IOP Conf. Series: Materials Science and Engineering **400** (2018) 022033 doi:10.1088/1757-899X/400/2/022033

A computer simulation as a tool for a production system analysis and optimization

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Abstract. In the paper results of the computer simulation of the real production system with Siemens Plant Simulation are shown. The simulation model was built basis on the existing production system. The production system was devoted for a car suspension manufacturing. The purpose of the computer simulation was to get initial information about existing system behaviour and its output. Basis on this initial simulation the four scenarios for the production system improvement were proposed. Each scenario included exactly the one idea of changes in the production system layout organization. The following changes in the production system organisation were proposed, (i) introducing of an industrial robot for servicing of the hardening station, (ii) replacement of the industrial robot by engagement of the two extra production workers for servicing of the hardening station and the heat-treating furnace, (iii) replacement of the industrial robot via introducing of the roller conveyor and engagement of an extra production worker for servicing of the hardening station and the heat-treating furnace, and (iv) introducing of the two roller conveyors for the same purpose. Computer simulations were performed to each scenario in order to examine, how the proposed changes in the production system organisation influence its production efficiency. Having the computer simulation carried out, the comparative analysis of the production system productivity was performed. It made the selection of the best organisational variant possible.

1. Introduction
The computer simulation is a method which tries to replay real processes that proceed in the real world by means of mathematical models using computer programs. Such kind of simulation is widely used for inferencing about processes course for which the direct observation is just impossible, for instance weather forecasting, predicting of the stock exchange behaviour etc. [6]. In the computer simulation the simulation model is used. This model has both the mathematical-logical description of the simulated object and the set of relationships which decide about its behaviour and its environment interactions [16]. The main purpose of the computer simulation can be defined as the possibility of performing of an experiment that gives answers for the asked questions in the reasonable time horizon; it is before the decision deadline. In figure 1 the essential relationships that occur in the modelling and simulation processes are shown. The simulation model depending on a given situation is built basis on the data that come from the real production system or the design assumptions made for the newly designed production system. In the next stage the model is being encoded in the shape of the computer programme. The computer programme processes the input data and next returns information about the model reaction for the input. The better the simulation model reflects the real production system the

more precise simulation results can be achieved, it means that these result are closer to the real [2,3,4]. In the computer simulation the simulation is repeated many times, every time with a new set of the input data, as long as modelled system parameters values are not optimal in the light of the accepted criterion set. The final simulation parameters are next conveyed to the real system in order to improve its functioning. The biggest advantages of the computer simulation are the possibility of eliminating of the experiments made in the industry conditions, which are usually very expensive and often impossible to perform, and also lower implementation cost. Moreover, the computer simulation is repetitive, and the achieved data are easy to understand [8].

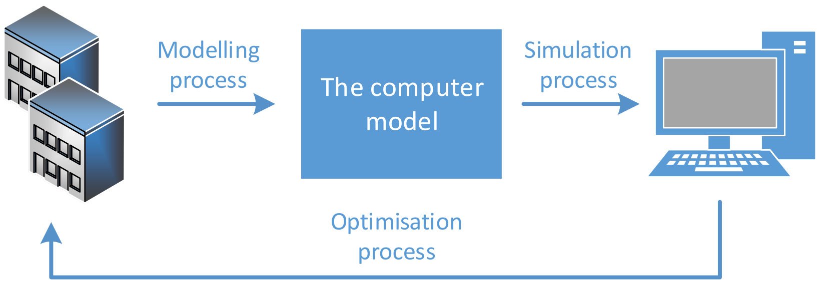


Figure 1. The schema of the computer simulation process.

The dynamic development of the computer simulation tools began in the early 80's of the 20th century. The main cause of that were the fast development of the computer science methods and the greater availability of the computer hardware. The coming up computer tools let to use the determined variables as well as random ones, for the very first time it was possible to apply the fuzzy logic in the math calculations. They could also process bigger sets of the input data parameters than it was possible in the past. In the beginning the computer tools were able to perform only the simple scrpits written in the high level programming languages, but over time they have evolved getting user interfece equipped in visual tools like schemas, diagrams etc. Along with the their development the simulation packages got the ability of application of the 3D models of the production systems, they also got data exachange interfeces to the external databases. In figure 2 the development of the computer simulation tools is presented.

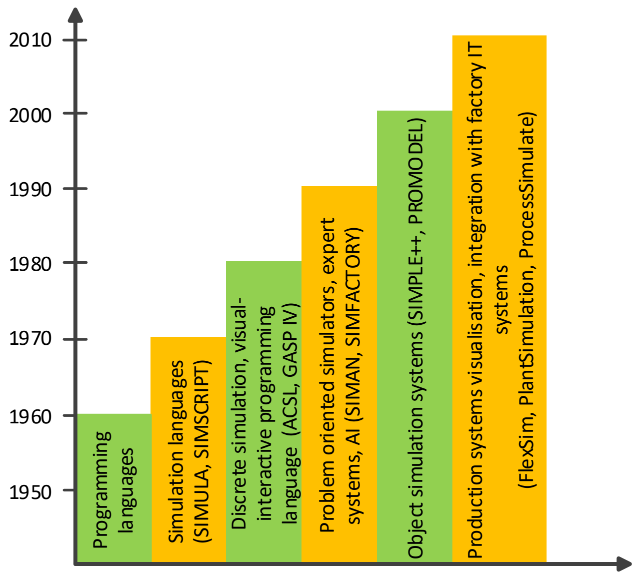


Figure 2. The development of the computer simulation tools.

