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Streamlining utilisation of the assembly line using computer simulation

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Abstract: The increase in computer computing power and the development of simulation software make it possible to realise very accurate predictions of the impact of decisions on systems. The cost of investments in streamlining logistics and manufacturing systems is usually high. Therefore, verifying whether the implemented improvement will have a real intended impact on the system is necessary. The use of simulation helps reduce the risk of uncertainty in such projects. The article describes the simulation performed in the software Tecnomatix Plant Simulation 15.2 and their use in its described methodology for simulation study with achieved results. The study was carried out to streamline manual assembly in a company engaged in the production of car seats, namely car rear seats and their manipulation processes. The simulation itself was supposed to answer the question of whether it is possible to produce faster customer line tact and whether it is possible to reduce the number of workers without influencing line performance. The very design of the content and number of simulation experiments was realised in two main aspects. These aspects are whether changing the organisation of the workplace will bring the desired effect and whether the installation of new equipment can improve performance even more. The resulting solution helped reduce the investment uncertainty and estimated that the best two solutions would increase the assembly line performance by 0.94% or 6.89%, respectively.

1 Introduction

Manufacturing companies are now increasingly facing problems of rapid implementation of change to their processes. Often these changes are introduced without careful consideration of all benefits and negatives. These negatives can outweigh all the benefits, and businesses will only find out after all the changes and innovations have been introduced. Therefore, during production, they have to deal with problems for which they were not sufficiently prepared. Ultimately, this can lead to higher workplace failure and, thus, a decrease in performance. However, the need for these changes is increasing to improve performance and quality.

Potential problems can be avoided by using various tools to predict the future state of the devices and the advantages and disadvantages of the individual solutions proposed. Current trends in the support tools of production systems designed to solve the problem of rapid seduction of change are directed to digitisation, making it possible to solve decision-making tasks in the digital environment. Now the trends of Industry 4.0 have become emergent in companies. Industry 4.0 technologies include simulation [1]. The production system, as we know, has three components (inputs, transformation process and outputs). In other words, just as we set up an efficient transformation process, such results we will be able to expect. Many companies have been successful for a long time precisely because they are volatilely trying to optimise and streamline their internal processes [2,3]. This brings added value to companies, especially in reduced costs or increased production. Various techniques from LEAN through Sig Sigma are used in optimising production and assembly systems. However, only some of the methods allow a glimpse into the future as accurately as a computer simulation [4,5].

Computer simulation imitates system behaviour and internal processes over time and appropriately concludes system behaviour. Simulation models are compiled using the simulation software. [6]. The simulation is used to predict the effect of changes on existing systems and the performance of new systems. Computer simulation allows verification of decisions and their variation to achieve maximum synergy effect without interference with the real system [7]. It is most often used in processes where we design new systems and do not know their specific behaviour, so their applicability ranges from mechanical processes [8-10] to production processes [11]. This allows us, for example, to accelerate the start-up of new products,

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verify future investments, verify our scheduling plans, check the current state of planning, optimise and streamline the current system. Using simulation is possible to find many statistics that help detect bottlenecks, even in places where they are seen in normal view. The advantages of using simulation lie in its benefits. The simulation can provide information on the proposed solutions already during the decision-making process. On this basis, the optimal solution can be chosen.

The saving of time and mainly costs that the simulation provides is a great asset due to the increasing pressure on the necessity of change. It is a very effective tool, especially in assembly processes, where it can detect and remove bottlenecks, thus improving the overall quality, whether product or production plan. The assembly process is a process that is particularly sensitive to the timely follow-up of processes. In other words, the performance of our system will be just as high as it is in its bottleneck place. This is especially true in processes where it is impossible to create buffers that compensate for time disproportionates. The height of the output from the assembly system depends on good line balancing and the correct distribution of logistics activities. Computer simulation allows testing the layout of activities so that times for individual workplaces are as close as possible.

