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APPLICATION OF DIGITIZATION PROCEDURES OF PRODUCTION IN PRACTICE

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Abstract:
The paper addresses application of digitazation of production processes, which is part of organizational digitization, also known as Industry 4.0. It deals with modernization and optimization of production systems by creating models in simulation software via digital engineering. For our analysis, 8 real assembly lines were used, with an average of 15 workplaces, which were integrated into one universal line by means of simulation. The aim of our research was to create a digital twin of the real assambly lien and to analyse effectiveness of the proposed modernization universal assembly line using the generated statistical data.

Key words: *digitization procedure, digital twin, Industry 4.0, Tecnomatix Plant Simulation (TPS), assembly line*

INTRODUCTION

Competitive market pressures on shorter innovation cycles, lower prices, more complex products, increased flexibility, individualized production or productivity are constantly increasing. Therefore, at the early stages of designing process, virtual prototyping methods are used, which enable the assessment of the adaptation of the future object to the forces and loads to which it will be exposed [13]. Further, as a result, new tools for optimization of production processes, increased flexibility in change management and dynamic production are developed [3]. Digitization of production according do the concept of digital organization is a tool to increase competitive advantage and flexibility of organizations, which fully utilizes information-communication technology [11]. A digital organization is a desired state of an organization in Industry 4.0, where all organizational processes are digitally interconnected and managed. This is possible through a so called SMART process via which organizations digitally communicate with customers, suppliers, and the external environment, using SMART networks, SMART buildings, and SMART logistics and produce SMART products.

Simulation is the reproduction of a real system containing dynamic processes in simulation models. In a broader sense, simulation involves the preparation, implementation and evaluation of specific experiments using a simulation model. The model is a simplified replica of a planned or real system characterized by processes in another system. Tecnomatix Plan Simulation (TPS) is a simulation tool that helps create digital models for systems such as production to generate system characteristics and optimize performance. Digital models allow experimentation with scenarios without disturbing existing production. They can also be used in the planning process long before the changes are introduced into the production process [1, 2]. The Tecnomatix solution through simulations optimizes business processes that determine the ability to deliver products faster. Tecnomatix makes it possible to match production capacities with the proposed intent, from product development to delivery, to reduce the lengthy introduction of processes, thereby improving their quality, and ultimately increase company flexibility, market share and brand value [12]. Creating a simulation model is currently a major challenge for businesses that aspire to engage in modernization of their processes through the latest trend in enterprise digitization, Industry 4.0.

The article deals with optimization of processes running on assembly lines using the computer simulation method. The result of this thesis is the design of a universal line that can replace any of the existing eight lines. Simulation results are also expressed quantitatively, using statistical data that characterize effectiveness of the solution. The research is part of the KEGA 011TZ Z-4/2017 which deals with integration of progressive information technologies into education.

THE DIGITAL TWIN CONCEPT

Industry 4.0 encompasses broad changes that quickly enter the current manufacturing market. The bearer of these changes is digitization of products, digitization and optimization of all organizational processes, including services. The digital twin concept is a functional system of continuous optimization, which includes physical production together with its digital "copy". It creates an environment of digital organization, where the organization can optimize production directly as part of its production cycle, can change parameters and processes and adjusts products to market requirements. Data that is generated during this process form a complex picture about a given product and a production process. The digital twin will compile information and constantly analyses it [4]. This allows, among other things, for shorter and more effective cycles, to optimize production, to decrease the time required for production of new products, and highlights ineffective set up of processes or production by human resources [5]. Advantages of the digital twin:

- Use of existing production equipment, mechanisms, operations complimented by use of small components (i.e. sensors, optimizing software solutions) used for data collection and evaluation and immediate optimization.
- Increase in productivity of existing production equipment, ability to flexibly adjust to changes in product offerings and practically immediately produce in an optimized regime.
- Minimal investment with fast return on investment.
- Quick implementation.
- Increase in productivity, decrease in error rate, increased quality, and application of predictive maintenance decreases malfunction of equipment and thereby lowers expenses.