Taking into account the way in which the simulation model is built, the computer simulation tools can be divided into the three groups, historically the oldest type of the computer simulation tools are high level programming languages, the second specialised simulation programmes, and the last one spreadsheets. The short description of each group is given below:

- the high level programming languages are used for writing computer programmes including simulation software. Thanks to their flexibility and universality they allow to write any class of simulation model but the at development stage they need participation of the skilled computer programmers, what limits the group of the prospective users. First simulation programmes were written in FORTRAN, over time the new object paradigm was developed, the new object oriented programming tools came into being, inter alia C++, C#, Python, Java etc. Despite high level programming languages merits, like mentioned above universality and flexibility they have one serious demerit, the simulation model preparation process is time and labour consuming.
- Spreadsheets compare to the programing languages are more universal. In practice, most often the MS Excel is used. It comes from fact that MS Excel is known worldwide; It has well-developed built-in functions library and makes different interfaces to external data sources like databases and external applications available. In case of lack of appropriate built-in function, the MS Excel functionality could be expanded by means of the Visual Basic for Applications (VBA) programming language. VBA allows writing program macros that automate work with spreadsheets. Besides the built-in functions, the MS Excel is equipped in the additional tools like Solver and AnalysisToolPack. These tools facilitate the analysis and simulation of the examined process. It would be enough to define an objective function, for instance the minimal cost, and to determine the set of the permissible solutions by defining of the limiting conditions in order to get the optimal values of the decision variables.
- The specialised simulation software constitutes the biggest group of the modelling and simulation tools. This group includes both specialised programmes dedicated for the specific application realm and also general purpose simulation packages. Most of the specialised simulation tools have user interface that allows preparing simulation model in the visual-interactive way. When, working with such kind of the simulation tools it is usually not necessary to know any programming language. The knowledge of programming languages is essential in case of the advanced use of the computer tool. The simulation model is built by means of defining and parametrisation of objects, and making of the relations that interact among them. Objects are most often represented by graphic symbols, whereas relations using lines. Such approach makes the building process of the simulation models easy. It is also easy to verify a model, and the model debugging is simple. Although, the specialised simulation software has unquestionable advantage over programming languages and spreadsheets it has one big demerit is the high purchase price.

The choice we make during the stage of the simulation tool selection has an essential influence on the effects that are achieved as results of the simulation. Although, at a glance this task would appear to be easy, but in fact it is hard and time-consuming, but if done scrupulously it would improve the solution quality and decrease the simulation cost. During the simulation tool selection, different criteria are taken into consideration. It is necessary to define application field, the group of the prospective users, and available budget. Next, an analysis of the available in the IT market tools should be conducted with regard to possible ways of the simulation model creation, planning and conducting of the simulation tests, simulated process visualisation tools (2D/3D graphics, graphic schemas both static and dynamic), outcome representation ways, and also the possibility of carrying out the statistical analysis. After narrowing the market offer down to the tools that meet the given criteria, an assessment of the offered software basis on opinions of the existing customers, consultant’s opinions, tests performed on the trial software versions should be made. It is also worth taking into consideration software working environment; it is the operating system, the market position of the supplier, finally software licence conditions, and the technical support scope. On the base of this assumption, the software ranking is built, and then the solution that matches the best to the user requirements and needs should be chosen [7,8,9,12,14].

In the last years the huge progress in application of the computer simulation in the Polish industry has been observed. Before that, in the production management static methods, theory of probability, linear and net programming were used. Generally speaking in the past, the computer simulation in the Polish conditions was the most often applied in the field of the financial analysis. The second place was occupied by production planning and control where simulation tools were used for decision support both at the strategic decision level and operational-tactical level. And finally, the computer simulation was used as a teaching tool in the processes of workers personal skills development. Currently, the main application fields of the simulation tools are assessment of the company market policy and its management strategic, making of the financial forecasts, planning and decision making.

2. Tecnomatix Siemens Plan Simulation

Tecnomatix Plant Simulation is a computer system developed by Siemens PLM Software. This computer tool is indented for simulation of the discrete production. It allows making of the production system digital model [1,14,15]. The digital model forms the base for the production system output optimisation. The computer models made in the Plant Simulation can be used for carrying out of experiments and scenarios that examine cause and effects relationships in the existing production systems or for the designing of the new ones. Plan simulation is equipped with well-developed analytical tools which allow making an analysis of the production system bottlenecks, and making out of diagrams and statistic. They all form a base for testing different scenarios for various input data sets. Simulation results provide useful information which can be next used in the decision making processes even at the stage of the production process planning and preparation [1,5,16]. Plan Simulation makes optimisation of material flow and production resources utilisation at each stage of the production process possible. Optimisation process could be performed both for the whole production system or single production line. Plant Simulation also allows to import 3D geometrical models from CAD systems. Thanks to this it is possible to visualise in virtual conditions the whole factory including robotised manufacturing and assembly stations. In figure 3 the main window of Tecnomatix Plan Simulation is shown.

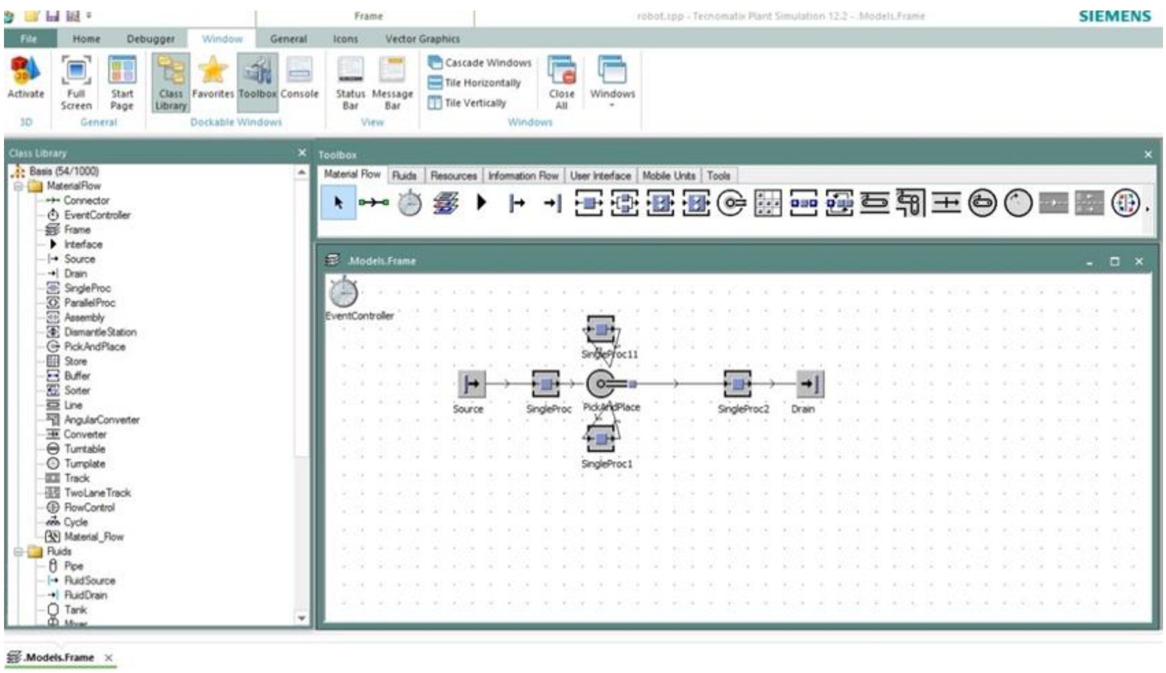


Figure 3. The main window of Tecnomatix Plant Simulation.