As it turned out in practice, the application of simulation has problems. Most often, problems associated with communication between the designer and the simulation specialist are pointed out. The basis of such issues can be a need for more knowledge about the possibilities of applying simulation on the part of the designers or their excessively high requirements for simulation [12]. Here, too, it is necessary to realise that a simulation is only a support tool for decision-making, it cannot replace the designer's creativity, and in the end, the designer must make the fundamental decisions and take full responsibility for them [13]. These problems gradually disappear after the participation of designers in the solution of several simulation studies. Designers better understand the possibilities of simulation, penetrate into the depth of problems, gradually become familiar with the simulation system and, over time, can solve simple tasks independently. Such a procedure is usually the most advantageous for project departments in companies.

At its core, the article describes the use of computer simulation for streamlining manual assembly respectively for determining the results of individual decisions on a solved system. The simulation model creation was carried out in cooperation between the simulation specialist and the responsible workers on the line, and the simulation was realised in cooperation between the specialist and the designer. Tecnomatix Plant Simulation 15.2 software is used for simulation, allowing dynamic system simulation.

2 Materials and methods

Modelling and simulation find their application in dealing with many tasks for which a routine estimate is no longer sufficient. It has been applied to a wide variety of settings. The following are just a few samples of areas where simulation has been used to understand and improve the system's effectiveness: airports, hospitals, ports, mining, amusement parks, call centres, supply chains, manufacturing, military, telecommunications, the criminal justice system, emergency response system, public sector, and customer service [7]. The simulation finds its dominant application mainly in industry, where vast volumes of money must be invested to establish production capacities. Therefore, the result we want to achieve must be verified in advance to achieve maximum effect. The production area covers both the area of manufacturing and logistics. Several works were involved in the application of simulation in production. The simulation of the production facilities and production flows was dealt with by [14-17]. The simulation of logistics processes carried out through supply tractors was dealt with by [18] testing different layouts of multi-company multimodal logistics systems [19] by analysing simulation techniques in logistics [20], optimising logistics warehouses [21] and [22], simulating logistical flow using the kanban system [23]. By simulating workers using genetic algorithms solved [24], worker allocation planning of a medical device distribution centre [25], and evaluation of the effect of worker turnover on productivity [21]. The simulation of reconfigurable production systems was solved by [20] simulation of progressive production concepts through metamodels in [26]. From the width of the current use of simulation in databases, it can be assessed that the application of simulation in production will only grow. The article itself is an extension of existing knowledge and its use, especially in manual assembly.

2.1 Chosen simulation study methodology and simulation tool

The actual implementation has been realised according to the general methodology of conducting a simulation study for the manual assembly workplace and its steps defined in Figure 1.

The simulation project begins with an analysis of the real system, a definition of the problem, and clarifying the simulation's aim. For the needs of the computer model, it is necessary to collect and process as much information as possible about the means of production or knowledge of the workers themselves from the solved assembly line since it is a manual assembly. After this step, an abstract logical model is then created, and the model created on a computer is validated. The next step is to create the model itself and verify the correctness of the model concerning the formulated parameters – verification and pilot runs. After that, simulation experiments are planned and prepared. We carry out experiments by changing parameters or modifying the model. Given results from the experiments carried out are evaluated and processed. If the results of the experiments are satisfactory, changes to the real system shall be applied.

