An Analysis of the Assembly Line Modernization by Using Simulation Software

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The article deals with the optimization and modernization of assembly systems by creating models in the simulation software. The creation of digital models is a current trend in enterprise digitization called Industry 4.0. The Tecnomatix Plant Simulation environment allows you to create a virtual model of a real assembly line with the input of its basic production parameters. To perform the 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 was to analyse the effectiveness of the proposed modernization universal assembly line using the generated statistical data.

Keywords: simulation, virtual model, Industry 4.0, Tecnomatix Plant Simulation (TPS), assembly line, quality of processes

1 Introduction

Optimization of the production processes in currently one of the most common optimization tasks in production. The complexity and demanding of the market environment forces businesses to pay particular attention to improving operating conditions [1]. The enterprise must work in such a way that the input-output transformation proceeds with the optimal consumption of production inputs, the optimal choice of production processes, resources and optimal utilization of production capacity [2]. At the same time, it must enable the company to compete, achieve goals and increase efficiency. In planning and manufacturing, modern sophisticated methods such as, for example, just in time / just in sequence, introduce Kanban, plan and build new production lines and manage production [3]. It's important to decide the basis of objective criteria that will help management evaluate and compare alternative approaches. Optimizing means choosing the best solution from many existing options.

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 to 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 [4, 5]. The Tecnomatix solution through simulations optimizes business processes that determine the ability to deliver the product faster. Tecnomatix makes it possible to match the production capacities with the proposed intent from product development to delivery to reduce the lengthy introduction of processes, thereby improving their quality, and ultimately to increase company flexibility, market share and brand value. Creating a simulation model is currently a major challenge for businesses with ambition to engage in the 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 characterizes the effectiveness of the solution. The research is part of the KEGA 011TZ Z-4/2017 which deals with the integration of progressive information technologies into education.

2 Assembly lines and their problem optimization

The assembly line can be defined by the production technique in which the product is transported in some form between workplaces. Different assembly operations are performed on these lines. It is usually a quick assembly of a larger number of identical products [6]. The more we increase the lines performance, the relatively lower the price of the product. The assembly lines designed and built for any particular product. Most prefer some that will be equipped with variability and versatility for mounting future innovative products. If there is any innovation in production, rebuilding systems will not cause a stop or, possible delay of production [7].

The assembly line consists of assembly stations that form the assembly chain. Each station is specific to a particular assembly process. There are only rare stations with the same process and time. In assembly lines and stations we define the following terms:

- Cycle time – measured real time assembly time for a particular operating station that is characterized by the start and end of the process.
- Target cycle time – calculated production line capacity time. Characterizes the time during

which the finished product will be routed on a regular basis.

$$TCT = \frac{available\ working\ time}{production\ capacity\ per\ day} \quad (1)$$

- Bottleneck – represents the key station of the assembly line with the longest installation time, which causes a slowdown in production. If affects stations that are in front of or behind this station. The places in front of the problematic place are overinglated and filled with assembly streams. For the cycle time of the whole line, we consider the bottleneck. On the line, the bottleneck usually occurs only once, but there may also be more workplaces with a similar mounting time.
- Tact time TT – the calculated time that is a crucial element for the customer. This is the ability of the manufacturer to deliver the required number of products. We define it as the time at which a finished product will be routed from the line at regular intervals. The aim is to make the cycle time equal to the target time of the cycle.

$$TT = \frac{available\ working\ time}{customer\ request\ per\ day} \quad (2)$$

Optimization means balancing any production or assembly line. The main goal of line balancing is the even distribution of tasks to individual workstations so as to minimize the time of inactivity of a person. Balancing is focused on grouping equipment or workers in efficient models to achieve the optimal balance between capacities and flows of production or assembly processes. Line optimization is a term that is commonly used as the basis for the decision-making process of assigning task to workstation in a serial production system. The assignment of tasks to each worker and workstation is achieved by balancing the assembly line, increasing assembly efficiency and productivity. The multifunctional assembly line, is characterized by the unevenness of the assembled products and the production system. To reduce production and cost times, this assembly is organized in modules, and it allows the correction of short-term production cost problems [8].

2.1 Characteristics of computer simulations as a tool for line optimization

Tecnomatix Plant Simulation (TPS) is a simulation tool that enables you to create digital system models to help you define system characteristics and optimize performance. Digital models allow us to experiment with scenarios without disturbing existing production of being able to use them in the planning process long before the changes are introduced into the production process. Extensive analytical tools such as narrow space analyses, statistics and graphs allow you to evaluate different production scenarios. The simulation of results provides the information needed for quick and reliable decisions in the initial stages of production planning. Using TPS, we can model and simulate manufacturing systems and their processes. In addition, TPS allows you to optimize material flow, resource utilization, and logistics for levels of production plant planning, through local plans to specific lines.

