Evaluation of Practical Application of Plant Simulation in the Form of Experiments

Procjena praktične primjene simulacije postrojenja u obliku eksperimenata

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Summary

This contribution deals with the Simulation of manufacturing systems. Plant simulation is a modern instrument for optimizing factory production; however, the initial investment is high, especially for human resources, since the creation of a simulation model requires a lot of data from manufacturing, which needs to be analyzed and used as input into the simulation so that the simulation model is as close as possible to the real manufacturing system. Simulation enables changes to first be carried out in the simulation model and the defining of possible problems, through which in this case it is possible to avoid when introducing changes into an operation.

The measure of effectiveness of using inputs is the productivity of a manufacturing system, and the aim of organization management is to monitor, analyze and improve a manufacturing system through optimizing for the purpose of increasing its efficiency, ensuring higher quality and a higher volume of production, shortening supply time in the scope of transportation, improving logistics and increasing the profitability of the given organization.

KEY WORDS

product lifecycle managment
plant Simulation
quality production
digital plant
digitalization

Sažetak

U ovom radu govori se o simulaciji proizvodnih sustava. Simulacija postrojenja je moderni instrument za optimizaciju tvorničke proizvodnje; međutm, početno ulaganje je veliko, posebice u ljudstvu, budući da pravljenje simulacijskog modela zahtjeva veliku količinu podataka iz proizvodnje, koje treba analizirati i upotrebiti u simulaciji tako da simulacijski model bude što vjeriniji stvarnom proizvodnom sustavu. Simulacija omogućuje da se promjene prije svega provedu u simulacijskom modelu i definiraju mogući problemi, a time je moguće izbjeći iste probleme kada se promjene uvedu u rad.

Mjera učinkovitosti upotrebe ulaznih podataka je produktivnost proizvodnog sustava, a cilj organizacijskog menadžmenta je pratiti, analizirati i poboljšati proizvodni sustav optimizacijom kako bi se povećala učinkovitost, osigurala viša kvaliteta i veća proizvodnja, smanjilo vrijeme nabave tijekom transporta, poboljšala logistika i povećala profitabilnost date organizacije.

KLJUČNE RIJEČI

vijek trajanja proizvoda menadžment
simulacija postrojenja
kvalitetna proizvodnja
digitalno postrojenje
digitalizacija

INTRODUCTION

Predicting the effects of different changes in the life cycle of a product can be achieved through use of a digital factory as software support, namely by simulation programs such as, for example, plant simulation, which enable predicting the course of the process of planning, transportation, logistics and manufacture in a short time. The use of this tool enables the performing of experiments without direct interference into production and verifying the correctness of technological proposals before actually introducing them into a real manufacturing system.

In the scope of conducting the experiments the process of lacquering and pressing of metal sheets and the process of manufacturing crown caps were described [1]. The processing of metal sheets itself runs on automated production equipment; therefore, the work environment in which the process of manufacture took place was selected as the area of optimization in the organization. Optimization related in particular to the shortening of certain times for processing the sheets, transport and logical links, in which time reserves were identified. These were suitable for using and thus increasing the productivity of the entire manufacturing system.

TOOLS AND METHOD

In the following sections of the contribution 5 experiments are carried out in which the independent and common effects of the proposed improvements in the manufacturing process organization using the simulation instrument PLANT SIMULATION will be tested. These are the proposals for improvement:

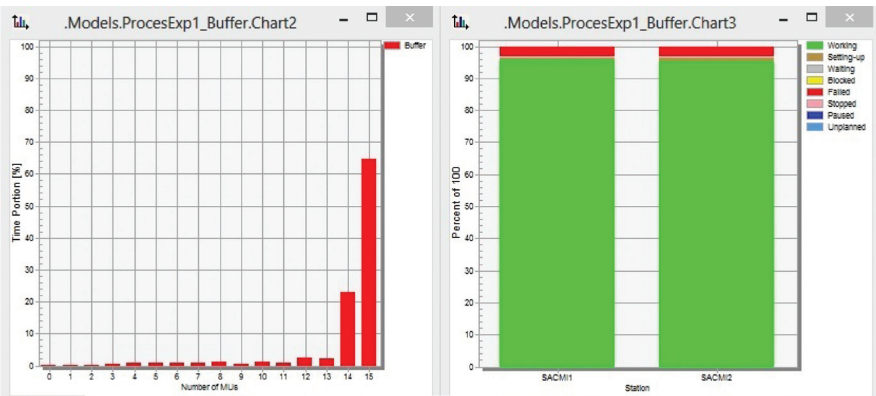
1. Shortening of the time necessary for the setting of the lacquer by introducing a drying oven into the process of production between the process of lacquering and the process of manufacture of the CC.
2. Shortening of the time necessary for a change of lacquer and colour on the LTG lines.
3. Introducing of a third series SACMI line for the manufacture of CC, (SACMI - ejectors line, LTG - printing line, CC - Crown Caps .