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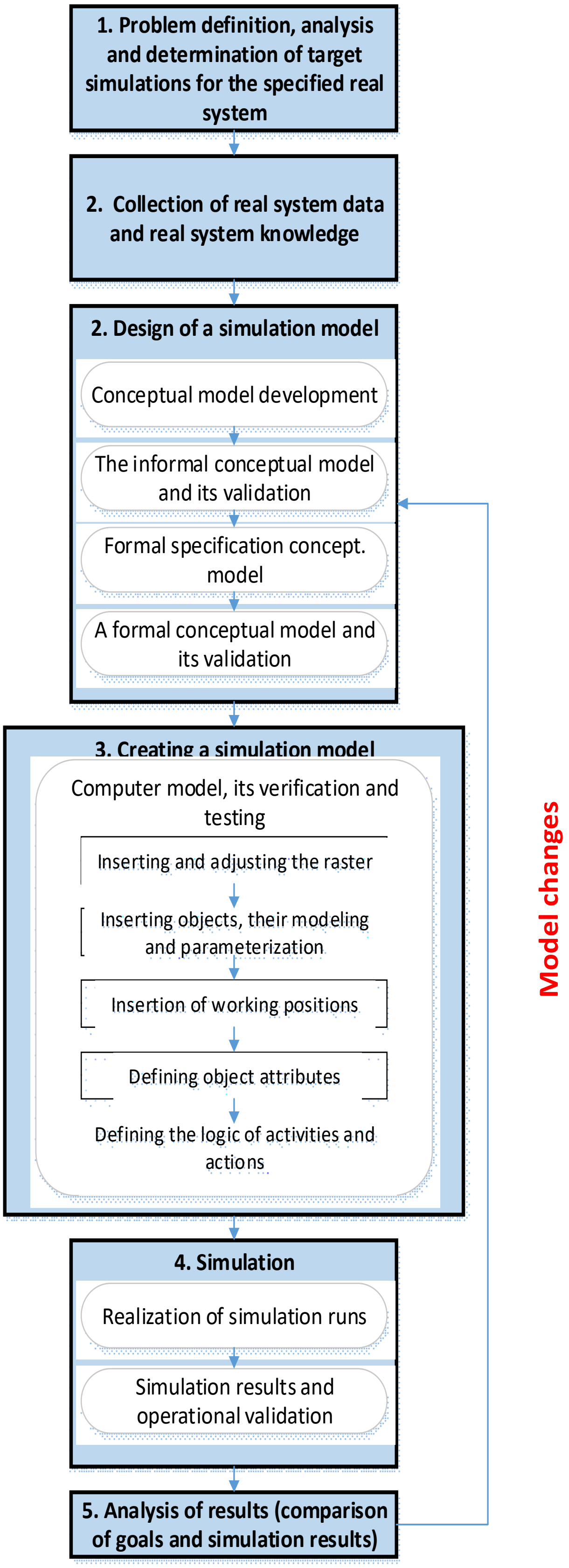

Figure 1 General procedure for carrying out a simulation study for a manual assembly workplace

In case of inconsistencies in comparing the objectives and results of the simulation, a model change shall be made. Tecnomatix Plant Simulation 15.2 has been selected as a simulation tool. This is software allowing dynamic simulation of the system. The functions of Tecnomatix Plant Simulation enable the creation of a digital model of real logistic systems (for example, production flow, material flow in supplying, etc.), thanks to which experiments and control of individual courses and system characteristics can be done.

2.2 Description of the simulated process

In the previous chapter, the methodology described was used to conduct a simulation study on the assembly line on which the rear seats of a passenger car are manually assembled. The display of the final product and input materials can be found in Figure 2.

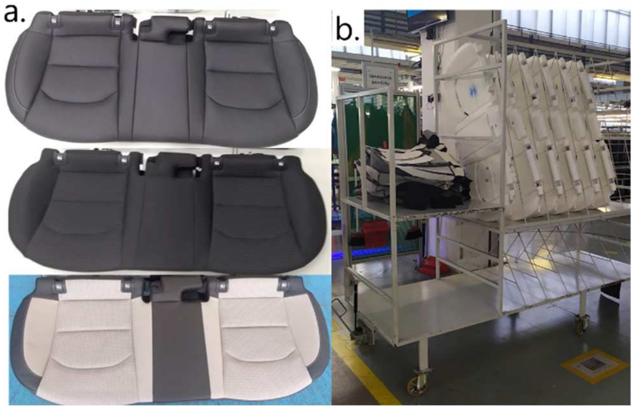

Figure 2 Illustration (a) of the final product; (b) of the input materials

It is a process where heating, pressure sensor, cables, cover, and isofix are gradually installed in the installation process. The initial hypothesis is that there is a distribution of activities and fewer workers where the output of the workplace is comparable to the current one. The layout of the selected material flow assembly process itself is in Figure 3. The selected assembly process and the activities carried out in it do not have specified times for the operation but are determined by the customer's line tact. Therefore, there is a situation where the tact may be higher or lower in the workplace. A workflow is defined for each workplace to ensure the required quality of the product. The static position of material and workplace buffers is also defined. In the workplace, various variants of seats are assembled. These differ in foam, cover (vinyl-semi leather, leather, textiles), and heating.