TPS models help the user:

- By revealing and removing issues that would otherwise require costly and time-consuming repairs.
- By minimizing investment cost on production lines, without compromising performance.
- By optimizing the performance of existing production systems by adopting measures that have been verified in the simulation environment.
- By identifying and optimizing time such as processing time, breakthrough time, recovery time, and so on.
- By determin the size of the trays and the number of machines that will be needed to ensure smooth manufacturing processes.

TPS allows you to create well structured, hierarchical models of manufacturing plants, lines and processes. This is accomplished through object-oriented modelling, which allows creating and maintaining very complex systems, including advanced control mechanisms.

TPS simulations are, used with high efficiency to optimize production and minimize process work. Simulation models make it possible to take into account the internal and external supply chains, production resources and business processes, allowing you to analyse the impacts of different production variants. It is possible to evaluate different production lines, control strategy and verify the synchronization of lines. The system allows you to define different material flows and determine their effect on the line and its performance. Control rules are selected from libraries and can be further modelled as highly sophisticated controls. Optimization can also be done automatically using algorithms in TPS. This is useful if there are a number of system parameters and limitations and it is difficult to find the optimal solution. Algorithms optimize system parameters for a number of limitations, such as throughput, inventory, resource usage, and delivery times. These solutions are further evaluated using simulations and are interactively searching for the optimal solution using the balance line and the different dose sizes. TPS analytical tools make it easy to interpretation of simulation results using statistical analysis graphs for the use of balancing items, machines and staff. It is possible to create extensive statistics and charts to support dynamic performance analysis including line load, failures, inactivity and repair time [9, 10].

The simulation of assembly lines in the TPS environment is an effective method for solving our research objectives aimed at analysing the efficiency of the assembly line modernization. In two models a simulation is performed:

1. Initial 8 assembly lines where handling is handled by standard conveyors.
2. A proposed line consisting of the components of all eight original lines, where modernization is solved by incorporating robotic arms for manipulation.

The 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.

3 Material and Methods

For the creation of simulation model, 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 the 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 in the creation of a single universal line that would replace its original line of business. When designing a universal line, the elements of all eight lines are taken into account by the assignor's request. Prior to the creation of a universal line, a line similarity analysis was performed to show which lines contain identical workplaces. For the transport of material between workplaces in the original lines, the conveyors required for the standard were used. In optimized models, we used robotic arms that are capable of meeting the requirement to move workpieces without the participation of a person [11]. 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.

3.1 Simulation procedure

Here's 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 the necessary data, such as, workspaces, times of operation, time of transport, used assembly components their amount, etc. After obtaining the data, it was possible to proceed to the first simulation step to create a visual distribution of the model elements representing a simulated line (Fig. 1). For better clarity and simpler work, it is appropriate to name individual elements. The layout in Fig. 1 shows the 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)*.

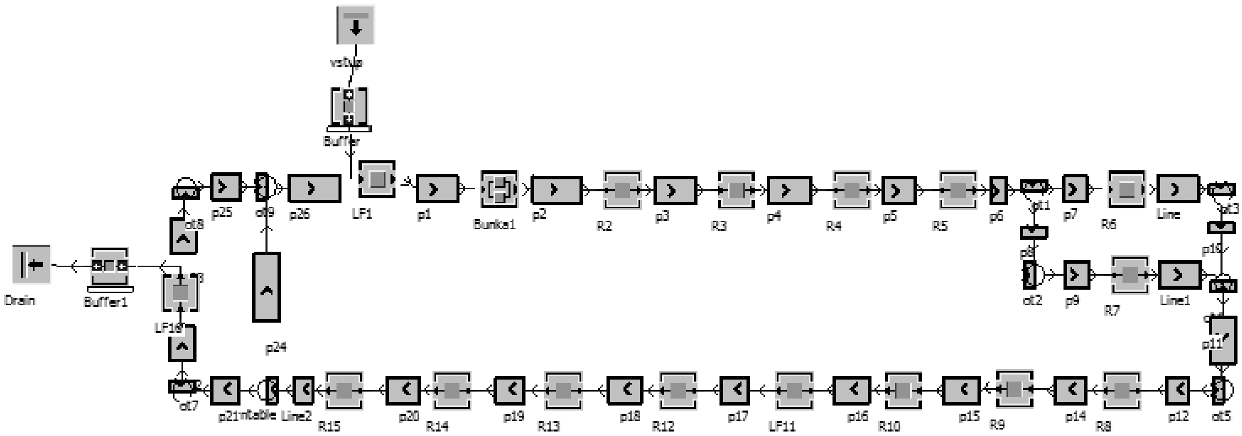


Fig. 1 *The simulation model of original assemble line*

A specific feature of the model is 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 have been interconnected in order to build on ourselves in the technological process. When the line model was ready, we defined the product in the MUs *(Moveable Units)* folder and then set the attributes of the individual model elements:

- Conveyors – the length and the speed at which the material is transported from one workstation to another (Fig. 2)
- Rotary elements of conveyors – the length and the speed at which they are rotated to continue the material flow (Fig. 3)
- Workstations *(Singlproces elements)* – individual operating times (Fig. 4)

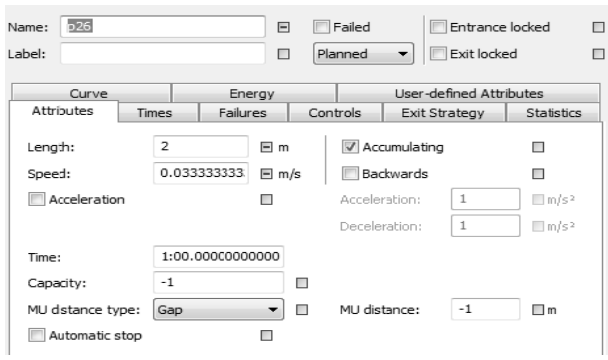


Fig. 2 *Attributes of conveyor settings*

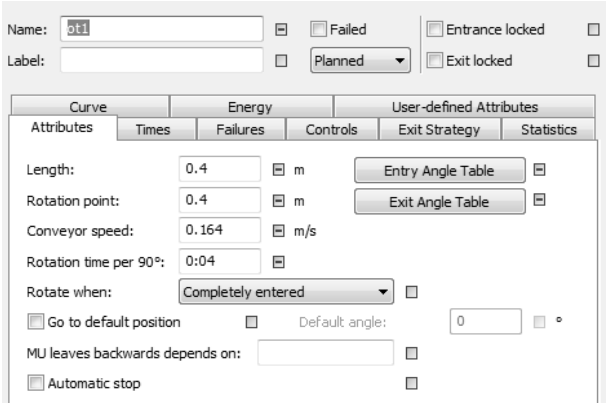


Fig. 3 *Attributes of Turnable settings*

In conclusion, the *EventControler* element has been given the 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 was started, the material flow was shown, simulated models were dynamically moved products *(MUs)*. At the end of the simulation time, basic statistics (Tab. 1) were displayed.

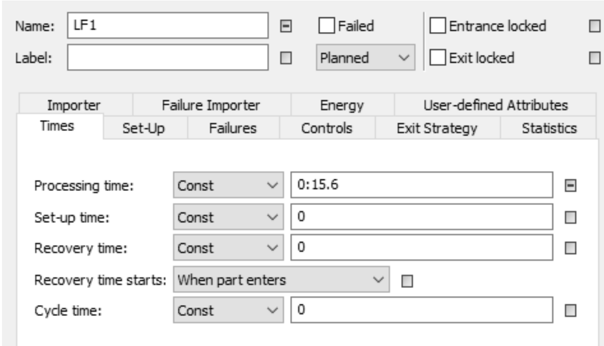


Fig. 4 *Set up of processing time*

3.2 Design of the optimized universal assembly line model

In the case of the design of the optimized universal assembly line, we proceeded according to the procedure in chap. 3.1. We have incorporated into the proposed model all the workstations 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 5 shows the optimized line model.