The digital twin concept can be used in production, warehouse or transportation logistics and in operations. The top left portion of Fig. 1 shows a concept model, which simulates not only a 3D shape, but also movements of the robot and basic steps of a drilling process. Based on the shown simulation study, we can confirm functionality of equipment – in the shown example we can drill holes with any angles, by holding in place a workpiece with the robot in any desired position – of a new or adjusted piece of equipment. Another use of the model is setting a timeframe for use and change. In a more detailed engineering phase, specific simulations of the process, as seen in the top right picture, develop program CAM for CNC equipment and calculate effects for the workpiece (e.g. quality), or a set of tools (e.g. sanding). Since conceptual models are always available via the digital twin technology, compilation of these models is easier. Additionally, consistency of operational processes is also validated. Repeated and continuous use of existing know-how is possible due to development and use of a production system. Therefore, all available data about a product are stored in the digital twin and are used for optimization of operations [8].

The best road to digital organization is data collection and evaluation. Today, organizations have a lot of data, however, they do not compile or evaluate it. To ensure that all necessary data is collected, which currently is not being collected is compiled, all is needed are simple sensors or a simple bar code reader and implementation of a primary software, which will collect and evaluate data. Hence, investment and difficulty of production can be minimal. Another important factor in every organization is communication and information sharing. As the organization digitalizes processes, collects and evaluates data, every employee has immediately access to all information required for their work [9, 10].

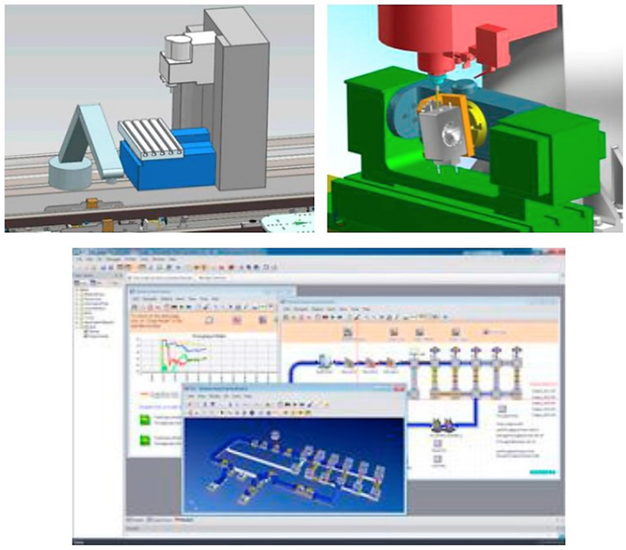

Fig. 1 Evaluation of concept, CAM simulation and production planning
Source: [8].

In our research we dealt with the optimization of processes on the assembly line. Simulation of assembly lines of our research in the TPS environment is an effective method for solving our research objectives aimed at analysing efficiency of the assembly line modernization. The simulation is performed in two models:

1. Original eight assembly lines where handling what is handled by standard conveyors.
2. A proposed line consisting of components of all eight original lines, where modernization is solved by incorporating robotic arms for manipulation.

Outputs of these simulations are resource statistics, from which we can determine the cost of individual workstations and thus determine the effectiveness of the solution. We can state that the simulated models of a real assembly line will become part of the digital twin assembly assembly in the analyzed enterprise in the future.

MATERIALS AND METHODS

To create simulation models, the real assembly lines used in the automotive company in Zvolen were used. Input data for line simulation was measured by cell authors in real assembly line operation. The basic input data that were considered in simulation modelling were: operation times of individual workplaces, transport time and assembly line speeds. The designation used in the article was changed for data protection purposes. The numbers of original assembly lines were eight. The optimization consisted of creation of a single universal line that would replace its original line of business. When designing a universal line, elements of all eight lines were taken into account by the assignor's request. Prior to creation of a universal line, a line similarity analysis was performed to show which lines contained identical workplaces. For transport of materials between workplaces in the original lines, conveyors required for the standard were used. In optimized models, we used robotic arms that meet the requirement to move workpieces without input from a person [6, 7]. Since the proposed solution is hypothetical, aimed at increasing efficiency and generating a universal line model, we did not consider counting the investment costs of creating a new line at this step.

