The Use of Simulation Models in Solving the Problems of Merging two Plants of the Company

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Abstract: This paper focuses on utilization of analysis of different possibilities of merging two production sites with the help of simulation model of company processes. Software SIMUL8 was chosen as a development environment for its possibility of dynamic discrete simulation of company processes. In the first phase, it analyses current status of both production sites. It is followed by suggesting several possible solutions for their potential merger. Each solution is analyzed with the help of simulation models. They have been evaluated and the optimal solution was selected.

Keywords: simulation models, merging of two production plants, manufacturing logistics

1 Introduction

The modern trend in these days is to optimize everything that we can, especially in logistics processes. The result is the achievement of predetermined targets, such as minimizing inventory in stock, optimal utilization of handling equipment, shortening shipping routes and the introduction of lean production [1, 2]. Procedures and methods for achieving successful targets are many [3–6]. One of them is the use of modeling and simulation of logistics processes. This method allows a reliable view of the possible development of production. For example, it is possible to model the entire production hall, including a detailed model of individual production lines and movements between them. So we have a simple way to test an infinite number of variants to solve the problem and for the actual implementation to choose the best possible solution to the situation.

2 Methods

As a basis for the creation of simulation models, analyzed processes of both production plants has been used. Gradual steps has been compiled in simulation models using SIMUL8 simulation software to get the most accurate results. Data from these models were used for the final evaluation. For our purposes we chose discrete simulation model. The appropriateness of discrete simulation model use is justified by the turn of events of particular activities. Each activity is assigned with a specific time and its distribution function. Distribution function affect duration of time period of the activity.

2.1 Discrete simulation

Discrete simulation models [10] are characterized, that all the state variables takes only discrete values and change over time in jump steps [11–15]. Discrete dynamical system is a mathematical structure designed by main three components:

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- Intervals in which all the possible values of the state variables lays;
- Function defined on specific interval;
- Differential equation which represents the "movement" equation of the system.

We quantify this change in terms of an updating function, which takes the current state of the system as an input, and specifies what the state of the system will be after some interval of time, an interval which corresponds to the specific updating function we are using. In general, an updating function is written:

\[ m_{t+1} = f(m_t), \]  

where \( m_t \) is the current state of the system, and \( m_{t+1} \) is the state of the system after one interval of time has passed. By iterating the above calculation multiple times, we can find subsequent states of of the system. Equation can be written in the form:

\[ f \circ f(m_t) = f(f(m_t)) = f(m_{t+1}) = m_{t+2}. \]  

This equation describes the changing states of the system in dependence on time. This equation is also used as a theoretical basis for understanding discrete time steps in simulation model that we created.

2.2 Input preconditions of the simulation model

The manufacturing enterprise which we describe, is engaged in the Czech Republic since 1994. It focuses on the production of interior components for the automotive industry. Customers are the most car manufacturers in the world, for example, ŠKODA AUTO, Volkswagen, Toyota, Ford, Mercedes Benz, BMW. The entire production processes, including supply of material, is controlled by the system "just in time". Company operates two mutually separate production and storage halls. These production halls were located approximately 10 kilometers apart. Management of the company thought about merging these two separate plants into one. The requirement was to analyze the current situation and to build the simulation models for each operation to get the most accurate results. From the simulation models was created a demonstration model for integrated operations.

Plant A was the original plant with two production lines. The final products were stored in the warehouse of finished products. The area included the basic material warehouse. The basic material for Plant B was dispatched on transport car. Furthermore, there was positioned manufacture of polyurethane boards (PUR), which were used as material for final production. Finished blanks for external supplies were stored in a warehouse PUR. And the whole operation worked in three shifts mode of working week in time period from Sunday 22:00 to Friday 22:00.

Plant B was built in 2011 as a completely new production space with four production lines. There was a warehouse of finished products with final shipment according to customers’ orders. The area also includes a warehouse base material. The store did not correspond to the actual needs to cover all production requirements. Therefore, there was placed only safety stock to cover the requirements of the production for one day. All the basic material was imported on transport car from the store base material warehouse in Plant A. Another part of the Plant B was the space for waste treatment. The entire Plant B functioned as Plant A in three-shift mode with a working period from Sunday 22:00 to Friday 22:00.

