Simulation modeling for optimal production planning using Tecnomatix software

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Abstract. Efficient use of production capacity is an important complex of engineering tasks. Faced with the need to modernize production in the face of high competition and changing customer needs, company owners are forced to test new engineering solutions. Maximizing the existing production capacity plays a fundamental role in maintaining competitiveness and improving the efficiency of resource use in the production of electronic equipment. Electronic equipment manufacturing uses a make-to-order strategy and has a large number of variants of the product in a very small batch. But it is a problem of implementing the standard solution for efficient use of production capacities. Using simulation methods allows one to make informed decisions on using planning and scheduling in small-batch make-to-order production. We describe the process of developing a simulation model of the assembly shop of electronic production using Tecnomatix Plant Simulation software. The focus is on the search for the optimal capacity utilization of the workshop. The created model allows getting detailed statistics about various aspects of functioning of the workshop, depending on the input data.

1. Introduction

The study of complex systems involves the construction of abstract mathematical models presented in the language of mathematical relations, which allows obtaining functional dependences of the characteristics of the system under study on the parameters. Mathematical modeling is the process of establishing the correspondence to a real object of a certain mathematical object, called a mathematical model, and the application of appropriate mathematical methods for studying this model in order to obtain the necessary data about a real object [1]. But the application of an analytical solution for this situation is impossible, they are used only in simple cases when sequential processing of a product of the same type and a constant processing time at each stage.

For more detailed information about the behavior of the object using simulation. Simulation is a special case of mathematical modeling. It allows reproducing the process of functioning of the system in time with the preservation of elementary phenomena, their logical structure and sequence of occurrence in time. According to the source data, information is obtained about the states of the process in the future at certain points in time. Simulation models allow taking into account factors such as non-linear characteristics of system elements, numerous random impacts and others that often create difficulties in analytical studies [2]. Simulation results describe the behavior of the system, the impact of various system parameters on its characteristics, identify the advantages and disadvantages of the proposed changes and predict the behavior of the system [3].
The assembly workshop receives different orders that require different processing times depending on the type of product being manufactured. Constant change in production volumes and components leads to uneven and inefficient use of the company's capacity. Thus, the task of planning, which is faced by any enterprise, is complicated. The flow of incoming orders is random in time and can change during the working day. Some equipment may temporarily fail, which inevitably leads to interruption in operation. It is necessary to find a solution to optimize workshop production capacity and obtain maximum overall productivity. It is possible to calculate the optimal values of the production system parameters for a production plan by using a simulation model.

2. Research methods
The simulation model (SM) is a dynamic model where all processes are considered on a non-decreasing time scale. There are four main approaches to SM: dynamic modeling, system dynamics, discrete-event and agent modeling [4]. Modeling of production and business processes may involve just the discrete-event approach [5]. Discrete event modeling is called such an approach to the construction of simulation models which represents the real actions of such events [6]. The discrete event method is used when the system can be reliably represented as a sequence of operations.

The development of a simulation model begins with the collection of data and development of an abstract model (Figure 1). Then the model is implemented using the software product. Then the created model is analyzed and a series of experiments with the working model is performed. The final step is to evaluate the results.

One of the fundamental concepts in discrete event modeling is queuing systems. Queuing systems are mathematical models of such real or projected systems, the functioning of which can be considered as a sequential interaction of some discrete objects with the elements of the system [7]. These objects, which usually come to the system from external sources, interact with the system elements for some time according to certain rules, and then leave the system [8]. The flow of applications in our case is
orders received in the workshop for the assembly of various products (Figure 2). They can be of several types and differ from each other in one or several parameters. The main parameter of the order flow is the time interval between the moments of receipt of two neighboring orders [9]. The order flow is considered as a random process, characterized by a distribution function of the period of receipt of orders. The element of the system in which the operations take place is called the service device; in this case it is the workplace along the technological route. At the time of the operation, it is busy; otherwise it is free. Service of each request by a channel means that the details in it are delayed for a time equal to the service period. After servicing, the order leaves the workplace. The random nature of the arrivals of the parts formed a queue.

Figure 2. Structure of the queuing system

3. Case study
The study was conducted on the assembly shop of electronic production, which operates in a large number of nomenclature products, a change in the type of the workpiece. Production in the order shop begins after a random time. The operations are preceded by the operation of issuing the order component to the worker, which is received for processing at the workplace. The duration of the assembly depends on its technological complexity of the final product. The order is made sequentially for operations with some averaged time values. At the end of the entire process, all assembled products are followed for final control.

Figure 3. Simulation model input
Figure 3 presents a set of parameters necessary for modeling the activities of the workshop. We used the Tecnomatix Plant Simulation as the environment of the simulation model. The block-oriented concept of the simulated process involves the description of queuing systems [10]. Tables 1 and 2 show collected data to create a simulation model. In the created model, the whole process takes into account the working time: 5 days in week from 7:30 am until 4:20 pm with breaks for 1 hour.