DESCRIPTION OF THE SIMULATION PROCEDURE

Here is how to simulate one of the eight original lines as an example of the solution. Before that start of the assembly line model, it was necessary to collect necessary data, such as, workspaces, times of operation, time of transport, used assembly components their amount, etc. After obtaining the data, we proceeded first with the simulation step to create a visual distribution of the model elements representing a simulated line (Fig. 2). For better clarity and simpler work, we named individual elements. The layout in Fig. 2 shows elements of the individual operating stations *(LF1, R2 – R15. LF11 LF16)*, the conveyance of the material by means of conveyors *(Line, p1 – p26)* and rotary elements *(ot3 – ot8)*. Other elements shown are container *(Buffer)* and input – output pallets materials *(Drain).*

Specific features of the model are rotating stations that represent places where the flow of material is branched or hinged. We used the *Turntable* feature to display these elements. These elements were interconnected in order to build on the technological process. When the line model was ready, we defined the product in the MUs *(Moveable Units)* folder and then set attributes of the individual model elements:

- Conveyors – the length and the speed at which the material is transported from one workstation to another.
- Rotary elements of conveyors – the length and speed at which they are rotated to continue the material flow.
- Workstations *(Singlproces elements)* – individual operating times.

The *EventControler* element has been given time to run the simulation process. In this case, a simulation process was carried out to produce 750 pieces of stems, i.e. of one production batch. After the simulation started, the material flow was shown, simulated models were dynamically moved products *(MUs)*. At the end of the simulation time, basic statistics were also displayed via TPS.

OPTIMIZED UNIVERSAL ASSEMBLY LINE MODEL CREATION

To design the optimized universal assembly line, we proceeded according to the procedure in previous chapter. We incorporated into the proposed model all workstations that we identified in the line similarity analysis. This analysis identified identical workplaces of each of the eight lines that became part of the universal line. In optimized models, we used robotic booms to transport the products that are able to meet the requirement to move workpieces without the presence of a person. Figure 3 shows the optimized line model.

