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IMPLEMENTATION OF COMPUTER SIMULATION IN THE ASSEMBLY PLANT IN TERMS OF AN INNOVATIVE SOLUTION FOR WORKFLOW OPTIMISATION

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Abstract
The paper deals with the implementation of computer simulation in the assembly plant in terms of an innovative solution for new production planning, workflow optimisation and cost-effectiveness. The paper describes the creation of a simulation project in which a simulation model of the assembly line was created to determine the use of the final assembly operator. Based on the results, an experiment was designed, in which variants (in the simulation model) with different employee utilisation were created. The simulation results from each variant were compared and the variant with a higher percentage of employee utilisation was selected. The selected variant was economically evaluated in terms of effective use of labour costs.

Keywords
Industrial engineering, simulation, simulation project, employee utilisation.

1. Introduction

Nowadays, more and more companies are starting to use computer simulation as a support tool for production planning, but they will also find application in optimisation, cost minimisation, wage cost efficiency and productivity growth. A simulation tests the effects of different decisions on the simulation model. This model produces a number of experiments that are subsequently analysed, evaluated, optimised, and the results are applied to the real system. When performing experiments, it does not interfere directly with production, thus avoiding possible errors. When the required changes are made (in the simulation model), the simulation verifies how the system will behave in the future, and allows removing or resolving problems in advance. The use of computer simulation is a significant benefit for the company and thus increases its market competitiveness [3, 4, 6].

To achieve the desired goals, companies must approach simulations as a project. The simulation project consists of individual steps (problem definition, model conceptualisation, data collection, creation of a simulation model, verification and validation, experiment execution, analysis of results and evaluation, model documentation, and the last step is implementation). These steps must be followed in a logical sequence. [1, 8].

2. Simulation project of the assembly work station

A simulation project is being implemented within the company that deals with the assembly of devices for air, rail and road transport. These devices are assembled by operators at manual assembly work stations. After consulting with the company, this assembly line was selected for the simulation project. Eight variants of the parking system are assembled on this assembly line. The variant Z3 was used for the simulation because this variant is most often assembled on the assembly line. The simulation project consists of certain steps, which were partially altered to solve the problem in the company, but the sequence of steps was retained. The simulation project (for the assembly line) consists of seven steps that are shown in Fig. 1 and are described in more detail in the following sections.

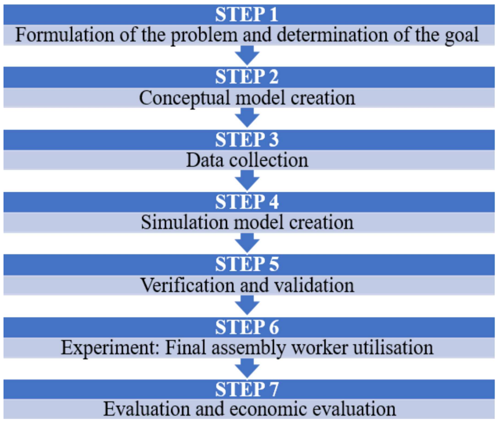

Fig. 1. Seven steps of simulation project for assembly line (source: authors).

2.1. Formulation of the problem and determination of the goal

After consultations with the company, it was found that the final assembly operator did not use all his working time. This is due to the fact that the final assembly operator is waiting for the components needed to assemble the final product. The goal is to create and simulate variants (simulation models) with a different final assembly operator utilisation and select an appropriate variant.

2.2. Conceptual model creation

In the second step of the simulation project basic information on the planned assembly work station was gathered. The number of assembly tables, the number of operators and the logic of the assembly line were found. After detecting the number of assembly tables and operators, the following designations for the simulation project have been defined (object names for a conceptual model and later for the simulation model): assembly table (MS), final assembly table (FMS), quality control table (KS), assembly operator (PM), final assembly operator (PFM) and quality control operator (PKS). Finally, a conceptual model (Fig. 2) was created.: assembly table (MS), final assembly table (FMS), quality control table (KS), assembly operator (PM), final assembly operator (PFM) and quality control operator (PKS). Finally, the conceptual model (Fig. 2) was created. In Fig. 2 (marked with a black frame), it can be seen, there is the assembly table with the assembly operator that was selected for the experiment.

