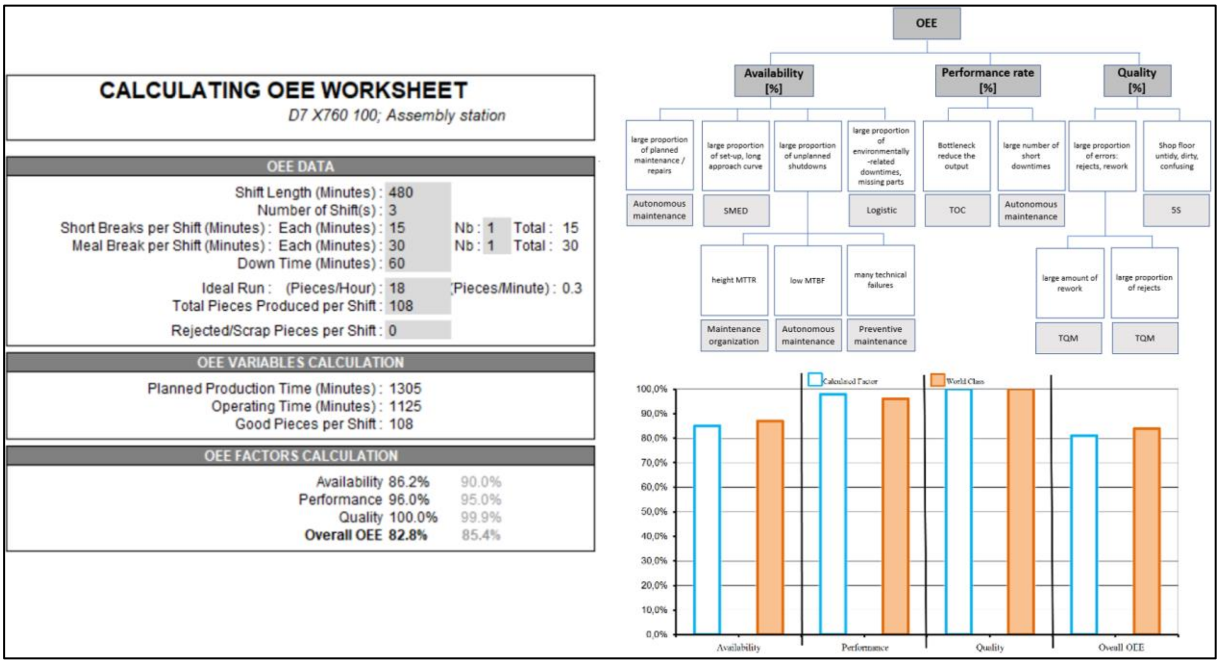

Figure 5: *OEE* calculation for assembly station and graphical representation compared to WCM.

3.3 Implementation of online Kanban system in a manufacturing company

The next part will be the comparison of individual variants of the implementation of the online Kanban system using Saaty's method of multicriteria decision-making and the choice of the optimal variant from the proposed options. It is a pairwise comparison method that is used for multi-criteria evaluation of criteria and variants. The goal is the analysis and solution of decision-making tasks, where the director selects the variant that best meets the set goal. The solver must define variants and criteria and then compare the criteria and variants in pairs and determine their preferences and the weight of the preference. The calculation will be solved by applying the principle of maximization. The following will be considered as criteria for comparing variants: Time criterion, Labor force criterion, Risk criterion, Digitization degree criterion. The following is a summary of calculations and calculations of the overall usefulness for individual variants of the online Kanban system design in Table IV.

Table IV: Calculation of total utility for individual variants.

		Variant A		Variant B		Variant C		Variant D		Variant E	
Criteria	Criteria weight	Usef.	$A \times U_{ij}$	Usef.	$A \times U_{ij}$	Usef.	$A \times U_{ij}$	Usef.	$A \times U_{ij}$	Usef.	$A \times U_{ij}$
Manpower	0.372	0.34	0.12	0.06	0.024	0.18	0.067	0.16	0.061	0.26	0.095
Time	0.195	0.12	0.024	0.10	0.020	0.07	0.014	0.25	0.048	0.45	0.088
Risk	0.197	0.16	0.032	0.10	0.019	0.07	0.014	0.67	0.132	0.02	0.003
Degree of digitalization	0.236	0.02	0.006	0.26	0.061	0.16	0.038	0.34	0.080	0.21	0.050
Overall usefulness U_j (stability index)	1.00	-	0.19	-	0.12	-	0.13	-	0.32	-	0.24

Note: Usef. is used for the Usefulness.

Based on the quantified overall usefulness resp. stability index, it can be stated that the optimal variant is considered to be Variant D with the highest value of overall utility. In Option D, the creation of a functional and design structure is considered as a separate stage, similarly to the other variants being compared. However, attention can be paid to the following stages of the proposal, which are: Creation of infrastructure, Software development, Digital model creation.