The assembly procedure is the same for all types of products, except the case of heating installation. For this case, time is different due to the installation of this component. The supply of material to the assembly process is considered 100% as the downtime is negligible. As such, the assembly process follows the processes of preparing the input material and workplaces, where the installation of the

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upper part of the seat is carried out and at the workplace E04_2, are paired. Therefore, these processes interact, and when it is unsynchronous, one process affects the other by delaying. Both processes then affect loading the finished paired parts into the technological pallet for automatic put-away. When creating a simulation model on which simulation experiments are to be carried out, results can also be expected as the inputs are precisely defined. The definition and interpretation of the collected data have an important role, the correctness of which is confirmed at the verification and validation stage.

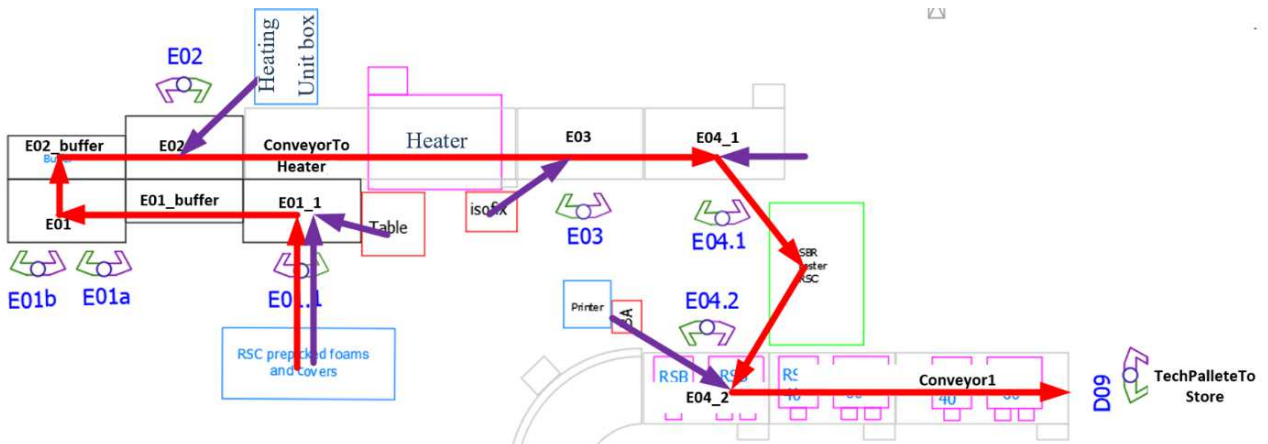

Figure 3 The layout of the manual assembly workplace and material flow

The data collection is based on the objective of the simulation project itself, based on which abstraction and reduction steps were carried out. As already mentioned, variations of the product differ in the foam used (PHEV, HEVSB, HEV, SB, 5DR, CUV), cover (vinyl-semi leather, leather, textiles), and heating (contains, does not contain). The material flow of the product is shown in Figure 3. The main flow of products is shown in red. The places of installation of the material are colour purple. The duration of activities in the workplace needs to be precisely determined. Their duration had to be measured directly in production. Based on data and the reduction of elements, a time has been set for three types of covers. Foams, even if they are different, do not change the duration of time for activity. A triangular distribution is selected for the data since, in production, it is possible to measure the minimum, maximum and medium duration of the activity, and the activities performed by humans are reflected in the time variation. For the possibility of future balancing of such times, the operation of the installation itself is divided into several activities. The activities come from workflows and are in the order in which they are carried out. The description of the process is as follows; take the foam, stick the pressure sensor, if it requires a heating application, then cover with a cover, shoot the cover on the seat, stretch the cover and attach it to the bottom of the seat, plugging in the heating unit and cabling, straightening, heating, installing the isofix, ironing and checking, assigning a label to control quality by the pressure sensor, final inspection and loading.