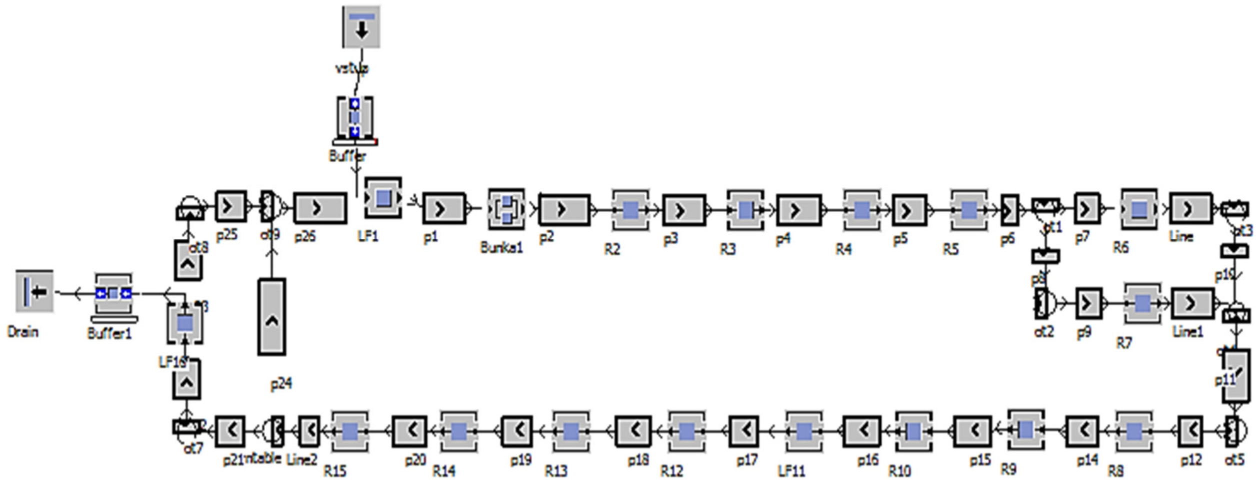

Fig. 2 The simulation model of original assemble line

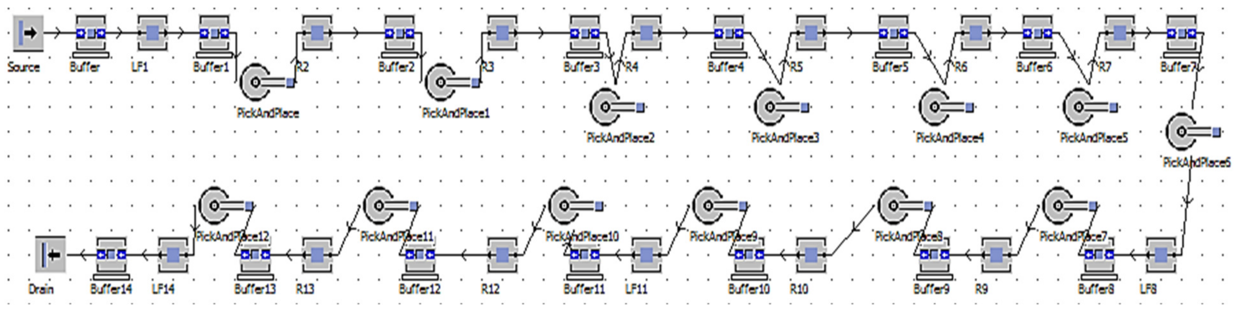

Fig. 3 The simulation model of the proposed line

RESULTS AND DISCUSSION

The TPS environment also provides opportunities for displaying source statistics in the form of column graphs. For graphs for workstations, we use the *Chart* tool to show workloads and resource statistics. Graph 1 (Fig. 4) and Graph 2 (Fig. 5) present percentage working, waiting and blocking for each workstation of the original line and proposed line.

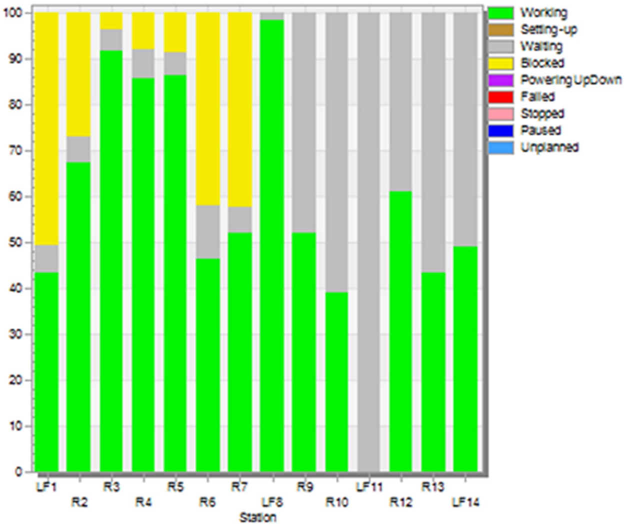

Fig. 4 Resource statistics of original line

More graphic tools are used to get more detailed statistics. Another option to obtain detailed statistics of individual sources in TPS is to use the *Method* tool. An example of the use of this method is shown in Fig. 6. *SimTalk* simple programming language was used to apply the method.

