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Study of Production Scenarios with the Use of Simulation Models

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Abstract

Simulation studies are gaining in popularity and are used in many scientific fields. Implementing computer solutions in production engineering allows reducing costs that an enterprise incurs due to erroneous decisions while planning and modernising production lines. This is also helpful in the reduction of the time required to develop plans for manufacturing new products. This problem is important in manufacturing companies that seek to reduce the volume of stocks while ensuring the continuity of the production process. The article presents possibilities of applying computer simulation models in studying chosen production scenarios. The basic methods of research used in the study were literature studies and computer simulation.

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Keywords: computer simulation; modelling; production process; production scenarios; simulation model; Tecnomatix

1. Introduction

Studying phenomena and processes is the aim of many research programmes. This involves the application of various methods, beginning with practical activities in the form of observations, and ending with theoretical analyses. Such procedures require a mathematical apparatus. In the contemporary world dominated by ICT tools, a computer simulation becomes an exceptionally significant and effective research method. It reflects the studied phenomenon or a process in a form of a computer programme, also called a computer model, which is created with the use of a mathematical model [1].

A computer simulation, as a method, is a system of research activities, i.e. a structure of stage activities aimed at achieving a research objective. These are the following activities [2, 3]:

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- formulating a problem
- creating a mathematical model
- formulating a programme for a computer
- checking the appropriateness of the model
- planning simulation experiments
- performing a simulation process and analysing the results.

Simulation is an approximate imitation of a studied phenomenon or behaviour of a given system in the virtual space with the use of its so-called simulation model. A simulation model is based on a mathematical model frequently recorded in the form of a computer programme. At present, there exist many tools for conducting computer simulations that allow for creating simulation models [4]. Simulation models are used in order to reduce the risk of failure while implementing significant changes into the existing manufacturing systems. Upon generating the model, a simulation analysis is performed so as to determine particular elements of the process. The model of a studied system presents its properties, features and limitations, as well as the manner in which the process in specific conditions takes place. Simulation, by means of adequate tools, allows for a respectively simple and cheap way of verifying different variants connected with the functioning of the processes [5].

With a view to the objective of the simulation, it can be divided into three types [6]:

- a simulation aimed at understanding the principles of the functioning of the system and its properties that are difficult to distinguish on the basis of a formal analysis
- a simulation aimed at facilitating decision making within the functioning of the system
- a simulation, whose aim is to train people within decision making concerning the functioning of the system.

The simulation of production processes is a technique used for solving problems occurring in the course of the manufacturing process. It is based on virtual models [7].

2. Simulation models in production engineering

Contemporary production is characterised by a wide selection of products, reduction of the product's life cycle, production costs and time span between designing and launching products [8]. Gathering operational data in the real time is essential for measuring the compatibility of results with the plan [9].

Simulation studies are applied to and are used in many scientific fields [10, 11]. The application of a simulation in production processes constitutes a form of experimenting on a computer model. Its objective is to provide an answer to the question on how the production system will react to various situations, according to arranged scenarios. Implementing computer solutions in production engineering allows for reducing costs that an enterprise incurs due to erroneous decisions while planning and modernising production lines. This is as well helpful in reducing the time required to devise plans for manufacturing new products. The application of simulation models allows for a more effective selection of manufacturing strategies by enterprises. Simulation models are typically used when it is impossible or very difficult to devise an analytical solution of a studied problem. This takes place in the case of analysing a dynamic behaviour of production systems and processes. An adequate selection of strategies and skillful management of chosen tools, including methods of computer simulation, allow for and facilitate solving problems occurring in the activity of an enterprise [12].

Simulation, as each method, has its pros and cons [13]. Benefits of a simulation:

- a simulation allows for arranging a form of a system with the use of experiments directly conducted on the studied model
- it may be applied for analysing large and complex decisional problems that cannot be solved with the use of other methods
- it allows for quick preparation of decisions thanks to analysing the effects of experiments conducted for many alternating periods

- it provides an answer to the “what-if...?” questions – simulation experiments allow for analysing various decisional alternatives
- it allows for analysing correlations of the effects of variable elements of a model that can influence the decision chosen in extreme conditions.

The main drawbacks of a simulation are:

- potentially long time of model preparation
- every simulation model is unique – its solutions cannot be used for analysing other decisional issues
- it allows for preparing alternative decisional solutions in subsequent experiments, but these are not optimal solutions for all conditions
- simulation models generate answers to the questions related to specific and changeable conditions. The decision-maker, while preparing decisions, needs to account for all circumstances and limitations of the analysed decisional variants.