3 Results

The created simulation model consists of a line model in which the entire process of assembling the product takes place. Creation of a simulation model consisting of steps defined in the general methodology for conducting a simulation study in an environment of manual assembly. First, a raster was inserted from the CAD file, based on which the objects were modelled to actual dimensions. This is due to the correct distances for walking workers and the right restrictive conditions. After inserting and modelling objects, parameters have been defined for objects, workers, and products with assigned logical critical rules. In the end, the model is verified and validated once more. It is validated using order sheets. In one order sheet is printed time when the order of 8 seats enters the real assembly system. When the following order of 8 seats enters, the time is also recorded to determine how much time consumption this order takes. This was done for one hundred orders. The resulting difference with the real system was +/- 0.38%. The simulation model created in 2D and 3D graphics is in Figure 4. For the design of experiments, it is necessary to consider the company's questions, whether it is possible to produce faster customer line tact and whether it is possible to reduce the number of workers without influencing the line performance. Furthermore, it is necessary to analyse the results from the simulation model, which is validated with the real one. Essential indicators include the worker's utilisation graph Figure 5 and the workplace utilisation graph Figure 6.

In the production line, it is possible to identify two bottlenecks, namely the places with the highest tact times, E01 and E04_2. Looking at the workplace workload graph, Figure 6, it can be identified that the E04_2 creates a

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MeasuringStation blocking and secondary blocking of E04_1. Also, the E02 and E03 workplaces are blocked due to E04_2 influence. The E01 workplace causes the blocking of the E01_1. The current output is 30.74 pieces per hour. The experiments were conducted based on analysis and are a combination of the number of employees, the deployment of work activities, their necessity and the ability to meet the requirements for customer line tact. At first, a series of merging experiments were carried out to determine the possibility of merging workplaces.

