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Simulation of the Production and Transport Problem in the FlexSim Environment

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Abstract. The method of building a simulation model of the production and transportation problem is described. In the FlexSIM environment, a simulation model of a part of the production process was built and the impact of changing input parameters on output parameters and the behavior of the technological system as a whole was investigated and analyzed.

1. Introduction

Modern industrial productions are complex dynamic systems characterized by a high level of uncertainty of initial information and the complexity of their behavior. To analyze and solve many problems associated with the management of such systems, it is advisable to use simulation modeling. Simulation modeling in the research of technological processes is a research method in which the system under study is replaced by a model that describes the real system with sufficient accuracy. Computer studies are conducted with it to obtain information about this system [1-3]. Simulation modeling is the most universal method of system research and quantitative assessment of their functioning characteristics. Modern simulation modeling of production processes[4] allows you to reproduce the sequence of operations or stages of the production process by simulating its individual elements, as well as to determine the best type of production line with optimal performance, the ability to perform testing with a variety of production parameters, including flow capacity and quantity necessary equipment. This allows you to determine the type of production that will be most effective for the production of the product, and the factors that affect the final indicators of the quality of the product being created. Thanks to simulation modeling and conducting experiments with the use of the model, it is possible to achieve an increase in the efficiency of the use of equipment, optimization of production, reduction of production cycle time, increase in production volumes and improvement of product quality[5]. New developments and technologies in simulation modeling, namely their appearance, make it possible to increase the efficiency of the technological process and bring it to the required production level [6].

2. Materials and Method

The method of simulation modeling is widely used in production to solve various problems from optimization of intermediate processes to strategic management. Such modeling allows analyzing not only a specific process, but also the production system as a whole, which makes it possible to check the capital intensity of a particular management strategy. A typical experiment of a simulation model includes the following stages:

— construction of the created model;
— analysis of the constructed model;
— implementation of a simulation model and conducting research;

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— analysis and evaluation of the obtained results.

In the process of simulation modeling, it is possible to reproduce not only the relationship between the objects of the system, but also to simulate the development of the system over time, which is very important for the enterprises of the machine-building industry. After all, the study of their industry structure requires a systemic approach and requires a comprehensive analysis of eco- nomic, statistical and other sources of information both at the level of a separate production process and at the level of the enterprise as a whole. The production and transport task is to ensure consumer demand with the lowest possible total costs. In addition to information about demand, not only transport tariffs for transporting a unit of products from suppliers to consumers and the production capacity of suppliers are taken into account, but also the selling prices of products from each of the suppliers. In a one-stage transport problem, products from suppliers go directly to consumers. On the contrary, in multi-stage transport tasks, products from suppliers first arrive at intermediate points (transport network nodes, distribution centers, warehouses), where, if necessary, they are reloaded or unloaded and stored for a certain time. That is, the final consumers receive products not from suppliers, but from the specified intermediate points of transport networks. There are two-stage transport tasks, when the transportation of products is carried out in two stages: first from the supplier to an intermediate point, then from this intermediate point to the consumer (**Figure 1**) and multi-stage - when there are several intermediate points on the way from the supplier to the consumer (**Figure 2**).

Figure 1. The structure of the two-stage transport problem

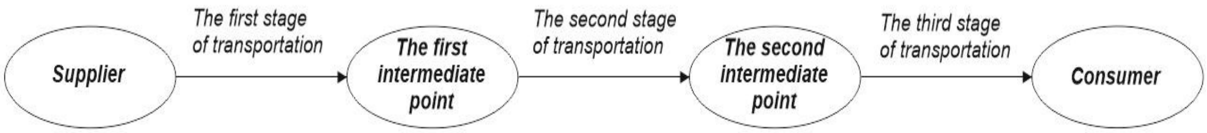

Figure 2. The structure of the multi-stage transport

The economic-mathematical model of the production-transport problem has the following form:

$$\begin{gathered} z = \sum_{i=1}^{n} s_i y_i + \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij}\, x_{ij} \rightarrow \min \\ \sum_{i=1}^{m} x_{ij} \geq b_j \; (j = \overline{1,n}), \\ 0 \leq y_i = \sum_{i=1}^{m} x_{ij} \leq N_i (i = \overline{1,m}), \\ x_{ij} \geq 0 \; (i = \overline{1,m},\; j = \overline{1,n}) \end{gathered} \quad (1)$$

where: m - the number of enterprises - producers of products (suppliers); i – individual supplier number ($i=1, m$); N_i– production capacity of the *i-th* producer;

s_i– sell-ing price of a product unit from the *i-th* supplier;

n - the number of consumers; – individual consumer number ($j=1,m$);

b_i – demand for products from the *j-th* consumer;

c_{ij} – costs for transportation of a unit of products along the route $i \rightarrow j$ $(i = \overline{1,m},\; j = \overline{1,n})$.

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x_{ij} – the volume of transportation along the route $i \rightarrow j$ $(i = \overline{1,m},\ j = \overline{1,n})$.

y_i – volume of products manufactured at the i-th enterprise and sent to the consumer;

z – total costs of purchasing products from suppliers and transporting these products to consumers.

The objective function of the problem reflects the requirement to minimize the total costs of purchasing products and transporting them to consumers. The limitations of the task take into account the requirement to satisfy the demand of each of the consumers, the condition that the purchase volumes correspond to the levels of the production capacities of each of the suppliers, and the balance equations for the distribution of the products manufactured by each of the supplier enterprises among the consumers. Requirements on the non-negativity of production volumes and transportation of products are also taken into account. Mathematically, the model (1) of the production and transport problem is a problem of linear programming of the transport type. It can be solved by the simplex method. It is also possible to reduce this problem to a transport problem and solve it using the method of potentials. But first you should check whether the condition for the existence of a solution to this problem is met. The production and transportation problem has a solution if and only if the total production capacity of all producers corresponds to the aggregate demand for products from all consumers:

$$\sum_{i=1}^{m} N_i \geq \sum_{j=1}^{n} b_j \tag{2}$$

Under condition (2), the production-transport problem can be reduced to a classical transport problem. And then such a problem is solved by the simplex method or the method of potentials.

In modern conditions, the transportation of products from the producer to the consumer is carried out in two ways: from the supplier to the consumer (the most economically advantageous) and from the supplier-base to the consumer (requires more transport and other costs). The delivery of products through the base to the consumer requires the construction of a model of a multi-stage transport problem, in which the minimum value of the total transport costs is usually taken as the optimality criterion. The transportation plan between suppliers and warehouses and the transportation plan between warehouses and consumers are independent of each other. Two independent transport tasks are solved separately and in any order. If the total capacity of the warehouses is greater than the total capacity of the suppliers, then it is necessary to make a single calculation in order to obtain a more economically efficient multi-stage transportation plan.

Sequential processes of production of various types of products, their delivery to processing points and other types of production of these types of products and their delivery to end consumers are the task of production and transport logistics. They are reflected in the setting of a multi-stage transportation problem, the objective function of which is to minimize all total costs for the production and transportation of raw materials and finished products. Solving such problems is problematic, as it requires the development of interconnected models, methods, and algorithms. Thus, the task of developing high-quality tools for building models of multi-stage production and transport problems is urgent.

One of the modern simulation tools is FlexSIM multifunctional simulation environment. With the help of the FlexSIM system, it is possible to build a model of the production and transportation task at the enterprise, as well as individual parts manufacturing sites and transportation lines by simulating all elements of technological processes even before the start of their real production. The advantage of the FlexSIM software tool is that this simulation environment supports design, model development, allows you to perform computer experiments with the model, including various types of analysis.

3. Results

Let's consider one of the variants of the two-stage production and transportation problem. The enterprise uses five types of resources to manufacture seven types of products. At each of the five sites, a certain type of resource (parts) is produced and processed. Further, these resources are transported to an intermediate point (warehouse), from where they arrive at branches (shops) for the manufacture of specific equipment (product). The network model of this problem is shown in **Figure 3**. The classic transport problem is one-stage in the sense that in it the products from suppliers come directly to consumers. However, in practice it is quite common for products from suppliers to first arrive at intermediate points (transport network nodes, distribution centers, warehouses), where, if necessary, they are reloaded or unloaded and stored for some time. That is, the final consumers do not receive products from suppliers, but from these intermediate points of transport networks.