Experiment 1 – shortening the period for the setting of the lacquer

The process of setting in the model is represented by the object Buffer, with a processing time of 24 hours. The proposed solution in practice represents placing a drying oven into the manufacturing system between the processes "pressing" and "striking of CC". The period for setting of the lacquer would in this way be shortened from the original 24 hours to an anticipated 4 hours (2 hours for setting of the lacquer, 2 hours for ventilating the ovens). By creating the experimental model, in the scope of which the period of processing in the object Buffer (see Fig.1) is defined as 4 hours, the influence of these changes will be verified in the total production of the manufacturing system and the impact on the capacity of loading of the object Buffer. The tables below shows the words "KU" and "sluzba" in software as a service and a CC.

From the above-presented image in comparison with Fig. 2 and Fig. 3 the following effect of the simulated change follows:

- the loading of object Buffer dropped by 10%,
- the period of processing of objects SACMI1 and SACMI2 grew by 2.8% for each piece of equipment, which had as a consequence growth in the volume of processed entities for the output of CC by 3.015%.



Simulation time: 30:00:00:00.0000

Cumulated Statistics of the Parts which the Drain Deleted

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Sluzba	Entity	1:17:59.4940	587	1	100.00%	0.00%	0.00%	30.77%	
KU	Entity	1:04:59:37.7122	410	1	16.91%	0.00%	83.09%	12.93%	

Figure 1 Statistical output from the model of experiment 1

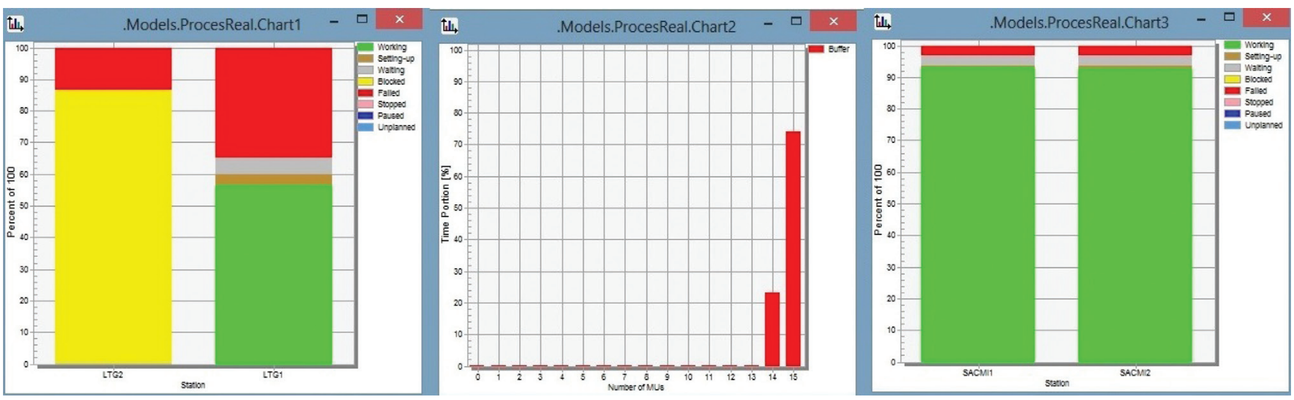


Figure 2 Use of the operation time of equipment before the change

Simulation time: 30:00:00:00.0000

Cumulated Statistics of the Parts which the Drain Deleted

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Sluzba	Entity	1:17:04.1187	598	1	100.00%	0.00%	0.00%	31.14%	
KU	Entity	1:06:39:35.0653	398	1	16.07%	0.00%	83.93%	12.23%	

Figure 3 Statistical output of the basic simulation model before the change

Cumulated Statistics of the Parts which the Drain Deleted

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Sluzba	Entity	1:13:02.7197	685	1	100.00%	0.00%	0.00%	32.86%	
KU	Entity	1:06:34:33.4523	398	1	15.71%	0.00%	84.29%	12.26%	

Figure 4 Statistical output of the basic simulation model

Experiment 2 – shortening the duration of the change of lacquer and colour

Each change of lacquer and colour lasts 30 minutes; however, it is essential in the scope of carrying out individual orders, because the type of lacquer and the number of colours are specific for each order (see Fig.4). The proposed improvement consists in optimizing the process of changing the lacquer and colours such that the duration of this process is minimized. In the experimental model a proposed shortening of the time needed for a change of the lacquer of object LTG2 and the colour in object LTG1 was introduced from the original 30 minutes to an assumed 25 minutes. The effect of this change was monitored by comparing the statistical output from the experimental model versus the output from the basic model.