As another alternative in terms of overlapping the individual stages in the implementation of online Kanban, it is possible to consider the stage of infrastructure development, the stage of software development and at the same time the stage of digital model creation as parallel activities, Fig. 6. With Option D, there can be a significant time saving when booting the system. An obvious disadvantage is a possible increase in the need for human labour if we assume that the same staff in the field of computer technology is responsible for the software development stage and the digital model creation stage. The increasing need for human labour ways increases the cost of the overall implementation of the system. It is, therefore, necessary to quantify the benefits resulting from the earlier introduction of online Kanban and compare them with the total costs associated with the implementation of the system. The following phases of testing follow each other and therefore they cannot be performed in parallel. After a successful test operation, it is possible to create manuals for the needs of knowledge and control of the software solution, and subsequently, the system can be used in a standard production operation. In Variant D is considered with the same beginning for the infrastructure development stage, the software development stage as well as the digital model creation stage and thus with their intertwining. However, in such a solution, it is necessary to consider the significantly increased need for specialists in the field of computer technology for the implementation of the project, which will affect the total cost of the project. However, the benefit is the completion of the online Kanban system implementation project in 11 working days. It takes 104 working days to implement the online Kanban system according to Variant D. Gantt chart for Variant D project phases is shown in Fig. 7.

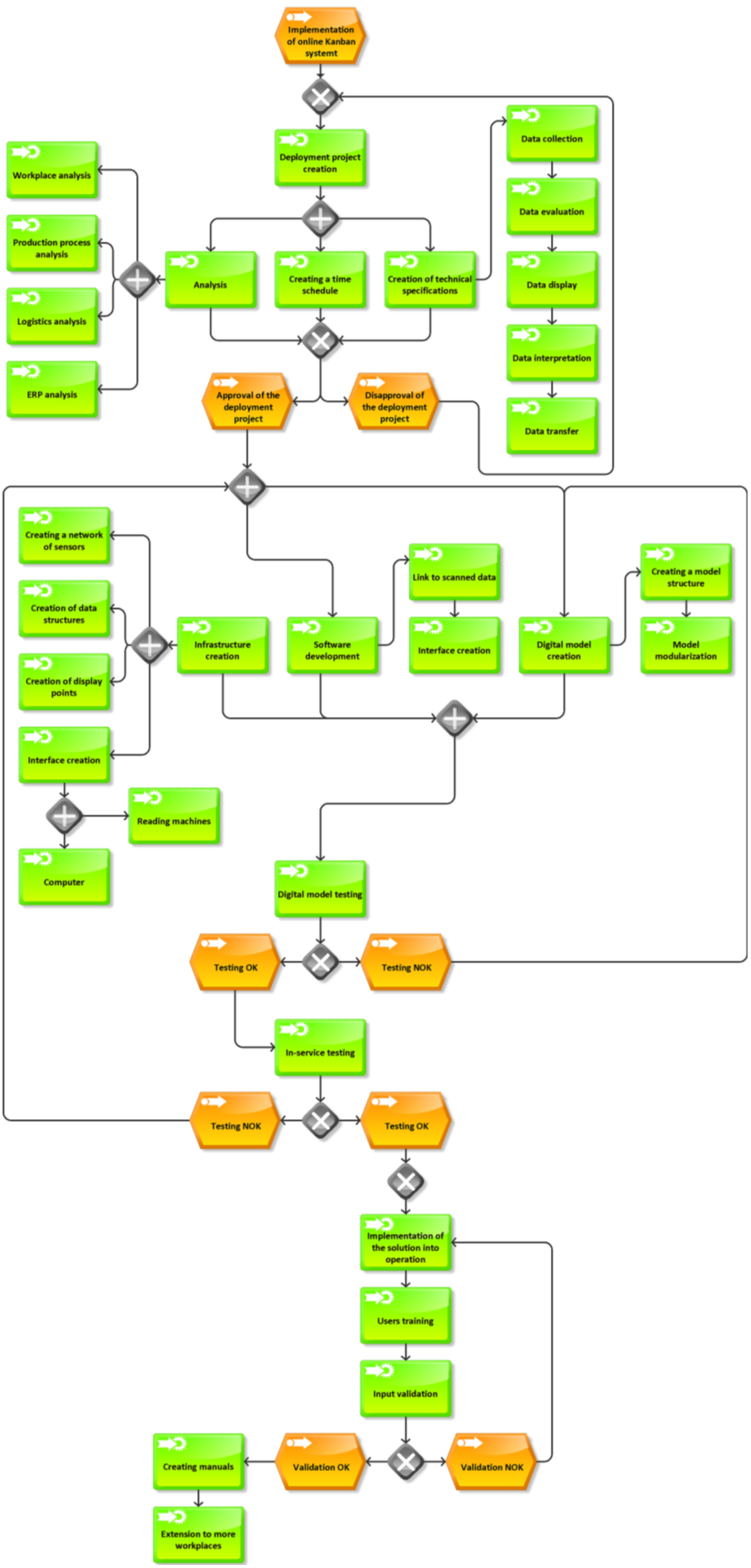

Figure 6: Proposal for the introduction of the online Kanban system Variant D.