3. Modelling and simulation of the production line with Tecnomatix Plant Simulation

Presented example is based on the real industrial data. Because of restrictions put by the industrial partner it was not allowed to show the production line layout, and publish the precise operation times, setup times etc. These data are stored in the parameters of the computer model objects. The computer model was worked out for the single the production line. The modelled production line is installed in a factory that plays a subcontractor role for a car manufacturer. In the production system, some parts of a car suspension system are manufactured; it is a car rear beam. The purpose of the performed computer simulation was to get initial information about existing system behaviour and its output. Basis on this initial simulation the four scenarios for the production system improvement were proposed. Each scenario includes exactly the one idea of changes in the production system layout organization. The following changes in the production system were proposed, (i) introducing of an industrial robot for servicing of the hardening station, (ii) replacement of the industrial robot by engagement of the two extra production workers for servicing of the hardening station and the heat-treating furnace, (iii) replacement of the industrial robot via introducing of the roller conveyor and engagement of an extra production worker for servicing of the hardening station and the heat-treating furnace, and (iv) introducing of the two roller conveyors for the same purpose. Next, computer simulations were performed to each scenario in order to examine, how the proposed changes in the production system organisation influence its production efficiency. Having the computer simulation carried out, the comparative analysis of the production system productivity was performed. It made the selection of the best organisational variant possible.

3.1. Modelling and simulation of the production line initial model

The initial model of the existing production line consists of the nineteenth objects. The production line input is represented by the single object of the *Source* type. In order to model manufacturing resources like hot forming station, cooler, hardening heater, furnace, and shot- blasting machine an object of the *ParallelProc* type was chosen. The turning lathe used for pins machining is represented by *SingleProc* object. As we know, the production flow needs the semi-finished parts to be stored as they often have to wait for the next production process operation, so there was a need for introducing of production line buffers, these buffers were modelled with the two objects of the Buffer type. Some of manufacturing recourses are served by industrial robots. Robots in the simulation model are modelled with *PickAndPlace* objects. In the initial model the four industrial robots were present. The first robot is responsible for transferring semi-finished products form the first production line buffer to the furnace, whilst the rest are intended to do, in the order of the production flow; the second robot takes products from the furnace and places them into shot-blasting machine, the third robot is located between the turning lathe and quality control workstation, and the last one is used for delivering finished products to packing area. The quality control workstation is represented by Converter object. The right products flow, after quality control procedure is done, is controlled by the single object of *FlowControl* type. In the production system output stream the two kinds of products can be distinguished, products that meet the quality requirements, and those that do not meet them. So, in the simulation model the two outputs are needed. These outputs are modelled with Drain type object. Finally, some means of transport are modelled by *Line* objects. In figure 4 the simulation model elaborated for the existing production line using Tecnomatix Plan Simulation is shown. The production process on the modeled production line proceeds as shown below. The Source object supplies the production line with semi-finished products every 35 seconds. Next, each element is transferred by the operator to the hot forming workstation, for which the processing time is equal to 30 seconds. After the forming process, the elements go to the buffer (Buffer_1), and then to the cooler, where cooling operation takes 15 seconds. After the cooling operation, the products wait in the inter-operation buffer (Buffer_2) for a hardening operation. The transport of products from the buffer to the hardening heater is carried out using an industrial robot (Robot_1). After a two-minute long hardening operation, the Robot_1 transfers the parts to the furnace, in which they remain for 45 minutes. Then they are taken from the furnace and transported to a shot-blast machine, for which the processing time equals to 20 seconds. Subsequently individual parts go to the turning lathe. The processing time for the turning lathe equals to 20 seconds. Finished products are next transferred to the measuring table. On the measuring table each element is subjected to quality control operation carried out by the industrial robot (Robot_4) equipped with suitable sensors.

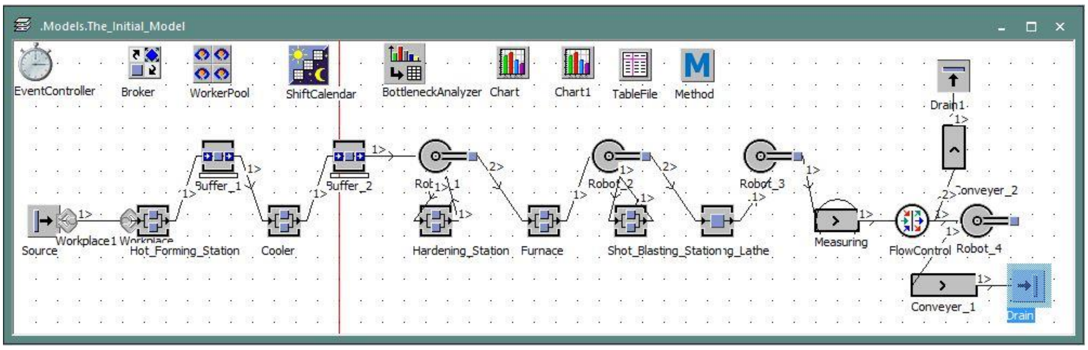


Figure 4. The computer model of the existing production line.