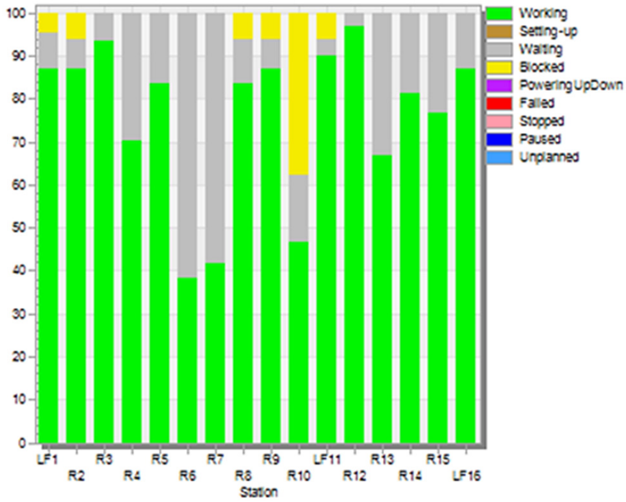

Fig. 5 Resource statistics of the proposed line

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is
do
    statistiky [2,1]:= LF1.statworkingportion*100;
    statistiky [3,1]:= LF1.statwaitingportion*100;
    statistiky [4,1]:= LF1.statnumout;
    statistiky [5,1]:= LF1.statemptymu;
    statistiky [6,1]:= LF1.statworkingtime;
```

Fig. 6 Method for statistic data in SimTalk

Detailed statistics of individual sources in the TPS environment using the *Method* tool (described at Fig. 6) are shown in Table 1 and Table 2. Advantage of obtaining detailed statistical data from simulation model is that they give a precise overview of performance of individual line work at a given production batch, which in our example represented 750 products [12].

Table 1
Statistical data for the original line

	string 1	real 2	real 3	integer 4	time 5	time 6
string	Pracovisko	Working [%]	Waiting [%]	Exit	Empty	WorkingTime
2	R2	86.84	7.03	750	3:56.7821	3:15:00.0000
3	R3	93.51	6.49	750	7:16.9093	3:30:00.0000
4	R4	70.14	29.86	750	5.3579	2:37:30.0000
5	R5	83.50	16.50	750	2.9611	3:07:30.0000
6	R6	38.41	61.59	375	22.0713	1:26:15.0000
7	R7	41.75	58.25	375	20.8745	1:33:45.0000
8	R8	83.50	10.19	750	6.8297	3:07:30.0000
9	R9	86.84	7.05	750	6.3750	3:15:00.0000
10	R10	46.76	15.38	750	10.7905	1:45:00.0000
11	LF11	90.17	3.81	750	13.1736	3:22:30.0000
12	R12	96.85	3.15	750	2:21.2729	3:37:30.0000
13	R13	66.80	33.20	750	5.9571	2:30:00.0000
14	R14	81.27	18.73	750	3.3606	3:02:30.0000
15	R15	76.82	23.18	750	4.1595	2:52:30.0000
16	LF16	86.84	13.16	750	2.3651	3:15:00.0000

Table 2
Statistical data for the proposed line

	string 1	real 2	real 3	integer 4	time 5	time 6
string	Pracovisko	Working [%]	Waiting [%]	Exit	Empty	Workingtime
1	LF1	43.25	6.16	750	17:48.1896	2:05:00.0000
2	R2	67.47	5.43	750	7:50.9611	3:15:00.0000
3	R3	91.70	4.75	750	6:51.8732	4:25:00.0000
4	R4	85.64	6.47	750	3.7880	4:07:30.0000
5	R5	86.51	4.97	750	3.8468	4:10:00.0000
6	R6	46.19	11.73	750	13.2917	2:13:30.0000
7	R7	51.90	5.82	750	13.2766	2:30:00.0000
8	LF8	98.62	1.38	750	2:00.0000	4:45:00.0000
9	R9	51.90	48.10	750	11.1052	2:30:00.0000
10	R10	38.93	61.07	750	14.1012	1:52:30.0000
11	LF11	0.00	100.00	750	23.0892	0.0000
12	R12	61.12	38.88	750	8.9780	2:56:37.5000
13	R13	43.25	56.75	750	13.1025	2:05:00.0000
14	LF14	48.88	51.12	750	11.8043	2:21:15.0000

The tables show percentages of the work and the waiting times of the individual workplaces. Results shown in the tables show that for the original line, individual stations are operated from 38.41% to 96.85%. The results of the proposed line reach a range of 38.93% to 98.62%. It shows that in both cases the lines are, used relatively equally. When queuing for a product, we can track the range for the original line from 3.15% to 61.59%, with the proposed line moving from 1.38% to 61.07%. We wait for the product waiting time at the LF11, because the workplace does not perform any operation in this particular case and only passes through the station. Additionally, we can see in the spreadsheets the length of time the workplaces were empty and the time they worked. Although the statistical results of both simulation models show only slight differences in favour of the proposed solution, it should be noted that the proposed line, is universal. The proposed line may replace any of the original lines, the composition and sequence of the assembly operations will be determined by a particular technological process.

Of great importance to the user is the high flexibility of the TPS models. Any changes in workstation capacity, the number of assembled products, or transport speed can be incorporated into the models that are created, where after simulation detailed model resource statistics are automatically recalculated. This provides valuable information for production planners, technologists and economists while the generated data is fairly accurate and usable for various areas of business processes. In the research we did not deal with the eco-nomic evaluation of the proposed changes on the assembly line. The aim of the research was an initial analysis of the effectiveness of the solution when changing the manipulation on the analyzed line.