From the above-mentioned image, in comparison with Fig.3., the following effect of the simulated change results:

- the average period of processing 1 entity as a service dropped by 5 minutes (represents the time-savings during the change of lacquer/colour),
- the number of processed entities for the output Service grew by 14.55%,
- the number of entities processed by lines LTG2 and LTG1 for the purpose of manufacture of CC grew; however, due to the loading of the object Buffer, this was manifested only in the collective in-process production.

Experiment 3 – increasing the production capacity in the manufacture of CC

At present the process of CC manufacturing is represented by 2 series of SACMI production lines. The loading capacity of the object Buffer (see Fig. 2) was evaluated as a space for introducing a third series of the SACMI production line. The proposed change was simulated in experiment model 3 by adding object SACMI3. On the basis of the statistical output from this model the effect of the simulated change in the loading of the object Buffer was monitored, as were the amount of processed entities and the loading capacity of objects SACMI1, SACMI2 and SACMI3.

Cumulated Statistics of the Parts which the Drain Deleted

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Sluzba	Entity	1:15:54.7158	570	1	100.00%	0.00%	0.00%	31.62%	
KU	Entity	1:05:04:57.2753	425	1	16.98%	0.00%	83.02%	12.89%	

Figure 5 Statistical output from the model of experiment 3

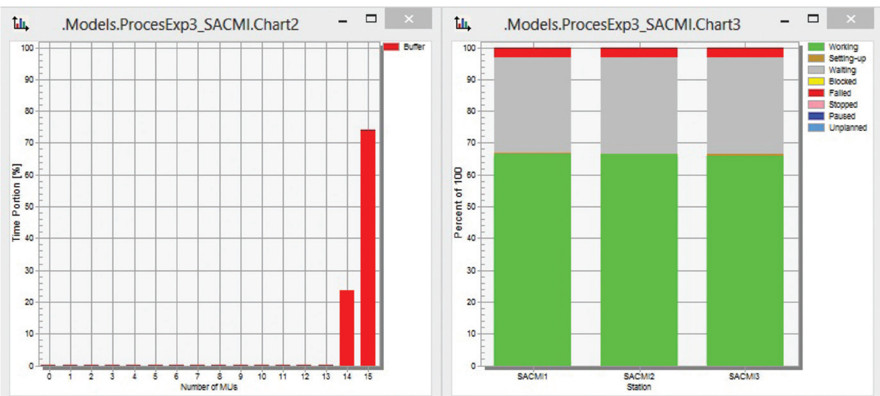


Figure 6 Loading of the equipment in the model of experiment 3

From the above-mentioned images, in comparison with Fig. 2 and Fig. 3., the following effect of the simulated changes results:

- the volume of the processed entities for the output of CC grew by 6.78%,
- the period of processing SACMI objects dropped to 66.3%, i.e. a reserve for further processing was created,
- the loading capacity of the object Buffer remained unchanged.

Experiment 4 – simulation of the combination of experiments 1, 2 and 3

In the individual experiments 1, 2 and 3 the effect of the simulated changed was assessed individually in comparison with the basic simulation model of the real manufacturing system. In experiment 4 their common effect on the overall productivity of the system was simulated; thus all proposed changes were implemented in the scope of a single model.

On the basis of statistical outputs the effect of the simulated changes on the loading capacity of the SACMI objects, the object Buffer and the amount of processed entities for outputs of CC and Service was monitored.

From a comparison of the above-mentioned images with Fig. 2 and Fig. 3., the following effect of the simulated changes in experiment 4 results:

- production of objects LTG2 and LTG1 grew by 8.63%,
- the share of processed entities in the output Service dropped by 21.74%,
- the share of processed entities in the output CC grew by 54.27%,
- the relative loading of the object Buffer dropped significantly,
- the period of processing of the SACMI objects grew by 2.8%.

Experiment 5 – simulation of the combination of experiments 2 and 3

Experiment 5 represents the simulation of common introducing of the proposed changes simulated in experiments 2 and 3. The change simulated in the experiment was excluded on the basis of the fact that the achieved benefit (higher volume of processed entities by 3% in the output of CC) is not considered as sufficient with respect to the financial demand of carrying out this change in practice (investment in the drying oven).