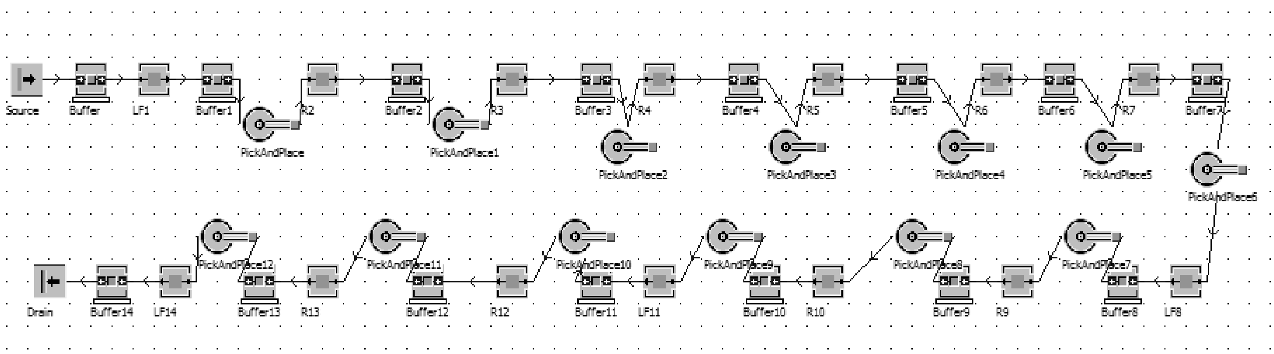


Fig. 5 *The simulation model of the proposed line*

4 Results and discussions

After simulation, we have obtained the basic cumulative statistical results (Tab. 1 and Tab. 2) which provide information on the percentage utilization of working time on individual lines with a graph showing the use of working time [11]. Table 1 shows the basic cumulative statistical results of the original line in the original table generated by the simulation software.

Tab. 1 *Basic statistical date of the original line*

Cumulated Statistics of the Parts which the Drain Deleted									
Object	Name	Mean Life Time	Throughput	THP	Production	Transport	Storage	Value added	Portion
Drain	strmen	1:55:57.4951	750	200	4.13%	8.89%	86.99%	3.37%	

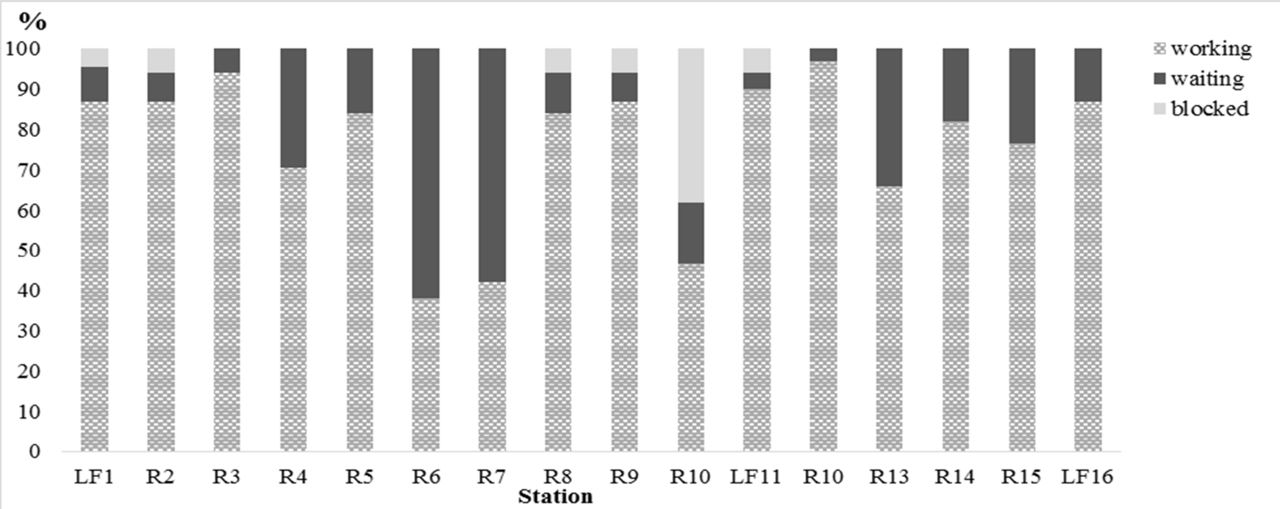
Table 2 shows the basic statistical results for the proposed universal line in the original table generated by the simulation software.