2.3. Data collection

By defining the problem in the first step, it was possible to determine what data would be needed to create the simulation model. The following data was obtained:

- Number of operators (3.2 Conceptual model creation): 5 assembly operators, 1 quality control operator.
- Work shift lasts: 510 minutes (working time lasts 480 minutes, break time lasts 30 minutes).
- Input materials: screws, nuts, washers, cable ties, electro components and plastic skeleton of the assembled component.
- There is a special Kanban rack in the assembly work station, into which the finished components are inserted for final assembly.
- The company performed time measurements at the assembly site in accordance with the time study for each device variant. Table 1 shows assembly tables, activity performed on these assembly tables and total assembly times. This data is needed for the experiment.
- Two different components (B and C) are assembled on MS2 assembly table. These components are required for the final assembly of the Z3 variant. Other assembly tables only assemble one component.

2.4. Simulation model creation

After creating a conceptual model and obtaining the necessary data, the simulation model can be created. The simulation model was created using the simulation software Plant Simulation developed by Siemens.

In the simulation model, resources that enter assembly tables (input material) were created, then assembly tables and a quality control table were created. For each table, an assembly operator was assigned. Then, at the MS2 assembly table, a rule was created to make sure the operator knew which component was to be assembled. The rule, based on the quantity in the buffer (in reality it is the Kanban rack), determines whether component B or C will be assembled on MS2. If the same number of B and C components were in the buffer, component C would be assembled because it has a longer total assembly time [2, 5].

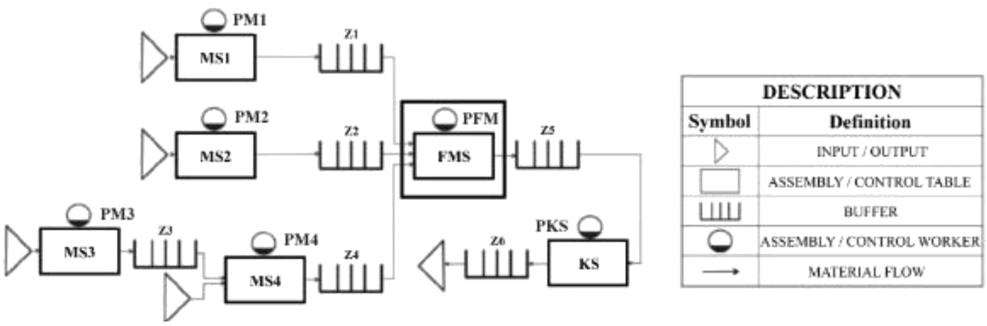

Fig. 2. Conceptual model (source: authors).

Table 1
Time table required for the experiment.

Table	Component/Product	Activity	Time [min]	Total time [min]
MS2	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	
MS3	D	drilling	5	25.8
		assembly	19.3	
		belt adjusting	1.5	
FMS	Z3	assembly	16,11	17.61
		storage	1.5	

