The use of Computer Simulation Techniques in Production Management

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Abstract. The purpose of this paper is to present the possibility of using computer simulation techniques to optimize production processes. The paper presents a simulation model, which is the basis for solving decision problems, in particular regarding the determination of alternative scenarios for the allocation of production resources. The simulation model was built in FlexSim. It consists of a finite set of decision variables and constraints that result from the analyzed technological process. The basic stages of creating a simulation model are discussed and the results of the simulation are presented.

Introduction

Companies around the world are constantly looking for ways to reduce costs and make the best use of available resources. Organizations are currently looking for Lean system solutions that would improve their activities by eliminating what does not bring value to the customer, while increasing the efficiency of the manufacturing process [1, 2].

Success in the global economy is often viewed in terms of competitiveness, risk and innovation [3, 4]. Success in business is based on speed in making decisions and solid information support in this process. Decision making is easy in simple systems and in a situation where there is no alternative choice [5, 6]. However, most production systems are difficult to understand. As a rule, they offer a large number of variants of action. It is difficult for an individual to analyze and make the right decision because each system has one or more of the following characteristics [7]:

- system components are subject to their own random actions,
- random actions of the environment affect the system,
- the behavior of the system is dependent on the time variable.

System components have many interactions, so there are many ways to connect paths between system components. When a decision-maker starts analyzing the system and formulates a plan to optimize its performance, then it can face extremely difficult problems [8]. In these situations, common sense thinking and the use of simple computational techniques is insufficient in view of the dynamics and random nature of the system's behavior [9]. Therefore, methods have been developed that help managers analyze processes and are commonly known as decision support systems. The decision support system acts as an analysis tool by which decision makers formulate action plans [5]. Simulation is one such tool. The simplest way to describe the role of simulation in the decision-making process is as follows: simulation is an experiment and a simplified imitation (with the help of a computer) of a specific action [10]. Process simulation requires prior construction of appropriate predictive models [11, 12], especially in the case of heavy industries [13-15], a high risk of contamination [16-20] or a risk of injuries [21-24]. The construction of predictive models requires the application of many data analysis methods to previously collected

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data, both parametric [25-27] and non-parametric [28-31]. The developed predictive models are components [32] that should be built into the quality management system [33, 34], taking into account various scenarios of events, including failures [35-38]. Of course, the successful implementation of such systems depends hugely on technical culture [39] and social attitudes of workers [40].

The Essence of Modelling and Simulation

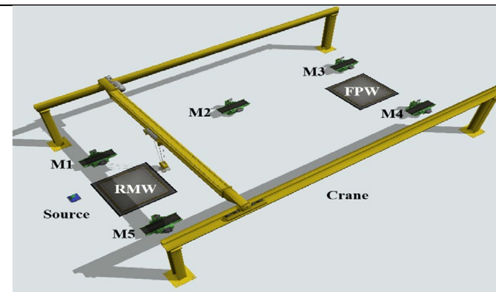
Modelling means the activity of selecting an acceptable substitute called a model for the original, i.e. it is an approximate reproduction of the most important properties of the original. In other words, it is building a model that reflects the most important features of the examined or designed object from the point of view of the task it serves in a specific reality or abstraction In general, modelling tools, and simulation in particular, provide mechanisms for studying the problem presented in them, for alternative experimentation, and for predicting the results of proposed external solutions. This approach significantly increases the decision space (allows to evaluate more different ideas), does not interfere with the real system and allows to estimate the risk of actions [41-43]. The main area of application of simulation is production. The production results were easy to predict when only one operator was working on the line. The pace of work depended only on the decision of one operator [44-46]. However, once with the start of the industrial revolution, and in particular with the introduction of the assembly line, production transformed into a complex system consisting of many pieces of equipment, many operations and activities, and involving many people interacting with each other [47-50]. Optimizing the process using the simulation method means finding the best configuration of input variables that will reflect the highest efficiency and stability of the process [51, 52]. And the optimization itself usually consists in maximizing or minimizing the selected parameter [53-54].