Tab. 2 *Basic statistical date of the proposed line*

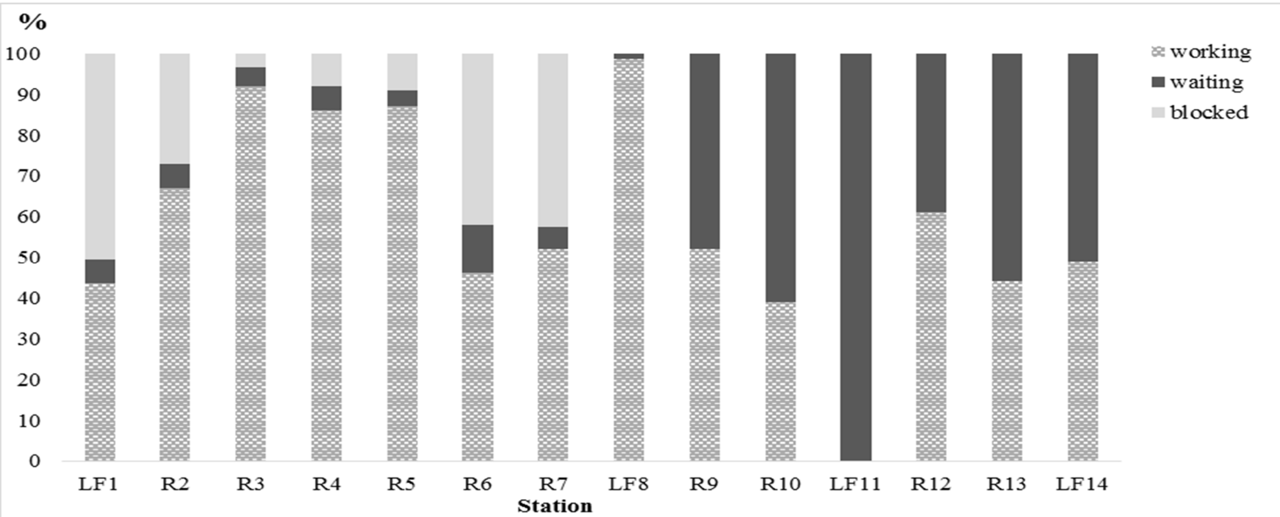
Cumulated Statistics of the Parts which the Drain Deleted									
Object	Name	Mean Life Time	Throughput	THP	Production	Transport	Storage	Value added	Portion
Drain	strmen	16:35.1406	750	156	25.34%	13.63%	61.03%	18.94%	

From the results shown in Tab. 1 and Tab. 2, it can be stated that the proposed line increased production from 4.13 % to 25.34%. The share of transport grew from 8.89 % to 13.63 %. On the contrary, the storage ratio dropped from 86.99 % to 61.03 %, which is positive.

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 the workloads and resource statistics. On Graph 1 and Graph 2, we can see the percentage working, waiting and blocking for each workstation of the original line and proposed line.



Graph 1 *Resource statistics of original line*



Graph 2 *Resource statistics of the proposed line*

```
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*

More graphical 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 the method is shown in Fig. 6. *SimTalk* simple programming language was used to apply the method.

Detailed statistics of individual sources in the TPS environment using the *Method* tool are shown in Tab. 3 and Tab. 4. The advantage of obtaining detailed statistical data from simulation model is that they give a precise overview of the performance of individual line work at the given production batch, which in our example represented 750 products [12].

The tables show the percentages of the work and the waiting times of the individual workplaces. The 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 case 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. In addition, 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.

Tab. 3 *Statistics data for the original line*

	String 1	Real 2	Real 3	Integer 4	Time 5	Time 6
string	Workplace	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

Tab. 4 *Statistic data for the proposed line*

	String 1	Real 2	Real 3	Integer 4	Time 5	Time 6
string	Workplace	Working [%]	Waiting [%]	Exit	Empty	WorkingTime
1	LF1	48.25	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	3:30:00.0000
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

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 data usable for various areas of business processes.

5 Conclusion

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. By digitizing a particular assembly plant and creating a "Digital twin" assembly line, is dealt with by our research, presented in the article.

The simulation of plant and assembly systems in Plant Simulation is specific in helping optimize but also in planning the next production processes, designing lines, and saving companies from designing production so as to avoid complications, reduce potential manufacturing errors, and increase the efficiency of production systems [13 – 15]. Simulation is a supportive tool that allows for a view of the future with relatively high accuracy. It allows for relatively quick testing and evaluation of various variants before applying a solution as well as, detecting and removing bottlenecks. It is one of the most sophisticated methods of solving where, due to the complexity or absence of information, it is not possible to precisely determine the limits of the solution and to evaluate the permissible errors. It helps find the best combination of input process parameters needed to make the desired changes.

It the research, has been designed a universal assembly line that could replace any of the existing eight lines. When designing a line, there has been used the best of the original lines at the request of the client. As a replacement for conveyors that are considered standard, it has been used robot arms for material handing in the design. Using the simulation program, here was compared the original assembly line with the design of the universal line in the corresponding layout. The result of the simulations is the quantitative statistical output of the load on the individual line workstations. The results show that the proposed line, has optimized production processes.

In conclusion, we can say that the simulated assembly line models help the user improve production, assembly processes and provide a flexible production control tool. TPS Simulation Modelling Models allow to simulate in advance 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. 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.

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