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WYKORZYSTANIE SYMULACJI KOMPUTEROWEJ DLA OCENY WARIANTÓW WYTWARZANIA NOWEGO WYROBU

Streszczenie: W artykule przedstawiono wykorzystanie symulacji komputerowej w firmie montażowej dla oceny wariantów wytwarzania nowych wyrobów. Metodą symulacji komputerowej porównywane są proponowane warianty z których wybierany jest najlepszy. Badanie przeprowadzono w utworzonym miejscu pracy, a wyniki eksperymentu przedstawiono w niniejszym artykule.

Słowa kluczowe: symulacja, model symulacyjny, projekt symulacyjny

COMPUTER SIMULATION IN THE ASSESSMENT OF NEW PRODUCTION VARIANTS

Summary: The article deals with computer simulation which was used in the assembly company when assessing new production variants. The simulation compares the proposed variants from which an appropriate variant was selected. An experiment has been proposed in the created workplace, the results of which are described in the article.

Keywords: Simulation, simulation model, simulation project

1. Introduction

Nowadays, more and more company are starting to use computer simulation as a production planning tool, but it also uses optimization, cost minimization, and productivity growth. [3,5]

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Using computer simulation, the effects of various decisions on the simulation model are tested. This model allows you to perform a number of experiments that are then analysed, evaluated, optimized, and the results can be applied to the real system. Experimenting does not interfere directly with production, which prevents possible errors. When the changes are made, the simulation verifies how the system will behave in the future, and it is possible to eliminate or solve the problems in advance. The use of computer simulation is a significant asset for the company and thus increases its competitiveness on the market. [1,2]

2. Solution of simulation project in the company

The simulation must be approached as a project in order to achieve the desired results. The simulation project consists of certain steps, which have been partially altered to solve the problem in the company, but the sequence of steps has been retained.
The simulation project in the company consists of the following steps:
1. Problems formulation and setting goals.
2. Model conceptualization.
3. Data collection.
4. Create a simulation model.
5. Verification and validation.
6. Experiment 1: Compare variants.
7. Experiment 2: Use of the worker.
8. Evaluation.
The following subchapters will describe the individual steps of the simulation project.

2.1. Problems formulation and setting goals (1. step)

The first problem is that the company has created several variants of the layout solution when designing a new workplace. Using a computer simulation, the company decided to find out if the proposed variants were able to be assembled 20 products in 8 hours.
The first goal of the simulation project was to verify by computer simulation whether the proposed variants (simulation models) would be able to produce the required quantity of products. Subsequent to the results obtained (variants evaluation), it was possible to select a appropriate variant.
The second problem was the use of the final assembly worker on the completed assembly workplace.
The second goal of the simulation project was to design and simulate variants using a worker and to select a appropriate variant.

2.2. Model conceptualization (2. step)

In order to create a conceptual model, it was necessary to collect basic information about the planned assembly workplace. It was necessary to find out the number of assembly and control tables at the workplace, the number of workers and the logic of the workplace. After the number of workplace tables in the simulation project has been identified the following designations are given: assembly tables (AT), final

assembly table (FAT) and control table (CT). Finally, a conceptual model was created (Figure 1).
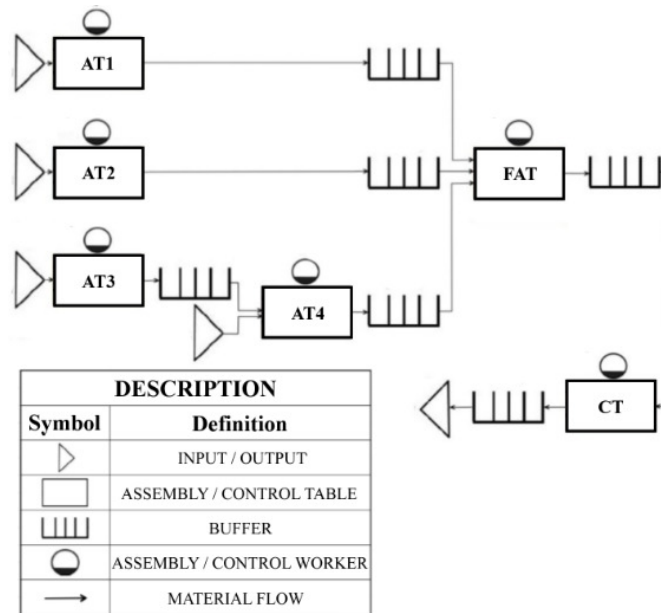