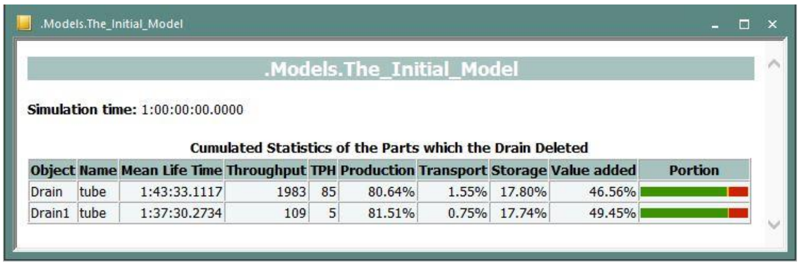
After quality control operation, faulty products are transported to the Drain_1 object by means of a conveyor (Line_1). The Drain_1 object represents one of the two exits from the production line. The rest, correctly made products are placed by an industrial robot (Robot_4) on a roller conveyor (Line_2). The roller conveyor transfers them to the Drain object that represents the second production line exit. The particular elements of the production line in the simulation model were connected by means of the connector type object (Connector). Connector objects unequivocally determine the direction of material flow in the production process. The real distances between the production line objects in the simulation model were omitted.

3.2. Modelling and simulation of the production line initial model

Simulation of the production process of the modelled line was carried out for the following assumptions:

- the simulation process covers the time of a single business day. The production process is carried out in a three-shift operation mode. Production workers are entitled to one fifteen-minute break during the production shift;
- initial conditions - empty production system, the level of stocks in the inter-operation buffers is equal to zero;
- the availability level of all machines is 95%;
- set-up times were not taken into account.

The analysis of the results of the computer simulation was performed on the basis of a summary report created by the Plant Simulation program. This report contains cumulative statistics on finished products in relation to Drain objects. Figure 5 shows the results report window worked out during the production line simulation for a single business day.


.Models.The_Initial_Model

Simulation time: 1:00:00:00.0000

Cumulated Statistics of the Parts which the Drain Deleted

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Drain	tube	1:43:33.1117	1983	85	80.64%	1.55%	17.80%	46.56%	
Drain1	tube	1:37:30.2734	109	5	81.51%	0.75%	17.74%	49.45%	

Figure 5. The simulation report.

An important subject of the system operation analysis is the work statistics of particular technological machines. They have been compiled in a bar graph shown in figure 6.

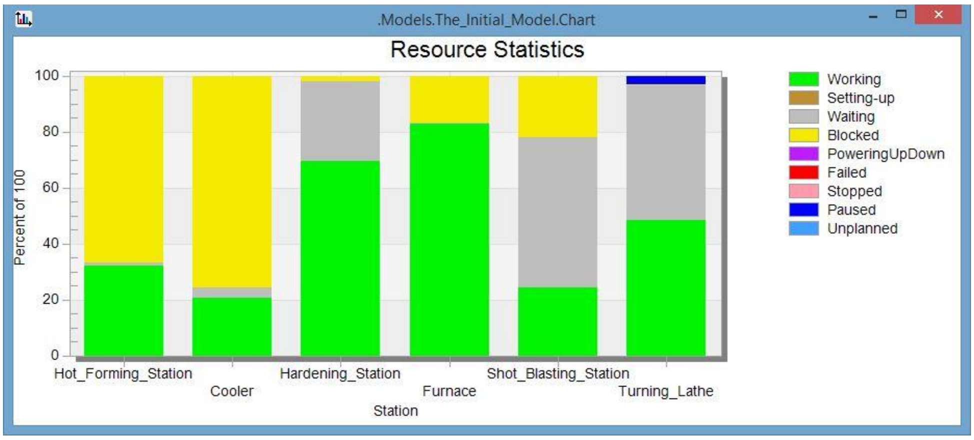


Figure 6. Graph of the percentage utilization of production resources for the initial production line model.

Simulation of the production line operation for the existing line organization allowed to draw the following conclusions:

- As a result of simulation conducted for the three shift working day it was found that the system output is equal to 2092 products. Comparing the obtained result with the production rate of the existing production line, it turned out that these values are very similar to each other. On this basis, it was found that the model was built correctly, and appropriately reflects the functioning of the modelled production line.
- The furnace is the most-loaded workstation of the production line and its total load is at the level of 83%. So, furnace makes a bottleneck of the production line limiting the productivity of the entire system.
- The smallest resources utilisation levels were got for the cooler and shot-blasting workstations. Their productivity is at a level of 24% and 21 % respectively. The biggest blocking levels were obtained for the hot-forming and cooling workstations. The workstation gets the blocked status when one or all of its stations work or are busy.
- Based on the simulation it was found that the flow of products through the first part of the production line; it is from the Source object to the furnace is slower and less smooth than for the rest of the production line. It results from the specificity of the modelled production line. The order of production operations causes that the bottleneck (furnace) is located just before of the hardening heater workstation. It means that the two workstations with the longest processing times neighbour each other. Lack of the smooth production flow could also be caused by the way the robot (Robot_1) serves of the workstations.

3.3. Proposals of changes in the production line organisation

The basic goal of making of changes in the production line organization was to increase its efficiency. In order to achieve this goal some corrective actions were undertaken. The following corrective changes were proposed; the first in regard to change the way of servicing workstations served by an industrial robot (robot_1) and the second one the replacement of an industrial robot with another type of transport conveyor. Proposed corrective actions allowed to work out 4 variants of organizational changes in the structure of the production line. For each variant, a computer model was developed and computer simulation was carried out. Based on the results obtained from simulation, conclusions were

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drawn in regard to the impact of the introduced corrective changes on the performance of the production system.

3.3.1. Variant I - Assessment of the impact of a change in the handling way of workstations by the industrial robot on production line performance

In variant I, the number of items carried one time by the robot that handles (Robot_1) interoperational buffer (Buffor_2) and the hardening station was reduced. After the modification, the handling algorithm is as follows: the robot takes two products from the inter-operation buffer and then transfers them to the hardening station. This operation is repeated. After delivering the second batch of products to the hardening station, the robot waits for completion of the hardening operation. After hardening, the products are transported by the robot to the next workstation. When one of the chambers of the hardening station is released, the robot loads it with another two products from the inter-operation buffer. The process is repeated every one and again until the working day is finished. The simulation model worked out for the variant II of the production line organisation is shown in the figure 7.