The creation of simulation models involves a computer representation of a given model, which exhibits an activity of an object or a system. The biggest requirement of the simulation is the reconstruction of the activities of the model’s prototype. There exist two types of models: mathematical and physical model. The former is most often recorded as a computer programme. It includes basic features of a system as well as exhibiting a connection to the environment. The latter model is reduced to the proper scale, as compared to the original. The reflection of the real model depends on the objective of the conducted simulation. The objectives of the simulation can be divided into two groups. The first one includes simulations of the already existing systems, where conducting a simulation in the real system is too costly or impossible. The second group entails computer simulations that indicate the behaviour of already gone systems or those in the design phase. The creation of a simulation model requires adequate knowledge on the presented object. It is also necessary to study the tools of the programme that are to be used. The aim is to achieve the simplest possible model. However, it should be taken into account that the model should describe the activity of the modelled process with the highest precision [14].

Using simulation tools does not exclude a traditional form of design. However, it may become a source of confirming the adequacy of a designed object. The application of a computer simulation for solving research problems relies on the proper creation of the model and adequate execution of a simulation experiment. The choice of the relevant tool for conducting a simulation is extremely essential. It is important that a given programme has an adequate functionality in the sense of the simulation’s objective.

3. Possibilities for applying Plant Simulation

Tecnomatix Plant Simulation, a product by Siemens, is one of tools for creating simulation models available on the market. It combines technological areas, production engineering and logistics, beginning with planning and designing, through process simulation and verification, up to manufacturing [9]. Plant Simulation enables conducting simulations and product analysis throughout the entire manufacturing process. This ensures planning a sustainable production process prior to its implementation as well as conducting the analysis and optimising already existing processes [15].

With Plant Simulation enterprises are able to perform tests and experiments according to selected scenarios and swiftly specify the best strategies aimed at significant intensification of efficacy, cost reduction, time-saving, as well as achieving quality targets. Such procedure makes the need to perform tests within the production hall redundant. Plant Simulation enables [16]:

- the observation and elimination of potential problems that could cause costly and work-consuming modifications of the process in the future
- the minimisation of investment costs
- the optimisation of the activity of the existing logistics and production systems by using modifications formerly tested on the simulation model.

Tecnomatix Plant Simulation is a tool of manifold usage, starting with planning manufacturing processes of individual parts, robotization of jobs, analysis and optimisation of existing production lines, up to quality management and designing entire production halls. Using such an environment brings the possibility of optimising the material flow, using resources at all levels of the enterprise, beginning with a global model, through local plants down to individual lines.

4. The analysed production scenarios

The model of a production system is based on an example of a real production department, with the use of Tecnomatix Plant Simulation software (Fig. 1). The input data are determined on the basis of the known technological data of the process and the data concerning material flow during production. It is particularly essential to reflect activities connected with the processing of individual components. The effects of the simulation are presented in the following part of the article. The conducted experiments entailed studying to what extent the change in the size of the batches of entered components influences the efficiency of the system.

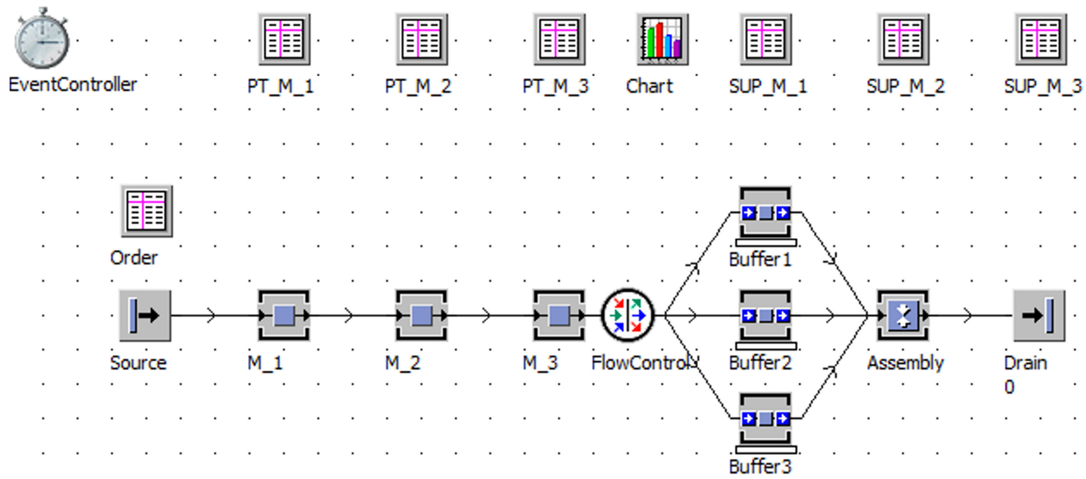

Fig. 1. Model of the analysed process.