Figure 1. Conceptual model

2.3. Data collection (3. step)

Describing the problem in the first step, it is necessary to determine what data will be needed to create a simulation model. The following data were obtained:
-   Number of workers (2.2 Model conceptualization): 5 assembly workers, 1 control worker.
-   Working time: 480 minutes, break time: 30 minutes.
-   Input materials (screws, nuts, washers, cable ties, electro components).
-   Planned times for assembly tables and control table.
-   Distances between tables and racks.
-   Speed of workers walking. [4]

2.4. Create a simulation model (4. step)

Using the conceptual model and the data obtained, a simulation model began to be created. The Plant Simulation from Siemens was used to create the simulation model. A basic simulation model in which basic distances and planned assembly times have been set is shown in Figure 2. Once the simulation model was created, verification and validation were performed. [6]

Figure 2. Basic simulation model

2.5. Verification and validation (5. step)

For further work on the simulation model, it was necessary to examine its accuracy in two steps:

Verification: the simulation model was run in order to detect errors that could have arisen in modelling. When the simulation was running, it was also checked whether the model included the necessary details due.

Validation: the identity of the simulation model with the planned workplace was checked. Due to the fact that the workplace was in the planning stage, it was checked whether the model worked on principles as workplaces similar to the planned workplace. [1]

2.6. Experiment 1: Compare variants (6. step)

Before the start of the comparison in the basic simulation model, the length of the workers' path (the distance between the tables and the stands) changed, leading to the creation of simulation model variants (Variant_01, Variant_02 a Variant_03). Before running the simulation, the simulation time was set to 960 minutes (480 minutes run-in from zero, another 480 minutes of work time - data collection).

Evaluation of the comparison

The results obtained from the simulation were processed into Figure 3 and Figure 4. Figure 3 shows that all four variants have assembled the same number of products, and it is not possible to select the appropriate variant from them. Figure 4 shows the distance travelled by workers during working time. In view of the distance travelled, it is not possible to determine the appropriate variant.
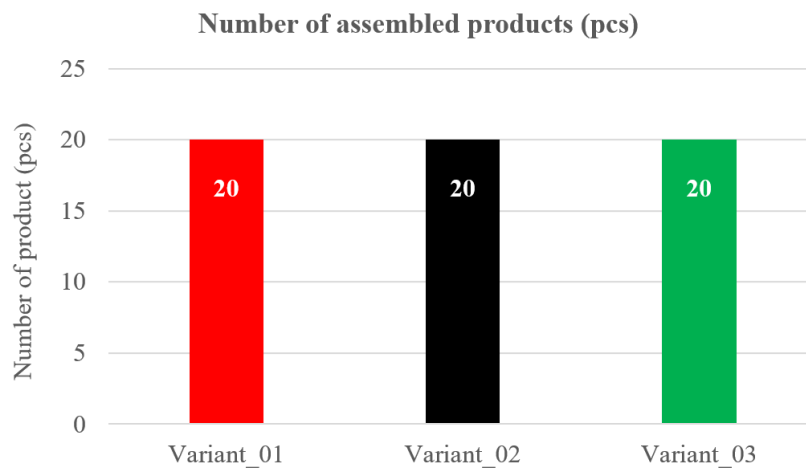

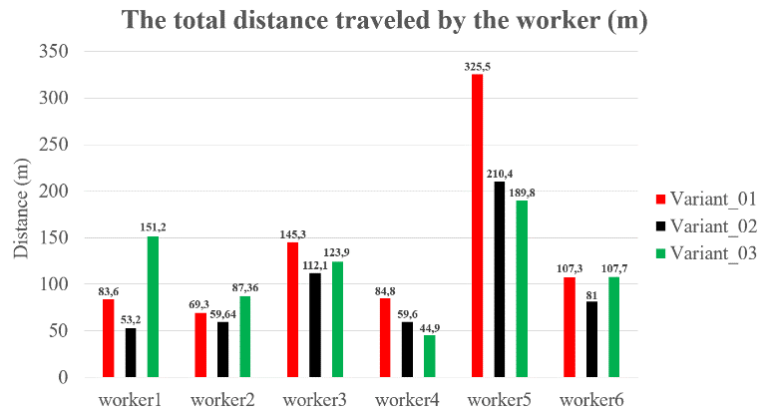
Figure 3. Number of final products

Figure 4. Distance

Table 1 shows production lead times. The difference between these times is minimal and does not affect the total amount of products assembled. It is not possible to identify the appropriate variant.