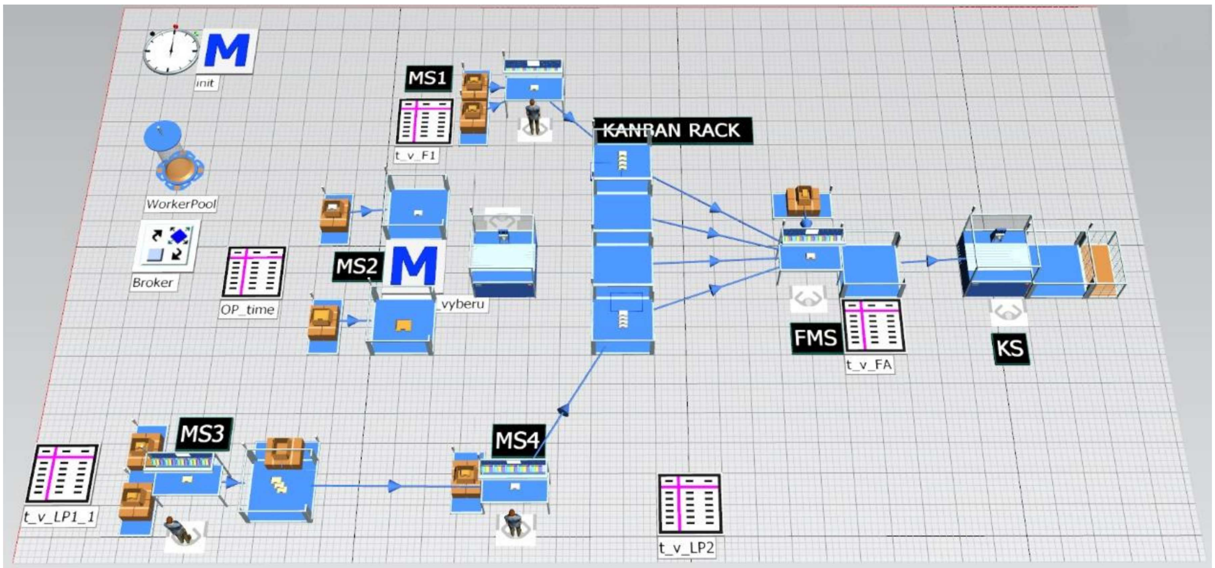

Fig. 3. Basic 3D simulation model.

Figure 3 shows the created 3D simulation model of the original assembly work station. After the simulation model is created, the next step is taken in which the model is verified and validated.

2.5. Verification and validation

Before experimentation simulation model was checked. The correctness of the model was checked in two steps:

Verification: When verifying the simulation model, it was checked whether the model's overall logic was correct. If the simulation model showed some errors, their causes were removed.

Validation: The validation mode compared the simulation model with the real assembly line in terms of the total number of assembled Z3 products. The number of assembled products is comparable to the real assembly line (16 pieces), so the simulation model can be considered as a real approximation to the real assembly line.

After successful verification and validation, the experiment could be run.

2.6. Experiment: final assembly operator utilisation

After verification and validation, the simulation time (480 minutes – run of the model from the zero state, and another working time of 480 minutes for data collection) was set and the simulation model was run.

From the simulation results, it was found that the final assembly operator 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 of final assembly). Based on the results, an experiment was designed, in which variants (simulation models derived from the basic model) with a different employee utilisation were created:

- **Drilling variant** (Dv): the final assembly operator will perform a drilling operation from the MS3 assembly table at the time of waiting. Drilling is carried out on a vertical stand drilling machine (VSDM) located on a separate table. The final assembly operator drills holes into the components that are needed to continue the assembly. The drilling time lasts 5 minutes and the table with the VSDM is located 7.7 meters from the final assembly operator. On the MS3 assembly table, the total assembly time is reduced by 5 minutes. The required number of drilled components for a work shift is 16 pieces.

- **Filing variant** (Fv): in this variant, the final assembly operator performed a filing operation from the MS2 assembly table. The final assembly operator scrubs plastic mouldings using a hand file (tool). The filing time is 5 minutes and is performed on the assembly table. On the MS2 assembly table, the time is reduced by 5 minutes. The required number of filed components for work shift is 16 pieces.
- **Drilling and Filing variant** (DFv): a combination of the previous two variants.

Once the simulation time was set, the simulation was run.

2.7. Evaluation

After the simulation results, it was found that the highest percentage of employee utilisation (98.90%) was achieved by DFv. The DFv produces unmatching number the drilled and filed pieces (10 and 16 pieces respectively). These quantities do not cover the minimum demand for a work shift and fewer products are assembled (15 pieces) compared to the real assembly work station (16 pieces).