Creating the simulation model constituted a basis for further activities. The next stage involved conducting simulation experiments meeting the objective of the research. The programme accounted for the conditions of the simulation, including: a machine park and the process topology, parameters of the stations, simulation timing, timing of individual activities and components for processing, as well as the volume of batches entered into the process. The possession of the tool in the form of a model allows for conducting a multiple simulation as well as the observation of work stations and the system as a whole.

Proper identification of basic properties of the system is crucial for achieving proper results of the analysis. The gathered information was used in creating virtual processes of manufacturing and defining their basic tasks. The creation of simulation models relied on approved assumptions concerning, i.al., the size of production batches, simulation times, performing specific operations and the availability of work stations.

The analysed process is composed of three processing stations and an assembly station. The research was performed within one technological line provided with materials from one warehouse. The manufactured products leave the process – they reach the warehouse of final goods. The volume of the batches in the basic process equals 30 items of each of the three components. In addition, the research covered variants with a larger (45 elements) and smaller (15 elements) number of parts in a batch.

Table 1 presents unit timing of processing at specific stations. Assembly timing is constant and equals 4:25.

Table 1. Components time of processing (in minutes).

Name of component	Machine 1	Machine 2	Machine 3
Component 1	1:50	0:35	1:10
Component 2	0:45	0:55	0: 55
Component 3	2:15	0:40	1:45

The timings of retooling the stations in a studied process are included in Table 2. They denote the time needed to change the basic parameters of a machine, lapsing from the last element of one type to the first element of the other type.

Table 2. Setup times (in minutes).

Name of component	Machine 1	Machine 2	Machine 3
Component 1	0:50	1:15	1:00
Component 2	0:45	0:20	0:45
Component 3	0:55	0:10	0:45

The level of machine availability is constant for all scenarios. It equals respectively 95% for machine 1, 90% for machines 2 and 3, and 80% for Assembly Station. The simulation period assumed one 8-hour shift.

4.1. Scenario 1

The analysis primarily focused on the scenario currently conducted in the enterprise. It assumes entering series of 30 items of each component into the system. The result of the simulation was 63 manufactured final products. Figure 2 presents a chart of efficiency for a basic production scenario.

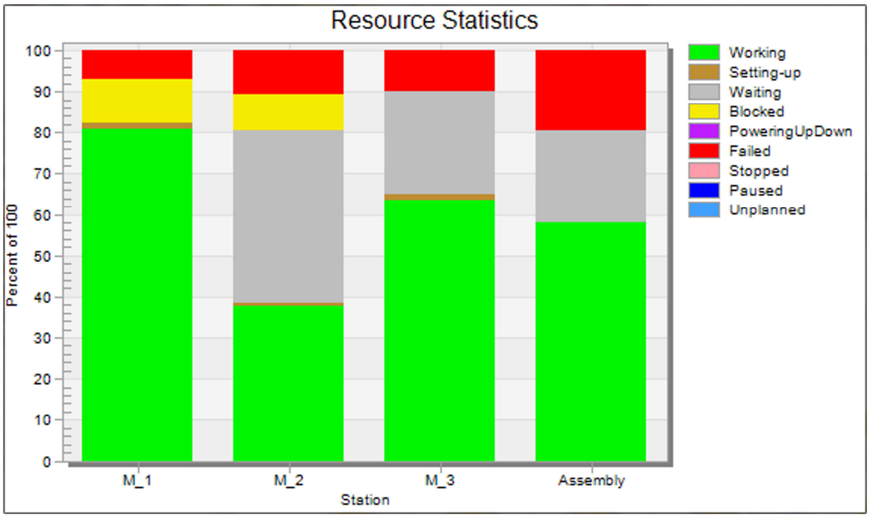

Fig. 2. Chart of efficiency for a basic production scenario.

4.2. Scenario 2

Subsequently, the production system underwent an analysis, where the batch was increased up to 45 items of each element. This change led to the reduction of the production down to 56 items within 8 hours of simulation.

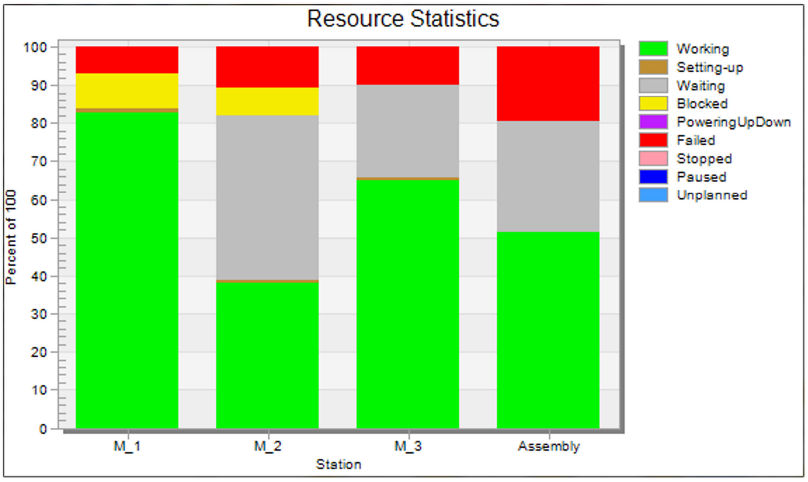

Fig. 3. Chart of efficiency for scenario 2.