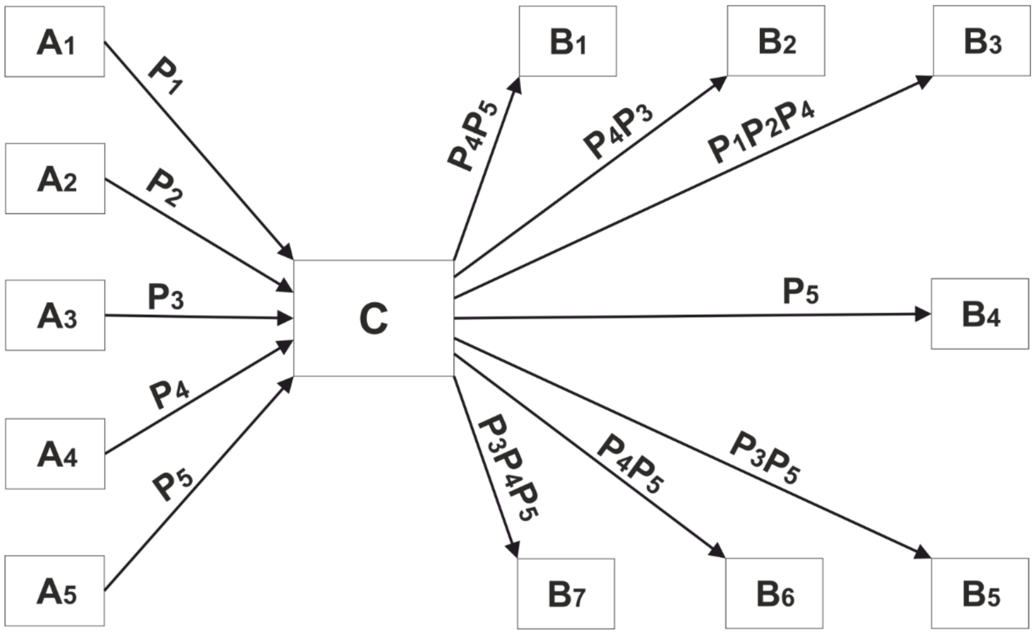

Figure 3. The transport network of the several stages transport task

We consider FlexSim software tools as an effective software to analyze transport tasks. As FlexSim is useful tool for solving transport tasks and effective for different technical tasks [1] , economical tasks[3], industry tasks[6]. Principle of simulation modeling, gave as a chance to analyze every part of process. We used the transport network (**Figure 3**) for creating the simulation process in FlexSim (**Figure 4**). We can see all stages are connected between each other. We used basic elements: sources (Source), processes (Process) and queues (Queue). In our case, sources are the elements from which information or objects enter the product model it is point A1 from **Figure 3**. Queues 1, 2, 3, 4, Conveyors, Separator, Racks 1, 2, 3, 4, 5, 6 Combiner in FlexSIM are intermediate stages of model (**Figure 3**). Sink 1 and Sink 2 we take as points B1 and B2 of our transport network. The algorithm of creating imitation model in FlexSim software is the next:

Step 1. Input, the first element is Source, where we specify the following logic:
Source1 – Source – FlowItemClass -Box.
Source1 – Flow – Send To Port – First Available.
Step 2. The next stage is the generation of products of different types (four types):
Triggers – On Creation – Set Item Type and Color-Item Type – duninform (1,4, get stream(current)).
Step 3. We have to divide each type of product into a different port.
We have four ports to each conveyor.
Separator – Flow – Send to Port – Port by Case.
Step 4. Create conveyors for distributing products to next stage.
Step 5. Create Racks and put the following logic for each rack:
Maximum content, Number of Bays, Number of Levels
Step 6. Create separator and combiner like intermediate points.
Step 7. Create Sink1 and Sink2 like points B1 and B2 (like destination points)
Step 8. Put connections between elements of the simulation model.