The Dv and Fv variants are appropriate in terms of the drilled and filed pieces, but variant Fv is optimal for the employee utilisation and for the assembled total number of products Z3. In the variant Fv, the employee utilisation is 84.24% (in the variant Dv, the employee utilisation is 79.53%) and is assembled one product more (17 pieces) than in the real assembly line (16 pieces) and in the variant Dv (16 pieces).

After the evaluation of the results, the selected variant Fv was economically evaluated in terms of the effective use of wage costs for the final assembly operator.

Economic evaluation

In the economic evaluation, the real assembly line was compared with the recommended variant Fv in terms of the inefficient use of the wage costs of the final assembly operator. The goal of the comparison is to point out the advantage of Fv variant. Before comparing, it was necessary to obtain the operator's hourly wage. For the purposes of the calculation, the hourly wage was calculated from the super-gross wage (1), which represents the employer's cost per employee. The hourly wage, calculated from the super-gross wage, is 6.25 EUR

$$\begin{aligned}\text{super gross wage} &= \text{gross wage of employee}\\ &+ \text{employer's contributions paid for an employee.}\end{aligned} \tag{1}$$

The experiment found that in the actual assembly line, the final assembly operator utilisation is 58.70% of the total working time of 480 minutes, where work shift lasts 510 minutes. It follows that the operator is unused for 41.30% of the total working time. After calculation of the employer's costs, it gives 20.65 EUR for a work shift. In terms of monthly costs, these amounts represent 413 EUR for the company. This amount reflects an inefficient use of costs because the company pays the operator for inactivity (waiting for components).

In the Fv variant, the non-utilisation of operators was reduced to 15.76% of the total working time. In terms of cost, this amounts to 7.88 EUR per work shift and it is 157.60 EUR per month (20 workdays). Compared to the current situation, the inefficient use of costs has fallen by 61.84%, which in monetary terms means a saving of 255.40 EUR per month. The employee utilisation could be increased if a final assembly operator assisted with drilling and thus increased savings in economic terms [7].

3. Conclusion

This paper considered the creation of a simulation project at the assembly line where eight variants of devices for the parking system are assembled. In the introduction, the steps of the simulation project are described, which were partially altered in the simulation project implemented for the company. The creation of simulation models (using software Tecnomatix Plant Simulation 13) and the design of experiments was done at the laboratory of the Digital factory at the Department of Industrial Engineering, Faculty of Mechanical Engineering at the University of Žilina.

In the first step, the problem was defined after the consultation with the company and the goal was set. In the second step, basic information about the assembly line was obtained and a conceptual model was created. After the conceptual model was compiled, the data needed to create the simulation model was collected in the third step. In the fourth step, the simulation model was created in which the logic of the assembly line and the times of the assembly tables were set. After creating the simulation model, in the fifth step, the model was verified and validated, and the experiment was performed.

From the simulation of the model (the real assembly line), it has been found that the operator remains temporarily unused (waiting for components for final assembly). Therefore, variants of the work station were proposed, whereby the operator would also perform other activities (drilling from MS3, filing from MS2 or drilling and filing) besides the final assembly. Based on the results, the variant Fv was selected. This variant was then economically evaluated in terms of the efficient use of wage costs for the final assembly operator. When comparing the real assembly work station with the selected variant Fv, it was found that the company, by using the proposed variant, would make savings of 255.40 EUR per month per operator of the final assembly. The company would effectively use wage costs for the final assembly operator. Variant Fv was recommended to the company.

When creating simulation projects in the company, it was found that there were often changes in the assembly work station (change of assembly procedure, type of input material, amount of input material). Therefore, it is recommended the company use an external company that deals with computer simulation. This company would create a parametric simulation model for the assembly work station. If the company decided to use the simulation for other work stations, it would be advisable to invest in the purchase of simulation software.

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