2.3 Conceptual models of Plants A and B

Before the start of the creation of a simulation model in a computer program, it is necessary to create a conceptual models (Figure 1 and Figure 2) for some basic understanding of the system. Figure 1 shows how the entity passes through the system. At the start of processes, there is the receipt and storage of the material. This is followed by the transfer of the material to production, where it becomes the finished product taken by the warehouse finished production. During the production, waste is formed and it must be taken for disposal. Production of PUR (polyurethane) has its own material warehouse at the production line. Finished preparations intended for its own production being shipped to the warehouse of materials. Semi-finished products for external customers being shipped to the warehouse of PUR. Finished products, PUR, waste and materials for the operation of Plant B must pass through the expedition, and then leaves the Plant A.

Conceptual model of Plant B is similar to the Plant A. Figure 1 also shows a running of the entities through the system of Plant B. The beginning of the processes is the receipt of material followed by material storage. The transporting materials follow to production across four production lines. On production lines they are becoming a material of the final product and a waste. Finished products are placed in a warehouse of finished products and waste is weighted at the disposal. Finished products in the warehouse of finished products and waste must be delivered after expedition, and then leaves Plant B. Conceptual models were modified to create simulation models in some variants of plants merging (Figure 2).
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3 Solution

According to the conceptual model of Plant A, its simulation model was assembled. The simulation model was divided into several parts: Receipt of material, Basic material warehouse, Production lines, Warehouse finished products, production PUR, PUR Warehouse, Waste Management and Expedition.

The simulation model of Plant B (Figure 3) is fully based on the above conceptual model. The simulation model of Plant B consists of practically identical parts as a model of Plant A. In the first phase we formed the backbone network of traffic routes, to which the individual parts successively implemented the model. Those parts are Material receipt, followed by Material warehouse extended on four storage branch for supplying four production lines. Stock of finished products is extended to four branches. At the end of the chain is Waste management and Expedition.

3.1 Processing of solution proposals

Simulation models of Plant A and B were processed and verified. During their creation, the individual parts of the models were subjected to testing their functionality. These tests should verify the actual functionality of the model that there are no errors during the simulation procedure. Simulation models of Plant A and B are in very good agreement with reality.

These models serve as a starting models to build three variants of a possible merger of the operations. For each variant, a conceptual design model of the mergers (Figure 2) was created and compiled its simulation model. Simulation models were verified and validated.

Three possible options of plants merging were created:

- Option 1 - moving the entire production capacity (excluding the production of PUR) from Plant A to Plant B, the base material will be imported into Plant B on transport car.
- Option 2 - very similar to Option 1 - a reallocation of entire production capacity (excluding the production of PUR) from Plant A to a new Plant B and transfer the complete storage base material warehouse. In Plant B stays only manufacturing and warehouse of PUR, transportation is provided by transport car.
- Option 3 - merge two manufacturing plants into one - the entire operations of the Plant A moves to Plant B. This solution requires extension of the storage capacity of the base material. It is also necessary to build a completely new space for production and storage of PUR.

3.2 Creation of models and simulation experiments

Simulation models of the different options were made, verified, validated and prepared for simulation experiments.
The actual simulation models were compiled by preparation or deletion of some parts. For example, by simple moving of production lines A1 and A2 of Plant A into Plant B. Integral parts of the model, their parameters and location were also changed. The main part of the model, that is changing as a result of the new traffic arrangements, is the number of forklifts needed for the transfer of all entities within the system of loading and unloading operations.

Simulation experiments works mainly with different numbers of forklifts and explores how changes the individual output data from the model. With the resulting data, it is decided how many forklifts are needed for the smooth running of operations.

Length of the simulation experiments reflects a three shift operation with time period from Sunday 22:00 to Friday 22:00. It corresponds to 7200 minutes of simulation time. The default number of forklifts for Plant A is five pieces and for Plant B is seven pieces.

Basic criteria of simulation experiments:

- Supply of basic materials on the routes may not be 0, there would be a cessation of production;
- A queue of finished products on a line can be up to three times the size of a shipping container;
- Waste on a line can be up to three times the size of a shipping container;
- The average queue length for receiving the material and for dispensing the material into Plant B must be less than 120 minutes;
- The average queue length for dispensing material to the line from the warehouse to dispense of finished products from the warehouse of finished products and for dispensing polyurethane must be less than 60 minutes.