In this experiment the introducing of a third series of the SACMI line and shortening of the time for changing lacquer and colour on the LTG lines and their common effect on productivity in the simulated manufacturing system was simulated. On the basis of statistical outputs the volume of the processed entities in the outputs Service and CC were monitored, as was the loading of the individual objects.

Cumulated Statistics of the Parts which the Drain Deleted

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Sluzba	Entity	1:13:08.8077	468	1	100.00%	0.00%	0.00%	32.81%	
KU	Entity	19:05:45.2199	614	1	24.96%	0.00%	75.04%	19.64%	

Figure 7 Statistical output from the model of experiment 4

Figure 8 Loading of the equipment in the model of experiment 4

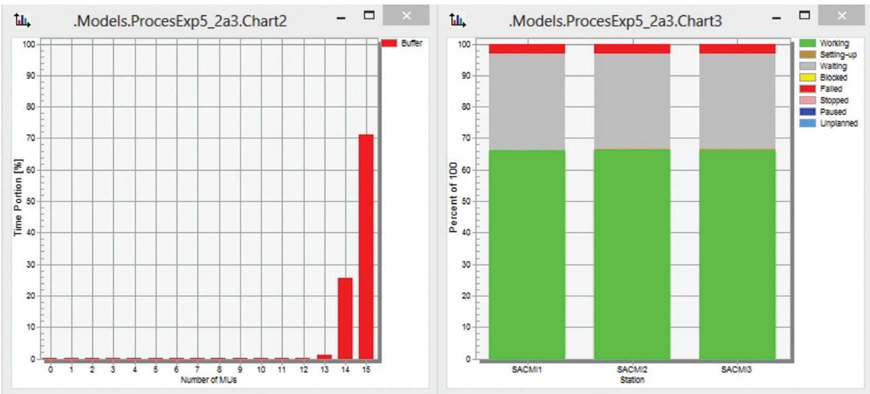


Figure 9 Statistical output from the model of experiment 5

Cumulated Statistics of the Parts which the Drain Deleted

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Sluzba	Entity	1:13:19.9149	658	1	100.00%	0.00%	0.00%	32.73%	
KU	Entity	1:04:52:32.2429	424	1	16.60%	0.00%	83.40%	12.99%	

Figure 10 Loading of the equipment in the model of experiment 5

On the basis of a comparison of the facts presented in Fig. 10 and Fig. 9 and with the statistical outputs from the basic model (Fig. 2 and Fig. 3) the following effect of the simulated changes result:

- the volume of processed entities in the output Service grew by 10.03%,
- the volume of processed entities in the output CC grew by 6.53%,
- the relative loading capacity of the object Buffer remained unchanged in comparison with the basic model,
- a decline in the overall period of processing the SACMI objects to 65.8% of the total operation time.

The reason for the decline in overall processing period for the SACMI objects is the insufficient capacity of the object Buffer (15 entities) and likewise the simultaneous division of the flow of material in the output from object LTG1 (41% of entities head to the object Buffer, 59% of entities head to the output Service). Placement of a third series of SACMI lines creates the space for a change of this ratio in favour of entities further processed for the purpose of CC manufacture.

In the second part of experiment 5, the ratio of 100% of the processed entities was divided in the output from object LTG1 in the simulation model as follows:

- 60% head to the object Buffer (entities processed for the purpose of CC manufacture),
- 40% head to the output Service (entities processed as a service).

Likewise, the capacity of the object Buffer was changed to 22 entities for the purpose of effective use of the operation time of the SACMI equipment, which (while the previously defined capacity of the object Buffer of 15 entities) expected 34.2% of its total operation time for the input to the process.

Cumulated Statistics of the Parts which the Drain Deleted

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Sluzba	Entity	1:11:12.5837	478	1	100.00%	0.00%	0.00%	33.70%	
KU	Entity	1:05:55:43.6332	597	1	16.02%	0.00%	83.98%	12.53%	