Apart from reducing the number of manufactured final products, there also exist changes in the efficiency of work stations. The work load of machine 1 dropped increased from 80,78% to 82,33%, as to machine 2 - it increased from 37,57% to 38,13%, and for machine 3 it increased from 63,38% to 64,84%, as referred to the basic process. Due to a longer waiting time for all components, the timing of using the assembly station fell from 58.13% to 51.55%.

4.3. Scenario 3

The third scenario assumes the reduction of volumes of entered batches down to 15 items. This resulted in the increase in the total production of the analysed process from 63 to 69 items of final products, preserving constant parameters of all objects of the model.

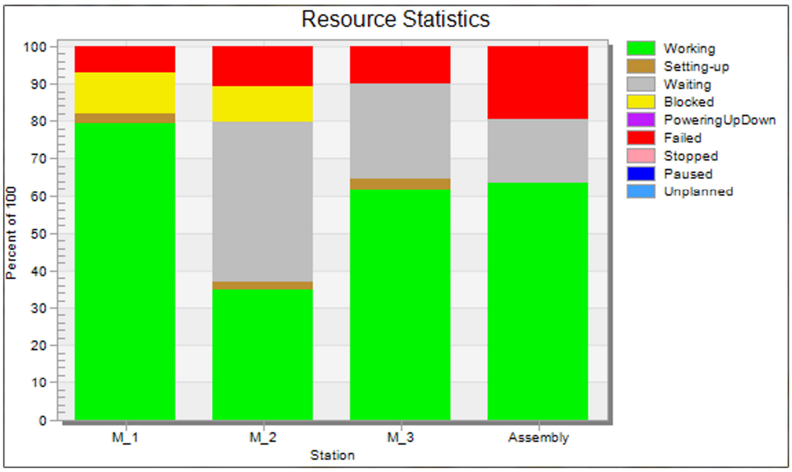

Fig. 4. Chart of efficiency for scenario 3.

The gathered statistics were compared to the basic process (scenario 1). As the chart shows, despite increased total production at the time of simulation, the work load dropped in all machines. Thanks to more frequent provision with necessary semi-products, the efficiency of the assembly station increased. This has a direct impact on the increase in total production. The total time of retooling grew at all stations, which was caused by frequent changes of processed elements.

Table 3 presents the comparison of basic statistics achieved in the analysed production scenarios.

Table 3. Working period (in percentage) comparison in the analysed production scenarios.

Scenario	Machine 1	Machine 2	Machine 3	Assembly station
Scenario 1	80.78%	37.57%	63.38%	58.13%
Scenario 2	82.66%	38.13%	64.84%	51.55%
Scenario 3	79.28%	34.95%	61.63%	63.63%

This leads to the conclusion that reducing the batches entered into the system may increase its efficiency and flow of the transfers. However, it should be emphasised that the research involved three exemplary scenarios. The research within a wider scope could help in determining optimal volumes of production batches.

5. Conclusion

The aim of the study was to investigate some production scenarios with using simulation models, built in a Tecnomatix Plant Simulation system. The study included three scenarios.

The simulation analysis leads to the conclusion that the highest efficiency was reached within the system providing elements in 15-item batches. It appeared that increasing batches of entered components lowered production efficiency.

A simulation model is a fine tool for verifying the functioning of processes and allows for clear visualisation of selected assumptions. Moreover, databases created for the need of a simulation model may constitute a basis for developing real processes. It should be noted that a tool in the form of a simulation does not excuse managers from decision making. The conducted simulation experiments provide only data and information on processes that assist in making the best decisions. Here, a computer simulation was only a tool allowing for substituting real experiments with computer ones. It is a method facilitating numerous repetitions with regard to the same conditions or the ones that are adequately changed to the research needs.

The use of simulation models facilitates a preliminary analysis of how the processes develop and a verification of suggested changes according to the approved conditions. The applied simulation allows for studying specific scenarios and process development without interfering into their course, as well as examining chosen solutions without the risk connected with testing specific assumptions.

The analyses required applying adequate software. They involved one of already available systems for designing and optimising virtual models of production processes, identifying possibilities of its use in analysing production processes. The information presented in this article provides a basis for conducting further work on modelling and simulation methods. Computer simulation may become a helpful and reliable tool for designing and studying manufacturing processes. It can also provide a ground for further studies aimed at using digital models within production engineering.

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