**Table 1.** The composition and number of assembly shop workers

| Number of profession | Name of profession          | Number of workers | Number of workplaces |
|----------------------|-----------------------------|-------------------|----------------------|
| 686                  | Collector                   | 9                 | 27                   |
| 343                  | Adjuster                    | 18                | 18                   |
| 266                  | Engraver                    | 1                 | 1                    |
| 460                  | Laser engraver              | 1                 | 1                    |
| 582                  | Electrician supervisor      | 7                 | 30                   |
| 050                  | Worker with cords           | 12                | 20                   |
| 463                  | Braider                     | 1                 | 1                    |

**Table 2.** The sequence of operation and time standards

| №   | Number of profession | Time standards | Operation             |
|-----|----------------------|----------------|-----------------------|
| 1   | 686                  | 0.6            | Assembly preparation  |
| 2   | 833                  | 0.15           | Stamping              |
| 3   | 189                  | 0.015          | Control               |
| 4   | 70                   | 0.11           | Engraving             |
| 5   | 185                  | 0.01           | Control               |
| 6   | 540                  | 0.7            | Preparation of mixtures |
| 7   | 551                  | 0.02           | Impregnation          |
| 8   | 343                  | 0.2            | Mounting preparation  |
| 9   | 343                  | 0.6            | Mounting              |
| 10  | 686                  | 1.3            | Assembling            |
| 11  | 343                  | 60             | Mounting              |
| 12  | 201                  | 5.5            | Control               |
| 13  | 686                  | 0.33           | Filling               |
| 14  | 201                  | 0.033          | Control               |
| 15  | 686                  | 1              | Assembling            |
| 16  | 266                  | 1.3            | Marking               |
| ... | ...                  | ...            | ...                   |
| 73  | 201                  | 0.16           | Control               |

Getting started is done by running the Plant Simulation program and in the window that opens, creates a new model. We select the basic objects of the material flow, because they are the necessary basic elements for building the scheme. We add the following elements to the model, such as "Source" (which are input of the flow of requests for execution) and "Drain" (the boundary object in the structure through which dynamic objects leave the model). Next we added "SingleProc" for each technological operation and parameters, such as processing time, set-up time, recovery time and others are set. Because the model is a queuing system, it is necessary to use the "Buffer" element to store waiting service orders. To account for the operating time, we add "Event Controller" to the scheme. This function allows coordinating all events during the operation and specifying the simulation time.
Features of the technological process require each element of "SingleProc" workplaces and workers. The worker is simulated by the following elements "Worker", "WorkerPool", "Broker" and "WorkPlace" [11]. Figure 4 shows the creation table of workers in "WorkerPool", which produces a number of different workers. While the worker is not on "Workplace", he is on the "Workerpool". After setting "WorkerPool" we control the instantiation of the workers in "Resources" and make worker-related settings. The "Workplace" is intended for only one worker, and while the work is completed, he remains at its workplace. In order to connect material flows from different sources, we use the element "Assembly". This element imitates the addition of parts to the main creating a new material flow. We introduce the "Chart" element into the model, which will depict the general picture of the equipment loading and working. To view the picture of equipment loading we add necessary elements to the "Chart" with the mouse (Figure 5).
The simulation model based on the Plant Simulation Toolkit is presented in Figure 6. Widespread use of the presented model is based on the ability to collect and analyze different types of information. In addition, various production changes can be verified by their effectiveness. The main advantages can be summarized as follows:

- rapid construction of the model;
- creation of a reusable model for the analysis and study of different projects and scenarios;
- possibility of updating data in real time following possible changes in the real system;
- reduced time, costs and modeling effort;
- integrated management of product data, processes.

4. Conclusion

In an era of digital factories, great attention is focused on simulation systems as a particular decision support tool to represent the increasingly complex modern production systems. Most modern electronic equipment production consists of small and medium-sized enterprises working exclusively with small series. Make-to-order production, in which production is determined by customer orders, is a key concept for the plant of the future. This concept stems from a trend to produce small batches of custom products. A common feature in custom production is that production is only carried out upon receipt of an order from a customer. To improve production efficiency, operations management should be carried out to achieve the required performance under specified conditions in real time. The relationships between production planning, maintenance tools and equipment performance are a critical factor. Decision makers have to adapt to the dynamic behavior of the production environment. This creates a demand for a model that allows making complex decisions under uncertainty while considering alternative solutions.

The aim of the present research is to develop a simulation model of an assembly shop improving the production and maintenance process. A discrete-event approach is used to simulate an assembly shop through Tecnomatix Plant Simulation. The simulation model developed in this study can visualize the work of the workshop where experiments can be conducted, which is useful for understanding the behavior of the production system. The output of this simulation gives the decision maker the most probable scenario.

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