Figure 11 Statistical output 2 from the model of experiment 5

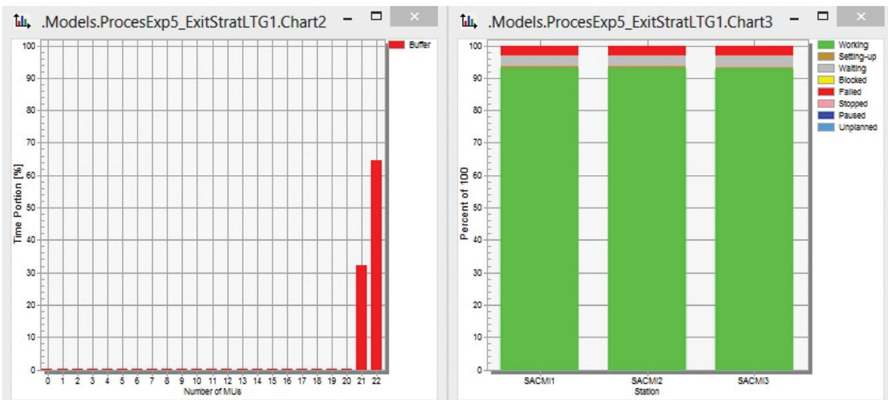


Figure 12 Loading of the equipment 2 in the model of experiment 5

Furthermore, the change versus all of the previous experiments consisted in a change of capacity of the object Buffer to 22 entities and a change of the ratio of the divided processed entities in the output from object LTG1. This change was shown to be effective, because the total period of processing the SACMI objects grew to 93% from the original 65.8%. This is also significantly manifested in the number of processed entities for the individual outputs:

- 478 entities in the output Service (a decline by 20.07% in comparisons with the basic model, a decline by 27.36% in comparison with the original model of experiment 5),
- 597 entities in the output CC (growth by 50% in comparison with the basic model, growth by 40.8% in comparisons with the original model of experiment 5).

In the following table the anticipated effect of the proposed improvements on the basic simulation of experiments 1-5 is described. The number of processed entities was monitored for a period of 30 days overall and for the individual outputs Service and CC. The weights of financial demand of the introduced changes in practice (1-low, 2-medium, 3-high) were assigned to the individual experiments, and the generated outputs were recalculated for their possible financial evaluation, because the processed entities in the outputs Service and CC have different selling prices. The selling price presented is inclusive of the price of the initial input – the sheet metal. In experiments 1-3 each of the proposals for improvement was simulated independently, and in experiments 4 and 5 the combination of proposals for improvement was simulated; therefore experiments 1-3 and experiments 4 and 5 will be evaluated separately. The change of the selected evaluations is depicted as a percentage with respect to the basic model (a decline by red, growth by green). The most suitable variant is in the table indicated by the pink colour.

RESULTS, DISCUSSION AND CONCLUSIONS

From experiments 1-3 proposal number 2, the effect of which was simulated in experiment 2, was selected as the most suitable proposal for improvement for introduction into the real manufacturing system. The feasibility of improvement of number two appears in the assumed low costs (in comparison with the costs necessary for carrying out the other proposals) and was the only one that generated growth of production of the simulated manufacturing system; however, only for the output of sheets processed as a service. For the process of CC manufacture this fact means potential for re-evaluating the current capacities of CC manufacture, since CC manufacture brings the organization 65.1% higher financial evaluation than the service itself – lacquering and colour printing of sheet metal.

Experiments 1 and 3, unlike experiment 2, did not lead to any overall growth of production, but only to a shift of part of the processed sheets in favour of the process of CC manufacture, which is financially more interesting for the organization. For the mentioned reason, experiments 4 and 5, in which a combination of introducing all three of the proposed improvements, were carried out. From the results depicted in Tab. 1 it is evident that experiment 4 achieved better results, which is related to the volume of production of the simulated system; however, after taking the necessary investment costs into account, experiment 5, in which the manufacture system was simulated after introducing of proposals 2 and 3, was selected as the most suitable. The benefit of the experimental

Table 1 Comparison of the results of individual experiments

Experiment	Description	Number of processed entities			Weight of fin. demand	Value of output in EUR			Fin. contribution in EUR
		CC	Service	Total		CC	Service	Total	
0	basic model	398 (100%)	598 (100%)	996 (100%)	-	1321887	1201980	2523867 (100%)	-
1	shortening the period of setting of lacquer	410 (+3.02%)	587 (-1.84%)	997 (-)	3	1361742	1179870	2541612	17745 (+0.7%)
2	shortening the period of change of lacquer/colour	398 (-)	685 (+14.55%)	1083 (+8.73%)	1	1321887	1376850	2698736	174869 (+6.93%)
3	increasing prod. capacity of SACMI lines	425 (+6.78%)	570 (-4.68%)	995 (-)	2	1411562	1145700	2557262	33395 (+1.32%)
4	combination of exp. 1,2,3	614 (+54.27%)	468 (-21.74%)	1082 (+8.63%)	1+2+3	2039292	940680	2979972	456105 (+18.07%)
5	combination of exp. 2,3	597 (+50%)	478 (-20.07%)	1075 (+7.93%)	1+2	1982830	960780	2943610	419743 (+16.63%)

part of the contribution is mainly in verifying the considered improvements in a virtual environment through modern simulation software. The management of the organization thus obtained the opportunity to imagine the possible benefits of the proposed solutions.

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