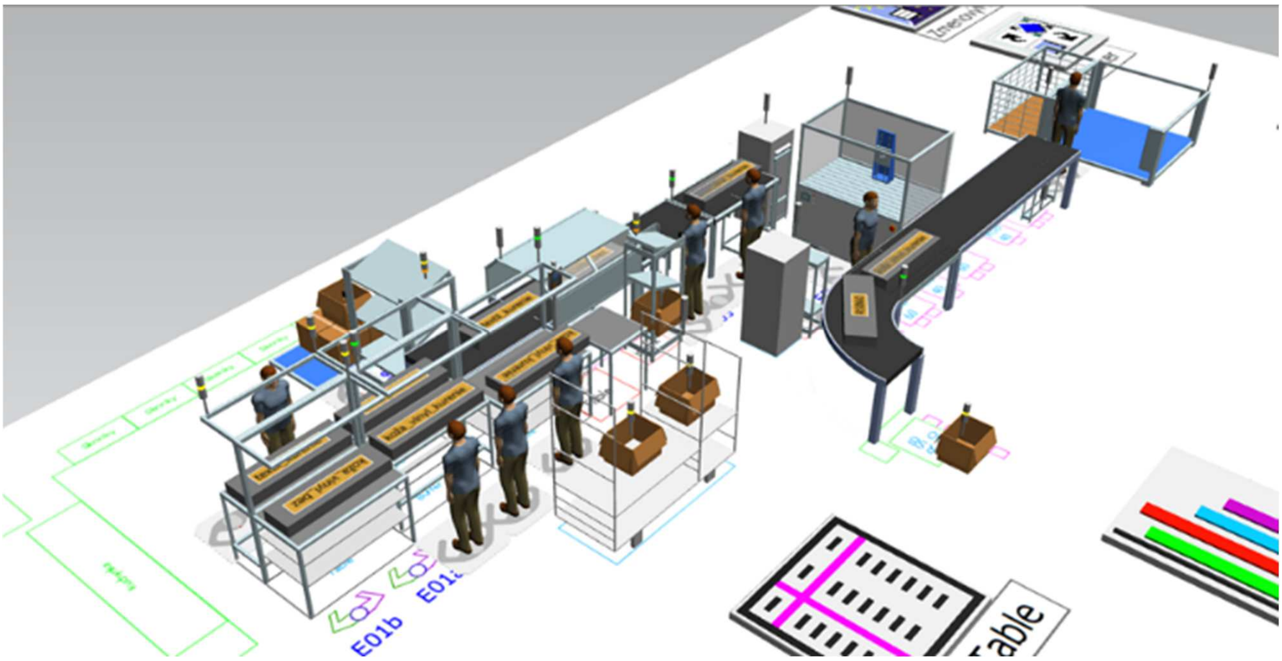

Figure 4 The layout of the manual assembly workplace and material flow 3D

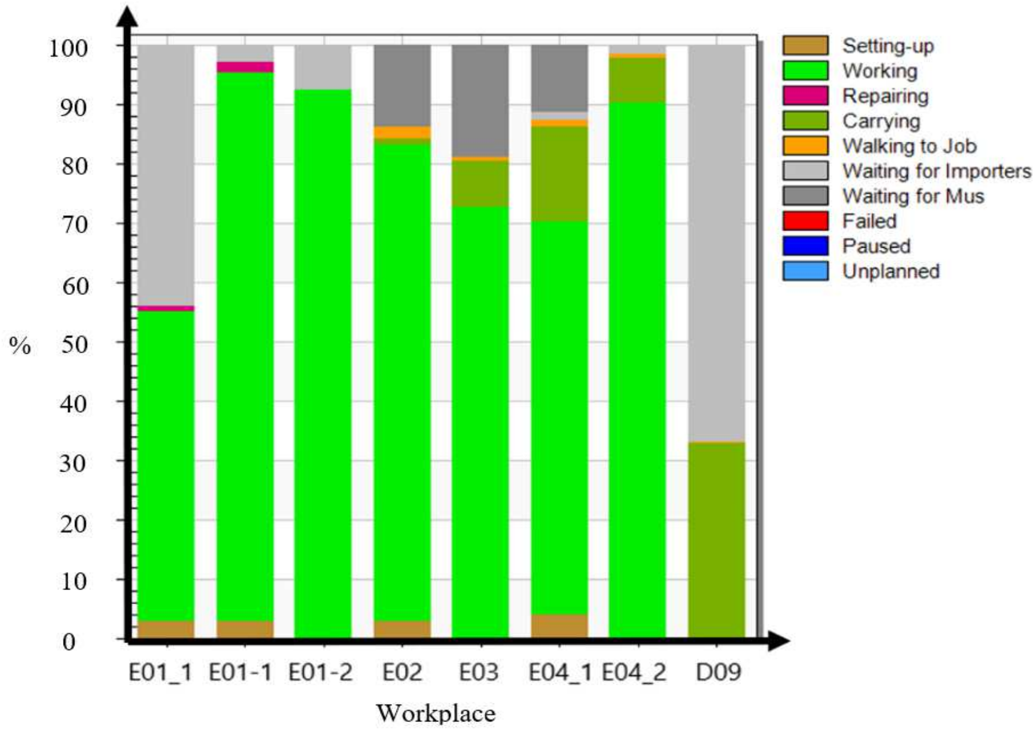

Figure 5 Chart of current worker's utilisation

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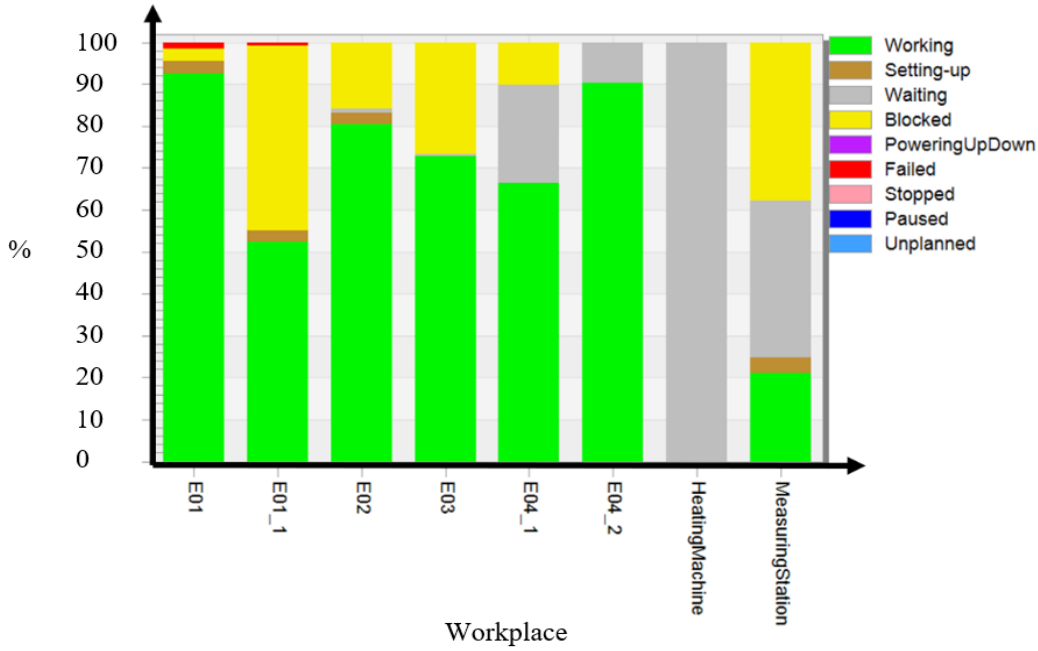

Figure 6 Chart of current workplace utilisation

From the resulting statistics, only in one case a minimum tact of the customer line was achieved, namely in merging the E01_1 and D09 workplace activities, which is not enough for the medium or faster tact of the customer line. However, there is the potential for testing in the distribution of activities. The next series of experiments is realised based on the distribution of activities so that the line is in reasonable balance. Experiment 12 is based on leaving the same number of workers. The worker from position E02 is helping in the E01_1 workplace, and one activity has been moved from the E01 workplace. Experiment 13 is an experiment without changing the number of workers. A worker from E02 is helping at the E01_1 workplace, where one of the activities of the E01 workplace has been moved. Also, the MeasuringStation and E04_1 were switched in this case. Experiment 14 is an experiment without changing the number of workers, and MeasuringStations, and E04_1 were switched. Experiment 15 is an experiment with