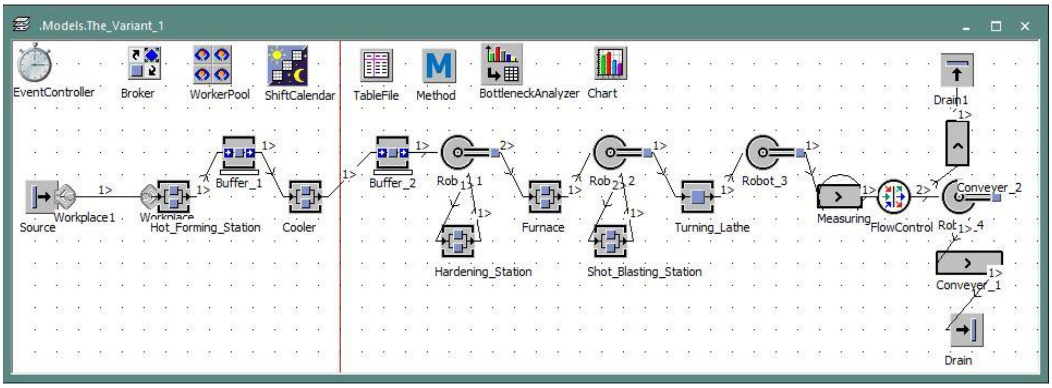


Figure 7. The simulation model of the production line for the variant I of the production line.

Figure 8 shows the results report window worked out during the production line simulation for the variant I.

.Models.The_Variant_1

.Models.The_Variant_1

Simulation time: 1:00:00:00.0000

Cumulated Statistics of the Parts which the Drain Deleted

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Drain	tube	2:19:10.8401	1156	50	75.74%	1.66%	22.60%	34.65%	
Drain1	tube	2:47:02.9400	58	2	78.42%	0.46%	21.13%	28.86%	

Figure 8. The simulation results achieved for the variant I.

After introducing of organizational changes in the structure of the production line that correspond to the variant I, the system efficiency was at the level of 1214 finished products. This is half the performance of the actual system. The change in the robot control algorithm (Robot_1) improved the material flow through the system, however, the double reduction in the number of items carried once by the robot increased the time of product passage through the production line, affecting the system's performance in a negative way. Figure 9 shows the graph of the percentage utilization of production resources for the variant I.

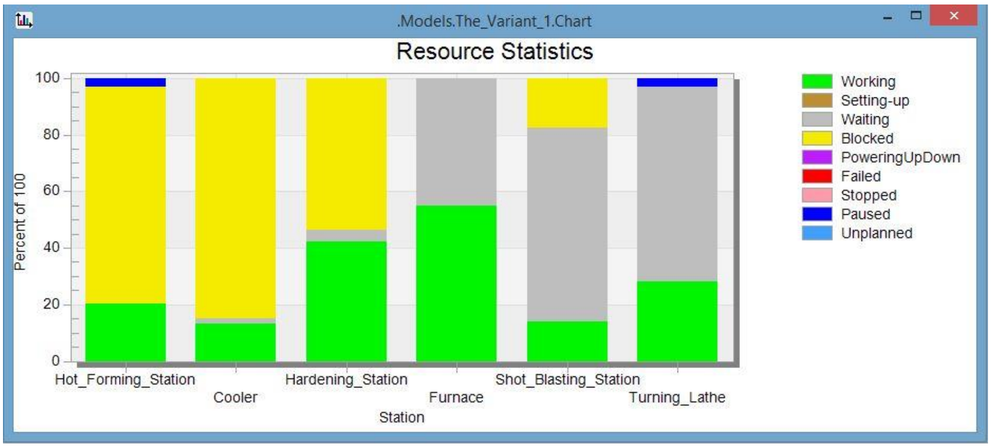


Figure 9. Graph of the percentage utilization of production resources for the variant I.

As a result of changes in the organization of production, the work statistics for individual workstations deteriorated. As in the case of the initial model, the most loaded production resources were the furnace and the hardening station, with their load reduced by about 30%. The greatest deterioration of results was obtained for the hardening station for which the blocking level is 45% of the working time fund.

3.3.2. Variant II - Assessment of the impact of introducing the two additional labourers on the productivity of the production system

In the second variant of the organizational changes, the robot (Robot_1) was replaced by two additional labourers handling, like in case of the robot's use, an interoperational buffer (Buffor_2) and a hardening station. The simulation model worked out for the variant II of the production line organisation is shown in the figure 10.

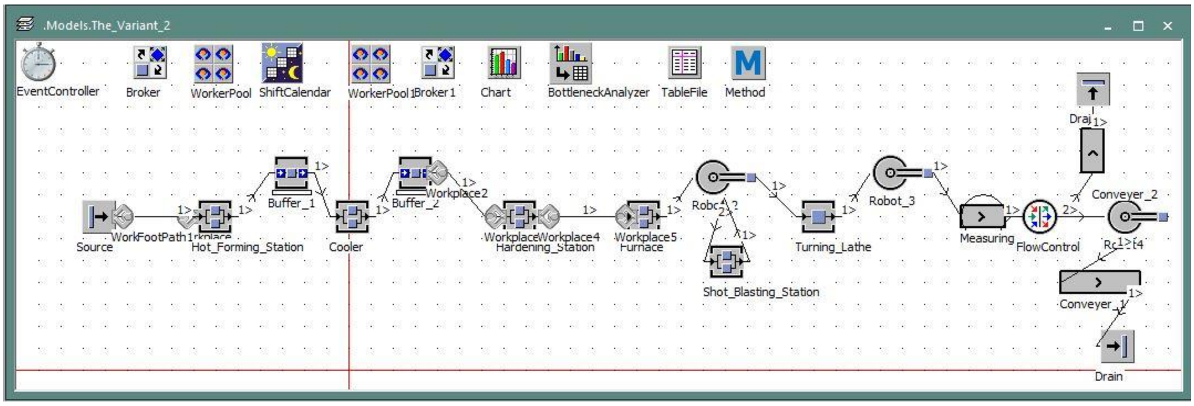
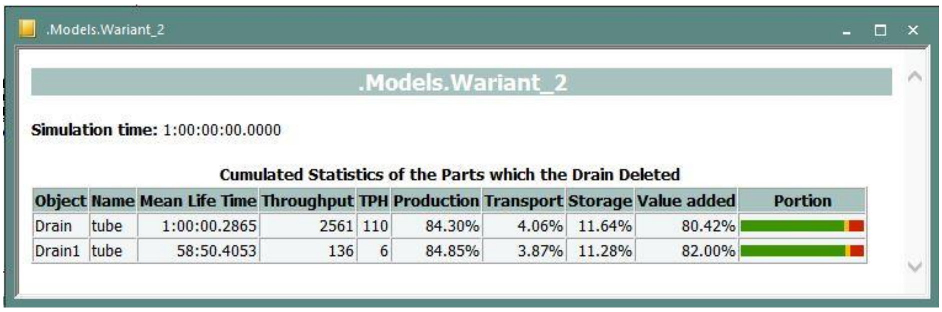