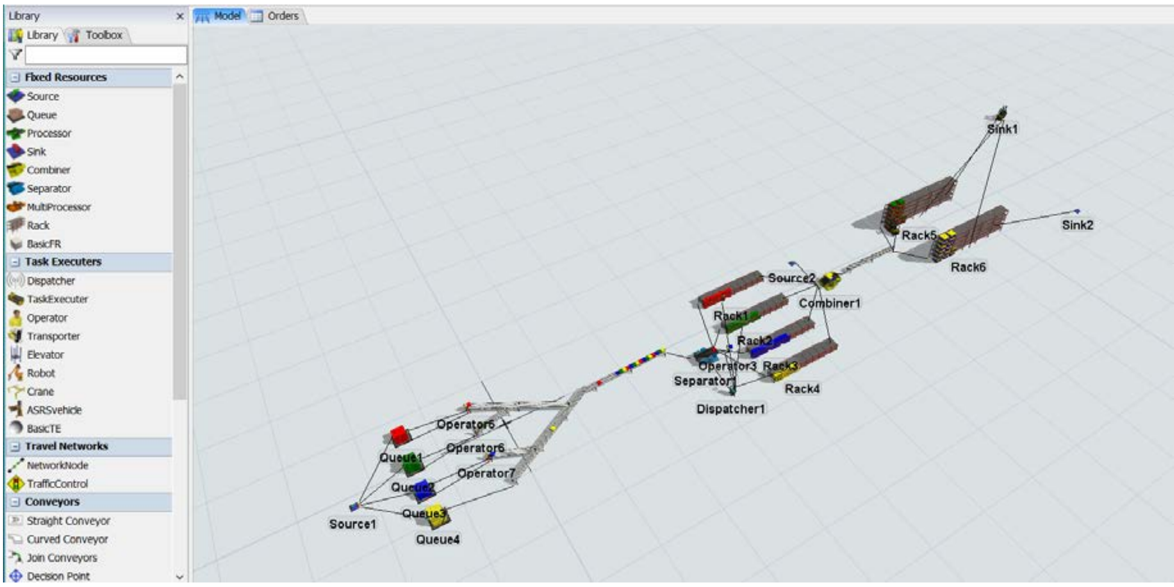

Figure 4. The simulation model of transport network of the several stages transport task.

The developed simulation model in the FlexSim environment allowed seeing the process of transportation. The study allowed us to set the parameters of transportation, for example, the moving products through intermediate stages to destination points (B_1 and B_2) FlexSim tools allowed to visualize the transport network of the optimal support plan (**Figure 5, Figure 6**).

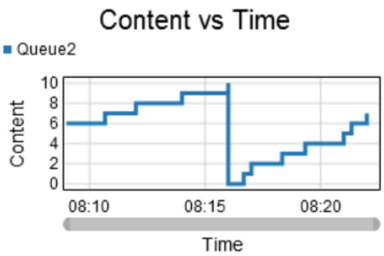

Figure 5. Dependence of the content and time for Queue2

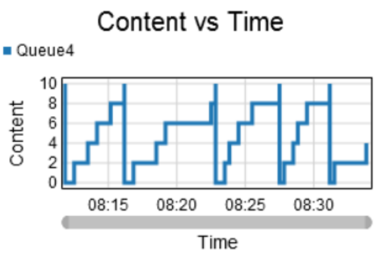

Figure 6. Dependence of the content and time for Queue4

The analysis of the study conducted a mathematical analysis of the transport problem is the basic step of creation the simulation model of this process in FlexSim simulation software. The result is the optimal path of movement of products from the producer through intermediate points to the consumer. The model of process in the FlexSim environment is created allows to analyze each stage of delivery. For example, the number of each type of product delivered to the consumer, stops of products in warehouses (Rack 1, 2, 3, 4), the number of surplus products for each warehouses.

4. Conclusions

The process of building a simulation model of the production and transportation problem in the FlexSim environment is demonstrated. A diagram of relationships between objects in a two-stage transport problem was created, which clearly demonstrated the impact of input data both on each object separately and on the technological system. The sequence of setting the logic for the interaction of the objects of this technological process is proposed.

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