4 Results

By using simulation experiments, we obtained results for different alternatives. The first criterion is the number of forklifts. The default number of forklifts used for the Plant
Table 1: Final costs of individual solutions – Options 1-3.

<table>
<thead>
<tr>
<th></th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cost</td>
<td>526 400 CZK</td>
<td>5 562 710 CZK</td>
<td>16 657 300 CZK</td>
</tr>
<tr>
<td>Monthly savings</td>
<td>264 120 CZK</td>
<td>528 240 CZK</td>
<td>460 120 CZK</td>
</tr>
<tr>
<td>Return of Investment</td>
<td>Approx. 2 months</td>
<td>Approx. 10.5 months</td>
<td>Approx. 36 months</td>
</tr>
<tr>
<td>Total savings over 5 years</td>
<td>15 320 800 CZK</td>
<td>26 131 690 CZK</td>
<td>10 949 900 CZK</td>
</tr>
</tbody>
</table>

A is five and seven for Plant B. That's twelve forklifts required for the smooth operation of both plants. According to the results we may serve different variants of solving the following number of forklifts that met the conditions:

- Option 1 - total of 10 pieces of forklifts;
- Option 2 - total of 8 pieces of forklifts;
- Option 3 - total of 10 pieces of forklifts.

The results of simulation experiments show that all three variants can save forklifts compared to the basic arrangement of the two plants. Namely, Option 1 and 3 two pieces and Option 2 four pieces of forklifts. It is necessary also to take into account a possible error of handling forklifts, in simulation models we are introducing it as a random variable number.

The second criterion is the demands on design variants in real traffic. Option 1 requires no alterations, only the necessary costs of moving two production lines from Plant A into Plant B, Options 2 and 3 require building modifications and merge plants without them is impossible. Processing projects in various alterations can be accurately quantified by the costs of the various options - merger savings compared to using fewer forklifts. It is possible now to decide, which of the proposed variants of solution is the best for optimum cost savings.

Qualified estimates of the cost of project implementation:

- To expand the store base material – cost 4 750 000 CZK;
- Construction costs for new space for PUR manufacturing – cost 10 620 000 CZK;
- For Option 1, the summary removal costs is 526 400 CZK;
- For Option 2, the summary removal costs is 812 710 CZK;
- For Option 3, the summary removal costs is 1 287 300 CZK;
- Average monthly cost on transport cars are among cost 196 000 CZK;
- Average monthly cost per head including forklifts service - cost 132 060 CZK.

Table 1 shows the final costs of individual optimization solutions variants - the total cost of implementation, the monthly savings considering the lower number of forklifts, the return of investment and the absolute savings (after deducting the cost of implementation in the period of next 5 years).

From presented results we can say, that in terms of return of Investment is the best Option 1. From the perspective of the overall cost savings in the next 5 years is the best Option 2. As the best solution was selected the Option 2. Production capacity of Plant A moves into Plant B, expand the storage of materials in Plant B and move the rest of the warehouse of Plant A. Option 2 has a refund of investments in period of 10.5 months, overall spared costs are twice as compared to the Option 1. Option 3 has costly high-refund period of investments.

5 Conclusion

Possibilities of using of the simulation models in praxis are large. Simulation models can be used with advantage in dealing with different logistical problems. As example can be the models of production logistics, distribution logistics, reverse logistics, transportation logistics and logistics services [3, 7, 16, 17]. In other fields simulation models are used to solve problems of crisis management and obtaining input data for solving various problems of human activities [8, 9, 18]. Simulation tools occupy an important place in improving the efficiency of logistics processes of companies, among them we can mention the so-called digital factory [10, 19] and a production information systems based on an internet of things [2, 20]. The aim of this paper is to demonstrate the specific use of simulation models for solving the merging of two manufacturing operation places located a few kilometers away from each other. This problem was solved in a manufacturing enterprise and subsequently realized. Simulation model was served as a basis for strategic decisions of the company management. We present an analyses of initial state of the two production plants and the preparation of conceptual models.
and simulation models for each operation. The paper describes three variants of merging two production plants, describes the assembly simulation experiments, execution and evaluation of the different options according to the simulation results. Simulation models has been used in solving the specific logistical problem - the merging of two manufacturing plants in the real company.

References