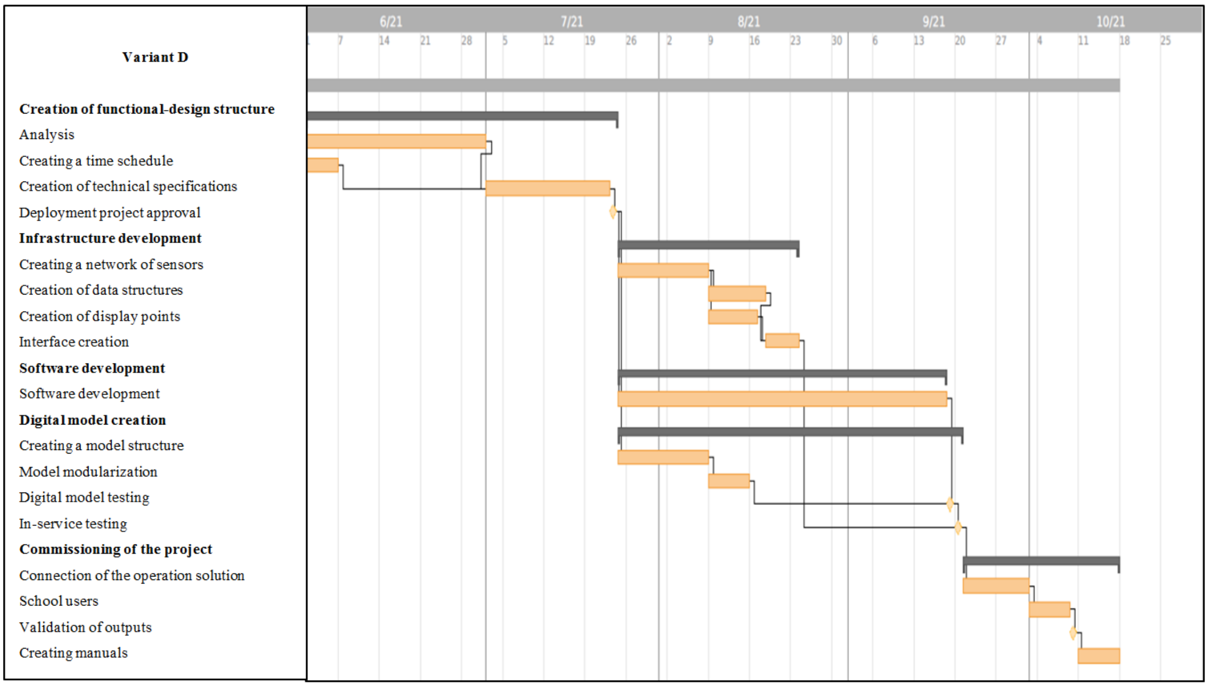

Figure 7: Gantt chart for Variant D.

4. RESULTS AND DISCUSSION

4.1 Analysis of the D7 project after the implementation of the online Kanban system

On the D7 project, it is possible to minimize the stocks of unfinished pipes arising between workplaces of pipe diameter reduction, pipe bending and pressing (see Table V). The stock is also reduced in the supermarket belonging to the bending area, from where the pipes are distributed to production. Project D7 is a specific project in which there is an increase in stocks between welding and assembly workplaces compared to the established inventory reduction Trent. As in previous projects, the MAG welding workplace is critical in terms of the availability of production equipment due to either technical failures or the availability of equipment is affected by the quality of input components. Since the stock between the welding workplace and the assembly workplace was set to 4 pieces, due to downtimes at the welding workplace, there were also downtimes at the assembly workplace. After the introduction of the online Kanban system, it is assumed that the stock will be set to at least one hour of production at the assembly site. Ultimately, the *OEE* indicator is expected to improve at the assembly site.

Table V: Expected VSM output for project D7.

Comparison	Hours	Days
Production Lead Time	206.56	9.5
Value Added Time	0.42	0.0193
Ratio between Value Added Time and Production Lead Time	0.20 %	

After the introduction of the electronic Kanban system for the D7 project, it is possible to state the reduction of the production lead time to 206.56 hours and the increase of the ratio of the production run time to the time value to 0.2 %.