changing the number of workers. A worker from E02's position is helping at the E01_1 workplace, where one activity has been moved from the E01. The MeasuringStation and E04_1 have also switched. The worker from the E04_2 are removed, and his activities are transferred to D09 workplace and worker. The switching of MeasuringStation and E04_1 is depicted in Figure 7.

Table 1 Experiments carried out to identify the possibility of merging workplaces and their activities

Experiment number	Workplaces whose activities are merged	Output [Pcs./hour]
Exp. 1	E01_1 and E02	**20.68**
Exp. 2	E01_1 and E03	**5.20**
Exp. 3	E01_1 and E04_1	**20.30**
Exp. 4	E01_1 and D09	**28.87**
Exp. 5	E02 and E03	**19.06**
Exp. 6	E02 and E04_1	**15.77**
Exp. 7	E02 and D09	**22.80**
Exp. 8	E03 and E04_1	**18**
Exp. 9	E03 and D09	**25.18**
Exp. 10	E04_1 and D09	**24.06**
Exp. 11	E01_1 and E02	**20.68**

Figure 7 Illustration of positions after switching MeasuringStation with E04_1

Experiment 16 is an experiment without changing the number of workers. E01_Instal_LSHog worker from E02's position assists in the E01_1 workplace, where the E01 site has been moved, and the MeasuringStation rescheduling with E04_1 has been carried out. At the same time, the conveyor and E04_2 activities are transferred to D09_1 and D09_2. The depiction of the location of the completed conveyor is in Figure 8.