Figure 10. The simulation model of the production line for the variant II of the production line.

Replacing an industrial robot with human work positively influenced the efficiency of the production system. In this case the system performance relative to the base model increased by around 29%. It should be noted, however, that this result was achieved in the conditions of computer simulation; therefore the performance of the production system for the variant II under real conditions would be somewhat lower. This is due to the interpersonal efficiency of the employee over time, which increases during the production shift, reaching the maximum value that lasts for a certain period, and then decreases with the increase in employee fatigue.

Figure 11 shows the results report window worked out during the production line simulation for the variant II.



Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Drain	tube	1:00:00.2865	2561	110	84.30%	4.06%	11.64%	80.42%	
Drain1	tube	58:50.4053	136	6	84.85%	3.87%	11.28%	82.00%	

Figure 11. The simulation results achieved for the variant II.

Figure 12 shows the graph of the percentage utilization of production resources for the variant II.

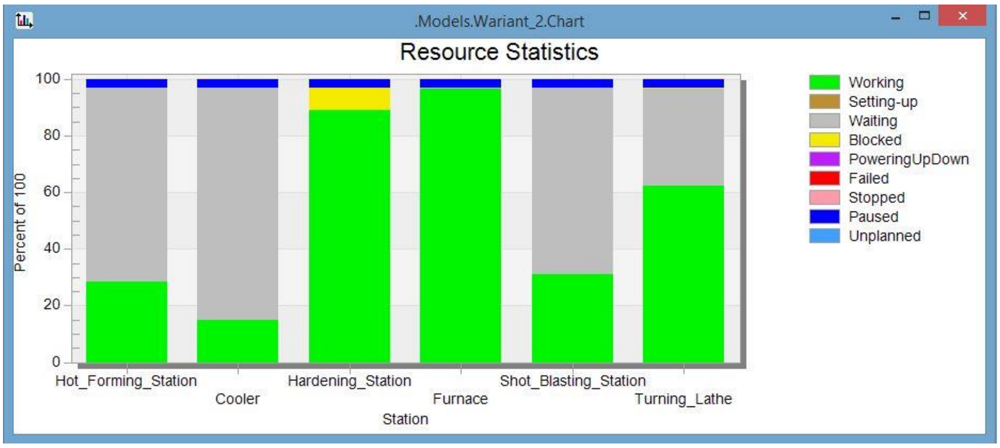


Figure 12. Graph of the percentage utilization of production resources for the variant II.

Despite the changes introduced to the model, the furnace remains the bottleneck of the system, just like in the case of the real line. The percentage share of furnace working time was increased by almost 14%. Compared to the real object model, the percentage utilization of the hardening station also increased significantly.

Other manufacturing resources from the blocking state (in the basic model) have entered into a waiting state. Low utilization of machines productivity and long waiting time for subsequent parts results indirectly from the short processing time. The elimination of the blocked state for particular workstations and the increase in the efficiency of the production process testify to the improvement of the material flow in the system.

3.3.3. Variant III - Assessment of the impact of introducing of the additional labourer and roller conveyor on the productivity of the production system

In the third variant of organizational changes in the work organization of the existing production line, the industrial robot (Robot_1) was replaced by a worker and a roller conveyor. In the variant III, the worker transfers one part from the buffer (Buffer_2) to the hardening station. After finishing the hardening operation, the part is transported by means of a roller conveyor to the furnace. Figure 13 shows the production line model corresponding to the organizational changes of the variant III.

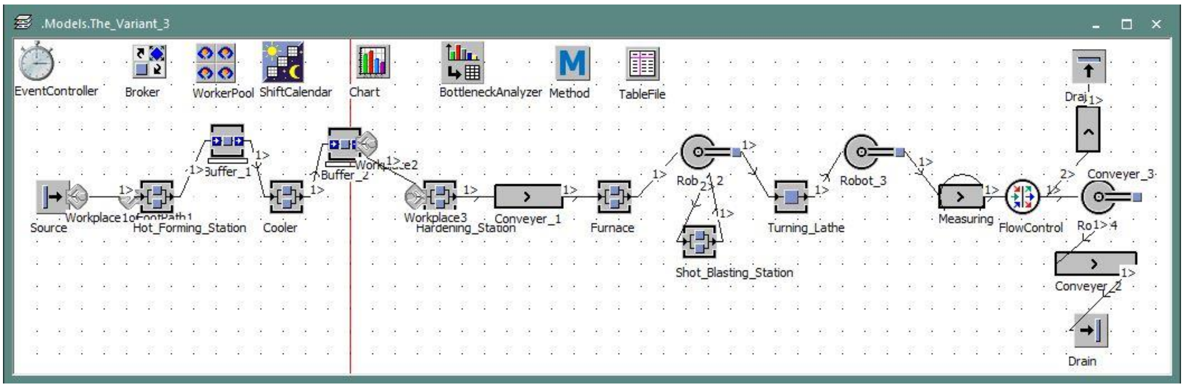
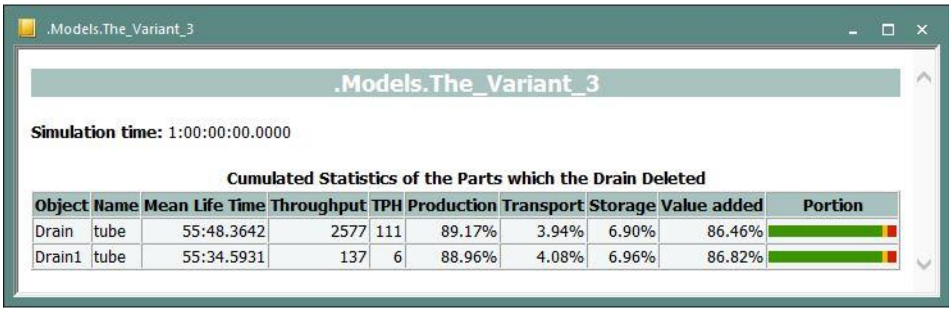


Figure 13. The simulation model of the production line for the variant III of the production line.