Table 1. Production lead time

Production lead time [mm:ss.xx]		
Variant_01	Variant_02	Variant_03
22:16.34	22:14.97	22:15.82

Because it was not possible to select the appropriate variant, the method of multi-criteria assessment of variants was used, with computer simulation being one of the criteria.

Multi-criteria assessment of variants to select the appropriate workplace variant

After consulting the company, it was concluded that the appropriate variant must contain the KANBAN rack for the use of the FIFO method and that the rack must have a lower capacity and a smaller area. Also, the warehouse worker's path was taken into account because the variants have different lengths of the supply path. After defining the requirements, the criteria listed in Table 2 created. [1]

Table 2. Criteria

Tag	Name	Variant_01	Variant_02	Variant_03
1	KANBAN rack	no	yes	yes
2	Capacity of the rack	48 pcs	16 pcs	16 pcs
3	Supply path	50,88 m	57,3 m	48,22 m
4	Rack area	2,94 m^2	4,5 m^2	2,25 m^2
5	Assembled product – 20 pcs	yes	yes	yes

The criteria were ranked according to importance. The criteria were assigned points by means of a quantified comparison matrix and the weighting of individual criteria was calculated.

Multi-criteria assessment of variants – conclusion

From the calculated weights of the criteria and the subsequent assessment of the variants according to the criteria, the weighted sum for each variant was calculated and the order was determined. (Table 3)

Table 3. Assessment of the variants

Criterion	Criterion Weights	Variant_01	Variant_02	Variant_03
Assembled products – 20pcs	0,43	0,333	0,333	0,333
KANBAN rack	0,256	0	0,5	0,5
Rack area	0,186	0,333	0	0,667
Capacity of the rack	0,116	0	0,5	0,5
Supply path	0,012	0,333	0	0,667
Weighted sum		**0,209**	**0,329**	**0,461**
Order of variants		**3**	**2**	**1**

Using multi-criteria assessment, Variant_03 was selected as the appropriate variant. This variant is recommended to the company. The advantage of the selected option is that by reducing the area of the KANBAN rack, the total area of the assembly workplace is reduced. By reducing the total area of the assembly workplace, an unused area was created. Subassembly tables and a product repair table were added to this area. These tables were planned elsewhere.

2.7. Experiment 2: Use of the worker (7. step)

Experiment with the worker was carried out on the realized assembly workplace. There are 8 product variants in the workplace. The company measured the times of each table according to the time study for each assembled product. After consulting the company, a variant of the product named Product_3 was used for the experiment, the times of which are recorded in the Table 4.

Table 4. The times of Product_3

Table	Component / Product	Time [min]		Total time [min]
AT1	A	assembly	19,46	**24,96**
		quality control	4	
		storage	1,5	
AT2	B	assembly	10,68	**16,18**
		quality control	4	
		storage	1,5	
	C	Grinding	5	**25,69**
		Assembly	15,19	
		quality control	4	
		Storage	1,5	

		drilling	5	
AT3	D	assembly	19,3	**25,8**
		belt adjusting	1,5	
AT4	E	assembly	19,15	**24,65**
		quality control	4	
		storage	1,5	
FAT	Product_3	assembly	16,11	**17,61**
		storage	1,5	
CT6		final quality control	20	**20**

The reason for selecting this product was that most often assembly in the workplace. On the AT2 (assembly table 2) for Product_3 assembled two different components.

For this reason, the simulation model had to be changed. In the simulation model, the work path was removed and a new logic of the model, more precisely the logic of the assembly table (AT2), on which two different components are mounted. After modifying the simulation model, the model was verified and validated:

Verification: correct logic was checked when the simulation model was run, whether the model contains all the details.

Validation: Validation compares the number of assembled products in the simulation with the number of real-assembled products at the workplace. The number of assembled products in the simulations is comparable to the real system (16 pieces of product), so the model can be considered as an approximation to the real state and an experiment can be performed.

After verification and validation began to work on design of experiment. During the consultations in the company, it was obtained that the final assembly worker does not use all his working time to assemble the products. Once the simulation time has been set and the time for each table has been set, the simulation model has started.