Methodology – Case Study

This article discusses a combinatorial approach to minimize the path for an overhead crane. The study took into account the problem of selecting individual machines to fulfil the order for 5 types of products. The developed model focuses on the planning of the production process, where it is necessary to decide on which machine each type of product should be manufactured - so that the total distance of the crane (operating time and operating costs) is as low as possible. In this concept, the 3D FlexSim simulation environment with the built-in OptQuest optimization module was used to solve the problem [55]. It has been assumed that this process will take place on 5 machines, and due to the changeover of machines, each type of product will be produced on one machine. The quantities of individual products and the operating time for each type of product are summarized in Table 1. Model of simulation of the analyzed production process performed in the FlexSim program is also presented.

This problem in its basic version seems to be very simple, because with one warehouse, knowing the position of the arrangement of individual machines, it is enough to send the largest batch of semi-finished products to the nearest station. Later, the next closest position should be selected and the largest batch of semi-finished products should be shipped, etc. However, with a greater number of warehouses, or a greater number of products or means of transport, this problem becomes complicated very quickly. To find the shortest route with only one semi-finished products warehouse and 5 machines, you need to calculate the so-called the number of inversions, which is 5! = 120 combinations. If the problem concerns more machines, e.g. 10, it will be 10! = 3,628,800 combinations. Thus, manual calculations are unrealistic, therefore it is necessary to use the OptQuest optimizer built into FlexSim. In the base model, standard objects from the program library were used, which were programmed according to the task conditions. The flow elements simulating individual product types are generated by the Source type object. In this model, the source works in the *Arrival Sequence mode*, where five types of items (semi-finished products) are defined and their respective amounts are given (Fig. 1a). The model should define a global table with dimensions (5 x 2), where the row is the number of the port to which the machine is connected, and the columns are: product type (item) (Col 1) and processing time (Col 2) (Fig. 1b). This arrangement means that the item number l is to be routed by the RMW stock warehouse to the exit port number l to which the machine M1 is connected, etc. The transport was then assigned to the RMW warehouse via the central port. The standard FlexSim object - a crane was also used for transport.

Table 1. *Data on the type of product, production volume and operating time for the discussed production process*

Product type	Production volume [pcs]	Operating time [s]	Simulation model
1.	40	1500	
2.	50	1200	
3.	30	2100	
4.	25	2600	
5.	45	1400	

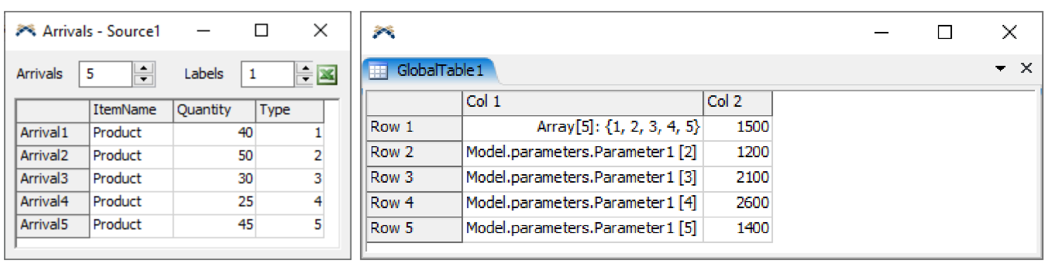


Fig. 1. *a) Defining the Source object for the analyzed research problem; b) definition of the allocation of ports and production time to specific types of products [own study]*

In this model, each Processor performs the function of individual M1 ÷ M5 machines. The processing time of individual products is set according to the performance of each machine. For this purpose, column 2 was defined in the global table and, similarly to the RMW warehouse, it was assigned to each Processor. Transport to the FPW finished goods warehouse is also set up in individual processors. The same crane was used for this purpose. After starting, the appropriate item type will be transported to the specific machine. However, such a choice is not optimal, because the access routes do not have to be the shortest. In order to optimize the selection of individual machines, it is necessary to define the operation of the optimizer. The optimizer will match the sequence of individual ports for the shipment of semi-finished products to individual machines until the optimal value was determined, at which the total distance of the crane will be the smallest.