Figure 14 shows the results report window worked out during the production line simulation for the variant III.



.Models.The_Variant_3

Simulation time: 1:00:00:00.0000

Cumulated Statistics of the Parts which the Drain Deleted

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Drain	tube	55:48.3642	2577	111	89.17%	3.94%	6.90%	86.46%	
Drain1	tube	55:34.5931	137	6	88.96%	4.08%	6.96%	86.82%	

Figure 14. The simulation results achieved for the variant III.

For the variant III, the total number of suspension system components produced amounted to 2714 units. In this case, the productivity of the production line is about 30% greater than the performance of the actual production line. The furnace is still the bottleneck of the production system. Better rates of resource utilization were obtained for hardening station, hot forming station and turning lathe station. Similarly as for the variant II, the state of blocked of workstations was eliminated. Figure 15 shows the graph of the percentage utilization of production resources for the variant III.

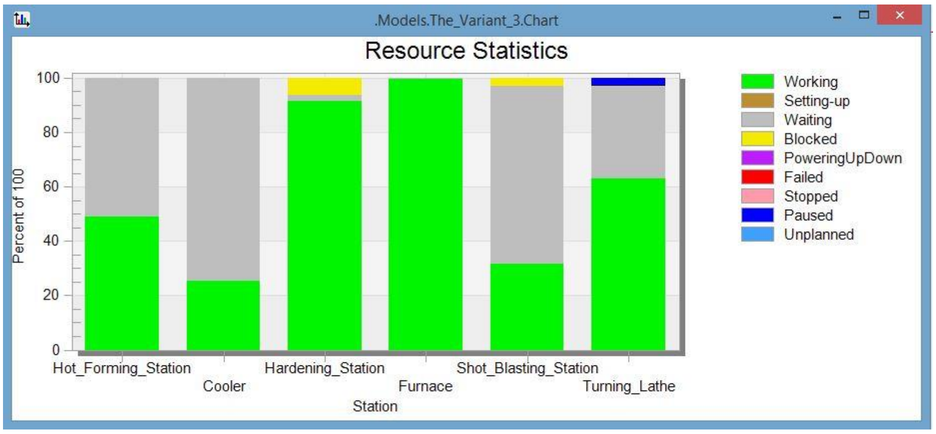


Figure 15. Graph of the percentage utilization of production resources for the variant III.

3.3.4. Variant IV - assessment of the impact of roller conveyors application on the productivity of the production system

In the variant IV, it was proposed to replace an industrial robot with two roller conveyors. The first roller conveyor transfers parts from the inter-operative buffer (Buffer_2) and places them in the hardening station. The second robot is responsible for transporting parts from the hardening station to the furnace. The model of the modified production line is shown in figure 16.

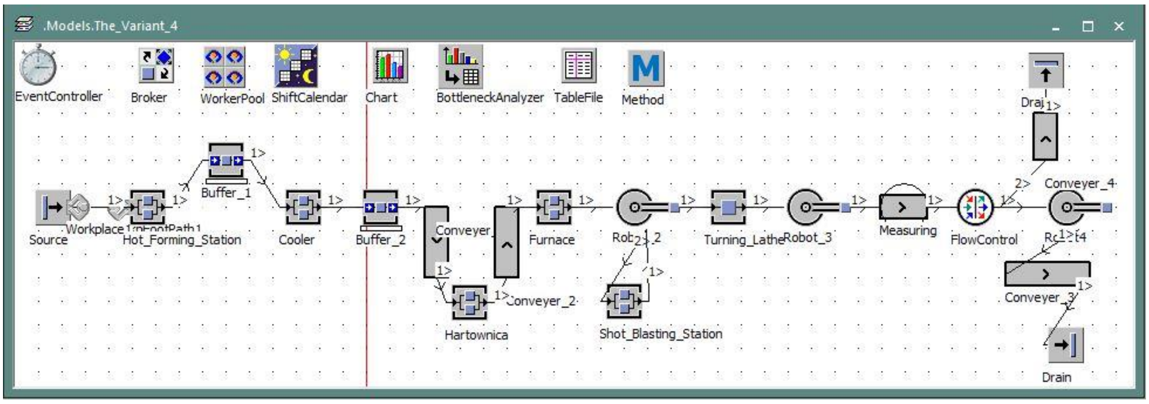


Figure 16. The simulation model of the production line for the variant IV of the production line.

The total productivity of the production line for the organizational changes proposed for the variant IV amounted to 2718 units. This means that the performance of the line after modification was about 30% higher compare to the original one. Figure 17 shows the results report window worked out during the production line simulation for the variant III.

.Models.The_Variant_4

Simulation time: 1:00:00:00.0000

Cumulated Statistics of the Parts which the Drain Deleted

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Drain	tube	1:22:27.8424	2581	111	79.02%	3.88%	17.10%	58.47%	
Drain1	tube	1:22:18.0457	137	6	78.91%	4.06%	17.03%	58.59%	

Figure 17. The simulation results achieved for the variant IV.

Figure 18 shows the graph of the percentage utilization of production resources for the variant IV. For the fourth variant, the furnace load value was almost 100%. The use of other production resources has also increased. However, the adverse effect of organizational changes proposed in variant IV on the blocking level of hot forming and cooler stations was observed. These levels amounted to 48% and 28% respectively. In addition basis on the graph of the percentage utilization of production resources for the variant IV, it can be stated that the obtained production flow is smooth, and the transport between the hardening station and the furnace is much faster.