Table VI deals with the comparison of continuous production times, times actually contributing to value creation and their ratios. This results in an improvement of the value stream on the project by 27.93 % for the L405 project, and up to 40.51 % for the X61 project. The most significant improvement can be achieved on the D7 project, up to 63.64 %.

Table VI: Comparison of value stream map outputs before and after the expected implementation of the online Kanban system.

Variant D7					
Comparison	**Current state**		**Future state**		**Improvement**
	Hours	**Days**	**Hours**	**Days**	
Production Lead Time	379.34	17.4	231.45	10.6	38.99 %
Value Added Time	0.42	0.0193	0.42	0.0193	0 %
Ratio between Value Added Time and Production Lead Time	0.11	-	0.2	-	63.64 %

4.2 Application of *OEE* in the process of implementing online Kanban system

During the analysis of the value stream mapping in Chapter 2, attention was also drawn to the *OEE* indicator, which was separately quantified for each production facility on projects L405, X61 and D7 based on available data. *OEE* at assembly stations is on average 90 % in the analyzed production company. During the mapping of the value stream before the expected introduction of the online Kanban system on the D7 project, 82.8 % of *OEE* was identified at the assembly station. Based on the data, it can be stated that the value of *OEE* is influenced mainly by the availability of production equipment (Fig. 8). Before the assembly site, the current state of stocks was not sufficient for the smooth operation of the assembly station. The reason for the insufficient stock is mainly the frequent failures of the welding workplace and downtime at the welding workplace due to the poor quality of the input components, as evidenced by the value of *OEE* at the welding workplace.

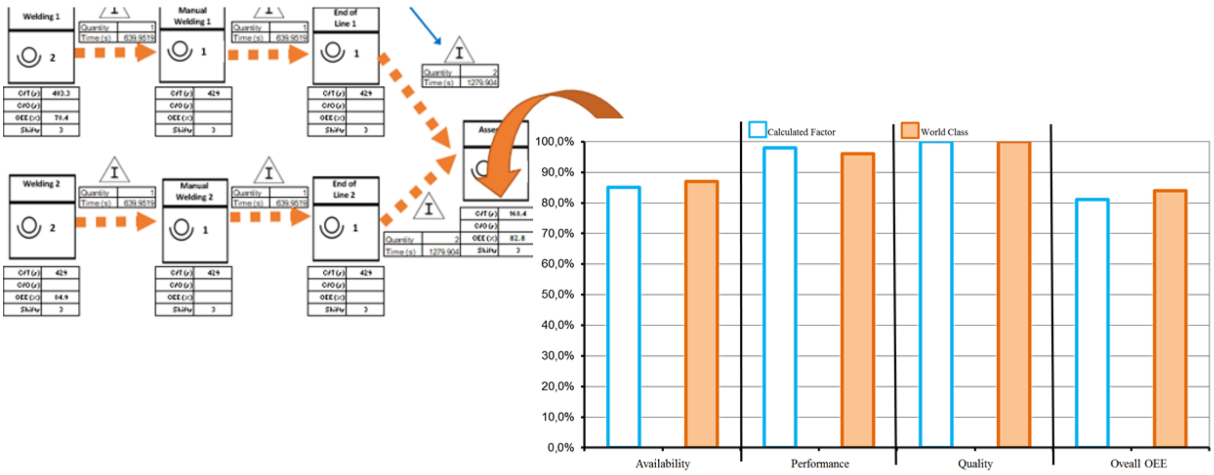

Figure 8: Detail of *OEE* assembly workplace for project D7 before the introduction of the online Kanban system – schematic representation.

4. CONCLUSION AND OUTLOOK

By implementing an online Kanban system, it is possible to set the optimal stock level before the assembly site, taking into account all the risks and specifics that affect the *OEE* value of the assembly site. The same assumption applies to all production equipment of the production process. Based on the analysis, it can be stated that when implementing an online Kanban system, it is necessary to examine and analyze the impact of online Kanban on the efficiency of the production facilities themselves evaluated by the *OEE* indicator, as stocks resp. the continuity of production affects the very availability of production equipment in the production process. In future it is possible to use simulation tools, e.g. from the Tecnomatix series, for creation the simulation model. It has the possibility of using lean tools in simulations such as

Kanban (KanbanSource, KanbanSingleProc, KanbanBuffer and KanbanChart), Value stream mapping, Flow control, etc. This is the way to test the assumptions for the relocation of processes and releases them only when all conditions are met. 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 evaluation of different manufacturing scenarios. The potential of digitalsation can be found in the context of logistics, especially in the decentralization and implementation of self-regulation of individual elements of production systems while increasing the efficiency of logistics processes as a whole through digital twin modeling and simulation.

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