Results

Based on the simulation (with input data from Table 1), the best combination of ports was obtained, with the shortest route. The result of the optimizer's work for all 120 combinations of ports, along with the length of travel, is shown in Fig. 2. As it can be seen at the presented results, the best sequence of port addressing is the combination of 3, 1, 4, 5, 2, obtained in the 31st iteration as Rank 1. This means that the first type semi-finished product in the amount of 40 items should be sent to the machine M3, semi-finished product of the type 2 in the amount of 50 pcs. for the M1 machine, semi-finished product type 3 for the machine 4, etc., machine M5 - product 4 and machine M2 - semi-finished product 5. Then the total travel route for the crane will be the shortest and will be 23.8 km. Fig. 3a shows a production flow cyclogram. A high degree of production sustainability can be observed, which translates into the end of production of the entire assortment at a similar time. On the other hand, Fig. 3b shows the degree of use of individual machines.

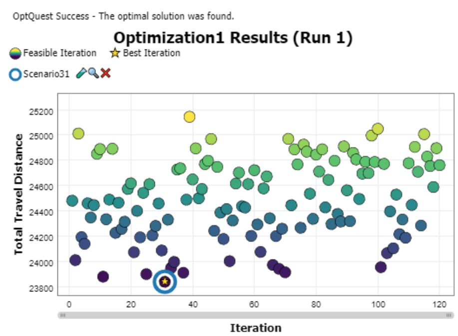


Fig. 2. *The result of the optimizer work for all 120 iterations (combinations of 5 output ports for RMW warehouse) [own study]*

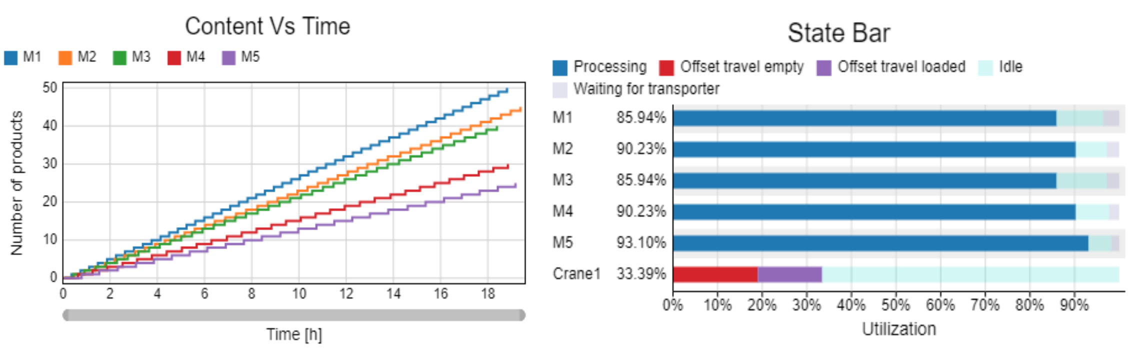


Fig. 3. *a) Production flow cycle for all types of products manufactured on M1 ÷ M5 machines; b) Loads of individual machines throughout the production cycle [own study]*

The diagram in Fig. 3b shows the so-called partial efficiency of machines. It is a value that represents the OEE coefficient without taking into account the quality of the manufactured products. This means that assuming that all manufactured products were 100% compliant.

Summary

The main purpose of the article was to present the possibility of using a simulation experiment to optimize the production process. The presented example shows how a discrete event simulation model can improve production process planning. The presented concept can be the basis for constructing more complex simulations. It can also be successfully used in logistics for route planning or finding the optimal location of the warehouse. The benefits of simulating real operations on average give savings from 5 to 25% as a result of lower operating costs and increasing throughput (flow) [7]. A significant part of the savings are already foreseen in the simulation process, which significantly reduces the analysis time and thus provides a quick method to try out changes and new ideas. Such analysis is especially important in situations of sharing resources and people involved in a given process or operation. The most important thing, however, is that the simulation shows the impact of plans and schedules on the actual performance, and also directs managers to choose the optimal actions. The main value of the simulation is also the fact that - based on historical and current features - it presents the dynamics of the simulated system, allowing it to be learned, studied, experimented and modified without interfering with and disturbing the real system. Alternatively, a simulation based on predicted or planned features represents the dynamics of the behavior of a system that does not yet exist and allows us to understand it before it arises in the real world.

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