CONCLUSION

The aim of our research was to apply industry digitization procedures and Industry 4.0 strategy to current production systems. By creating digital business models, businesses increase their ability to quickly adapt to the rapidly changing market conditions and their competitiveness. Simulation models of production are becoming part of the worldwide trend of industry digitization presented by Industry 4.0. The simulated assembly line models help the user improve production, assembly processes and provide a flexible production control tool. TPS Simulation Modelling Models allow us to simulate in advance of any change in production, an increase in workstation capacity, a number of assembled products, or a transport rate that is automatically converted to detailed model resource statistics after the simulation.

The trend and the current challenge for businesses is the Industry 4.0 concept, the fourth industrial revolution aimed at digitizing all business processes. The basic method for digitizing dynamic production processes in enterprises is simulation. Our article addresses digitization of a particular assembly plant and creating a "Digital twin" assembly line.

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REFERENCES

[1] H. Alavi and P. Habek. Optimizing outcome in the university – industry technology transfer projects. *Management Systems in Production Engineering*, Vol. 22, No.2, pp. 94-100. p-ISSN 2299-0461, Poland, 2016.

[2] S. Bangsow. *Manufacturing Simulation with Plant Simulation and SimTalk*. Springer-Verlag Berlin Heidelberg. pp. 289, 2010.

[3] W. Bialy and J. Ružbarský. Breakdown cause and effect analysis. Case study. *Management Systems in Production Engineering*, Vol. 26, No. 2, pp. 83-87. p-ISSN 2299-0461, Poland, 2018.

[4] M. Buckova et al. Impact of digital factory tools on designing of warehouses, 2017. *Journal of Applied Engineering Science*, Vol. 15, no. 2, pp. 173-180. ISSN: 1451-4117, 2017

[5] N. Kumar and D. Mahto. Assembly Line Ballancing: A Review of Developments and Trends in Approach to

Industrial Application. *Global Journal of Researches in Engineering Industrial Engineering,* Vol. 12, No. 2, USA, [online] [cit. 2017.05.21] Available on the Internet: https://globaljournals.org/GJRE_Volume13/4-Assembly-Line-Balancing-A-Review-of.pdf . 2013.

[6] P. Polerecký. *Proposal of manufacturing system improvement*, The Bachelor Thesis, pp. 53, Zvolen. Slovak Republic. 2016.

[7] P. Polerecký and E. Sujová. Assembly line optimization through Tecnomatix Plant Simulation. In: Conference Proceeding: *Recent advances in agriculture, mechanical engineering and waste policy*, pp. 200-207, Nitra. Slovak Republic. 2017

[8] R. Rosen, G. Wichter, L.O. George, K. D. Bettenhausen. About the importance of autonomy and digital twins for future of manufactuing, IFAC-PapersOnLine 48-3(2015) 567-572 (2015)

[9] V. Senjom and E. Evin. Increasing of the assembly line productivity by unloading assembly stations using the Yamazumi method, [online] [cit. 2017.05.21] Available on the Internet: https://www.sjf.tuke.sk/transferinovacii/pages/archiv/transfer/13-2009/pdf/073-077.pdf. 2009.

[10] SOVA DIGITAL. Digital twin leads the companies to Industry 4.0. [online], [cit. 2017.04.15] Available on the Internet: http://www.sova.sk/sk/tlac-a-media/tlacove-spravy/digitalne-dvojca-od-sova-digital. 2018.

[11] P. Štarchoň, M. Vetráková, J. Metke, S. Lorincová, M. Hitka. Introduction of a New Mobile Player App Store in Selected Countries of Southeast Asia. Social Sciences, vol. 2018, No. 7, doi: 10.3390/socsci7090163

[12] TPS. Tecnomatix Plant Simulation, [online] [cit. 2017.03.29] Available on the Internet: http://4dsysco.com/siemens-plm/tecnomatix/tecnomatix-plant-simulation.

[13] J. Tokarczyk. Migration of computational models in virtual prototyping of complex mechanical systems. WCECS 2012, World Congress on Engineering and Computer Science 2012, Volume II, San Francisco, USA, 24-26 October, 2012. Lect. Notes Eng. Comput. Sci. 2012, s. 1334-1337. ISSN 2078-0958.

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