From the simulation results, it was obtained that the final assembly worker worked 58.70% of the total working time (480 minutes). It follows that 41.30% of the total working time is unused (waiting for components for final assembly). Based on this, an experiment was proposed in which the final assembly worker would perform a drilling operation from the AT3 assembly table or a grinding operation from the AT2 assembly table or perform a combination of these operations. On AT2 and AT3 tables, the total time would be reduced by 5 minutes and the worker would be more used.

The drilling operation is carried out on a stand-alone table on which is placed a stand drill. The assembly worker drills holes into the component that are needed to continue the assembly. The grinding operation is performed on the AT2 assembly table, where the assembly worker abrades the plastic mouldings needed for further assembly using. Three copies of the modified simulation model were created before the simulation started: V_g (a variant of grinding), V_d (a variant of drilling) and V_gd (a variant of grinding and drilling). The variants were set as follows:

- **V_d:** a path was created for the worker in the final assembly to the table with the stand drill. The length of this route is 7.7 m. The final assembly worker at the time of waiting will drill holes in the components. Table time is set to 5 minutes and the time for the AT3 assembly table is reduced by 5 minutes.

- **V_g:** in this variant, the final assembly worker grinding (flat file) plastic mouldings. The grinding time is set to 5 minutes. At AT2, the time is reduced by 5 minutes.

- V_gd: this variant is a combination of the previous two variants.

After setting the simulation time to 960 minutes, the simulation started, and the simulation results are processed into graph (Figure 6). [1]

2.8. Evaluation (8. step)

At the end of the simulation, the obtained results were processed into the graph of Figure 6. Figure 6 shows that the highest percentage of worker use (98,90%) has the variant V_gd. The variant is not suit in the case of drilling (10 pcs) and grinding (16 pcs). These quantities do not cover the minimum daily need, which is 16 drilled pieces and 16 ground pieces. In this variant, a smaller number of products is assembled (15 pcs) than in the original state (16 pcs).

The V_d and V_g variants are suitable for the drilling and grinding pieces, but variant V_g are suitable for the use of the worker and for the assembled total number of products. In variant V_g, use of the worker is 84,24% and one product is assembled more (17 pcs) than at V_d (16 pcs) and in the original state (16 pcs).

Based on the data obtained from the experiment using the final assembly worker, the V_d variant is recommended.
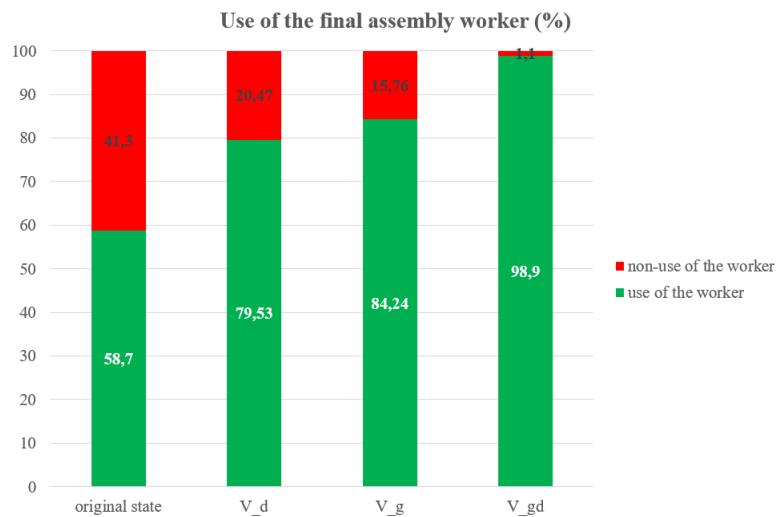

Figure 5. Use of the final assembly worker

3. Conclusion

This article deals with the realization of a simulation project in an assembly company. The simulation verified whether the proposed variants (simulation models) of the planned assembly workplace are capable of producing 20 pieces of products in 480 minutes. It was obtained that the simulation models of the proposed variants produced the same number of pieces and it was not possible to determine the appropriate variant. From the point of view of the distance travelled by the workers and the production lead time, it was not possible to determine the appropriate variant. For this reason, the multi-criteria assessment of variants was used, with simulation

being one of the criteria. Through a multi-criteria assessment, the appropriate variant was found.

The second part of the article deal with the design of an experiment using a final assembly worker on a completed assembly workplace. In the simulations of the original workplace, it was found that the worker of the final assembly was not used sufficiently. Therefore, variants with the use of a worker were proposed, which were subsequently simulated. Based on the results, a suitable option was selected, which was recommended variant to the company.

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