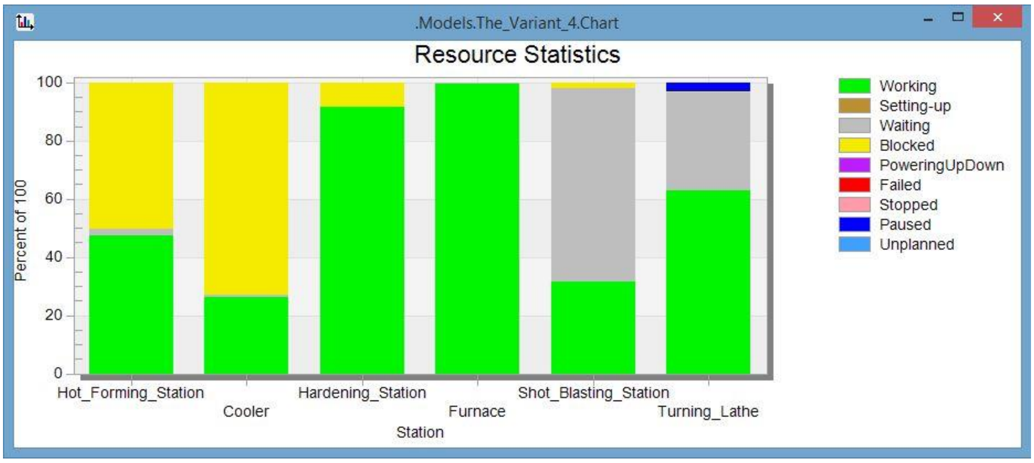


Figure 18. Graph of the percentage utilization of production resources for the variant IV.

3.3.5. Discussion of the results obtained for individual simulation models of the production line
Table 1 shows the total and percentage production efficiency obtained for individual simulation models of the analysed production line.

Table 1. The total and percentage production efficiency obtained for individual simulation models of the analysed production line.

Margin		**The initial model**	**Variant I**	**Variant II**	**Variant III**	**Variant IV**
Total number of parts produced		2092	1214	2697	2714	2718
The difference in the number of pieces produced compared to the initial model	Expressed in number of produced parts		-878	+605	+622	+626
	Expressed in [%]		-41,97	+28,91	+29,73	+29,92

As a result of the productivity comparison for all variants worked out for the analysed production line, the following was found:

- only for the first variant the production line productivity is smaller compared to productivity of the existing line,
- the increase in the efficiency of the production line occurred after modifications proposed in case of variants from II to IV and amounted to 30% for each.

In the table 2 a summary of the percentage utilization of workstations within one working day for individual production line organisation variants is shown.

The analysis of the results presented in table 2 allowed to draw the following conclusions:

- the greatest efficiency of the production line was obtained for variants of organizational changes III and IV,
- the smallest waiting state values were obtained for the model corresponding to the variant for the current production line organisation and for the variant of organizational changes IV.
- the lowest percentage share of the blocking of production resources was obtained for the variant of organizational changes III.

Taking into account the criterion of maximum efficiency of the production line, it was found that the optimal variant in the light of this criterion is the variant IV.

Table 2. A summary of the percentage utilization of workstations within one working day for individual production line organisation.

		Hot forming station	**Cooler**	**Hardening station**	**Furnace**	**Shot-blasting machine**	**Turning lathe**
Initial model	Working	3.26	20.64	69.53	82.93	24.23	48.43
	Waiting	1.03	3.55	28.55	0.38	53.93	48.3
	Blocked	66.72	75.81	1.92	16.69	21.84	0.15
Variant I	Working	20.29	13.28	42.14	54.76	14.07	28.11
	Waiting	0	1.91	4.35	45.24	68.26	68.68
	Blocked	76.59	84.81	53.5	0	17.67	0.09
Variant II	Working	28.34	14.72	88.96	96.55	31.23	62.44
	Waiting	68.54	82.15	0.2	0.32	65.65	34.25
	Blocked	0	0	7.71	0	0	0.19
Variant III	Working	48.83	25.18	91.4	99.68	31.44	62.85
	Waiting	51.17	74.82	0.32	0.32	65.46	33.84
	Blocked	0	0	0	0	3.1	0.19
Variant IV	Working	47.5	26.41	91.59	99.68	31.48	62.94
	Waiting	2.05	0.58	0.19	0.32	66.45	33.75
	Blocked	50.45	73	0	0	2.07	0.19

4. Conclusion

Modern production companies must be able quickly adapt to changing customer requirements. That is why it is very important to be able to use techniques and tools that enable modelling and simulation of production flow. Computer simulation is undoubtedly a tool that greatly facilitates the process of production planning or production optimization for existing production systems. Verification of proposed changes in the organization of production carried out on the real production system is associated with the need to incur large capital expenditures, is labour-intensive and often impossible to carry out due to the inability to suspend production. This causes that this way of proceeding is inadvisable and very often impossible to implement. Computer simulation allows to check different models of organizational solutions and to follow the long-term behaviour of the system in a simple and effective way. The article presents the results of simulation tests of the flow model of the production system. The model was developed on the basis of a real company producing components of a car suspension. A simulation model for the original model of the production system was developed and four variants of organizational changes were proposed. Each variant included exactly the one idea of changes in the production system layout organization. The following changes in the production system were proposed, (i) introducing of an industrial robot for servicing of the hardening station, (ii) replacement of the industrial robot by engagement of the two extra production workers for servicing of the hardening station and the heat-treating furnace, (iii) replacement of the industrial robot via introducing of the roller conveyor and engagement of an extra production worker for servicing of the hardening station and the heat-treating furnace, and (iv) introducing of the two roller conveyors for the same purpose. Next, computer simulations were performed to each variant in order to examine, how the proposed changes in the production system organisation influence its production efficiency.

Having the computer simulation carried out, the comparative analysis of the production system productivity was performed. It made the selection of the best organisational variant possible. The results got during making the research unequivocally indicated usability of the computer simulation in organisational problem solving for the existing production system.

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