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Figure 8 Illustration of the position of the supplemented conveyor

Table 2 shows the experiments and results achieved.

Table 2 Experiments and their impact on hourly line performance

Experiment number	Output [Pcs./hour]
Exp. 12	**30.74**
Exp. 13	**30.27**
Exp. 14	**30.14**
Exp. 15	**31.04**
Exp. 16	**32.87**

A Figure 9 graph is created to better understand and interpret the experiment's results.

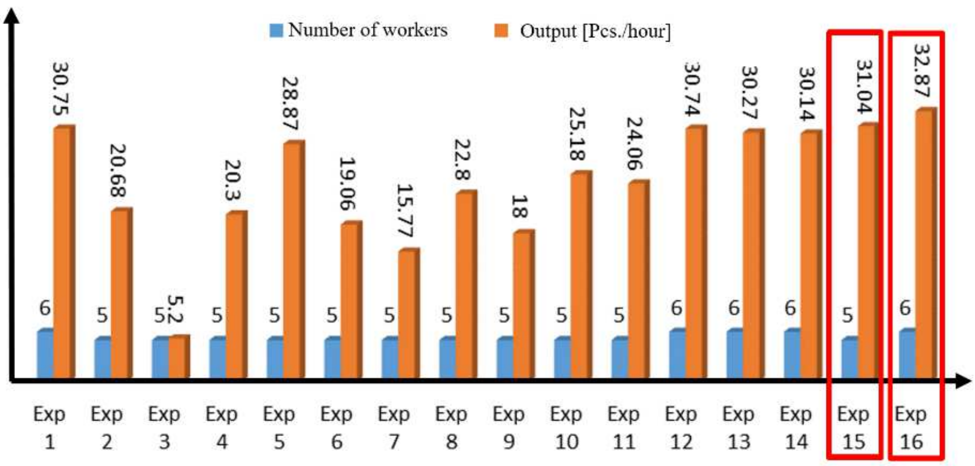

Figure 9 Summary graph of experimental results

In the graph in Figure 9, two experiments 15 and 16 are marked. If we consider reducing the number of workers and, simultaneously, the highest possible output, then the result from experiment 15 is optimal. If we consider streamlining the line to cover even faster tact from the customer line, then the solution from experiment 16 is best.

4 Conclusions

In the current market competitive environment, the success of each company depends on the ability to adapt, which is a prerequisite for satisfying customer requirements. Each competitive company examines its processes to make them more efficient so that it ultimately obtains an increase in production or reduces waste of resources (e.g. materials, raw materials, capacities, money). In assembly processes where there is a time follow-up, the height of times along the line must be balanced, and the bottlenecks must minimally affect the final output. Sometimes such bottlenecks can be detected normally by looking, especially if there are buffers in the system that display this state. However, if the line has no buffers in which pieces accumulate, the bottleneck locations without a time study are more difficult to detect.

Computer simulation helps to detect bottlenecks of the reasons for their emergence as well as follow-up problems. A simulation model that is properly validated by the actual system helps us verify our decisions without intervening in a real system. Most bad decisions are characterised by the fact that their correction or retention has a negative impact on production as well as costs.

The article aims to describe the use of simulation carried out in the framework of the simulation study and the results achieved. The study was implemented using a computer simulation realised based on general simulation study methodology to increase the efficiency of the assembly line in the company. The case study described in the article used a simulation tool, Siemens's Tecnomatix Plant Simulation 15.2, to perform computer simulations. As part of the solution, the essential requirement from the corporate hypothesis that there is such a new distribution of workers and activities where there will be an increase in performance was met. Two proposed variants, where one allows the number of workers to be reduced by one worker

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and meets the requirements for medium and slow customer tact of the line by better organisation and logistics, match this hypothesis. At the same time, performance will improve by 0.94% by using this variant. A faster customer tact can be achieved without reducing the number of workers, and performance might increase by 6.89%. The proposed simulation study methodology is especially suitable for companies with essential data and layouts and needs to verify their optimisation solutions associated with investment costs.

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Review process

Single-blind peer review process.

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