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MATERIAL FLOW OPTIMIZATION WITH THE APPLICATION OF GENERALIZED NETWORK FLOW MODEL

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Abstract

It is essential for every company to know their business processes well, because these companies must allocate their resources in an efficient way in order to keep or strengthen their market position. During the research we aimed at optimizing the material flow at a wooden box producer company with the use of the generalized network flow model as this model is widely used for modelling production processes. In the first part of our work we calculated the optimal material flows focusing on two objectives, and in the second part we determined a compromise solution. Finally, we compared and evaluated the results of the three models.

Keywords*: material flow, optimization, network model, generalized network flow model.*

Introduction

One of the most important elements in production is the provision of optimal material flow. Having identified the optimal flow, a company's inventory level can be reduced, along with inventory and storage costs **[1]**, and in this way wastes are also revealed in the production **[2]**. There are widely used operations research methodologies available for performing planning and scheduling tasks. Computers and related software applications can help to calculate optimization models quickly and effectively.

1. Literature background

1.1. Production based layout

According to Demeter et al. **[3]** there are two basic types of production layouts: one is the process based layout, while the other is the production based layout. During process based production machines are arranged according to the production process to place all the process stages close to each other. Typically, with this production layout large batches can be produced **[4]**. In production-based layout machines are arranged in workshops, so semi-processed products have to be moved from one workshop to another **[4]**. This kind of production layout can generate extra material handling and inventory holding costs **[1]**. However, this latter layout can meet the requirements of unique manufacturing **[3]**.

1.2. Operations research

Operations research is a branch of applied mathematics, which was invented in the XX. Century to solve military problems effectively **[5]**. However, operations research methods can be used for solving both technical and business tasks, for instance production control, transportation, distribution and financial fields **[6]**.

1.2.1. Network models

Modelling and evaluating production processes can be accomplished with the use of network models [7]. The application of network models is widely-used in practice [5] and it has many different versions. The shortest path problem is one example of these versions together with relocation models, shortest path problem, maximum-flow problems, as well as CPM and PERT methods applied in project management [6]. Among these models, a special extended version of the relocation model, that of the generalized network flow model, can be perfectly used for modelling production processes [7][8].

2. Methodology

The first step of the research was data collection: the production model and machine efficiency were calculated with the help of operators, cost data were provided by the financial department. Based on the received data, the following objectives were assigned in the network model:
- minimal production cost;
- minimal setup cost;
- compromise solution (the combination of the former 2 objectives).

At the end of the research, results were evaluated.

3. Case Study

3.1. Production presentation, basic database

The main profile of the researched company is wooden box manufacturing and its sale. The production process consists of 5 stages, every phase is located in a separate workshop. 12 m3 processed wood is required for the manufacturing of 200 pieces of wooden box, which means approximately 16 m3 wooden raw material is necessary due to the manufacturing process waste. The first operational phase is the use of the pendulum saw, where the wooden raw material is cut to the required length. It is followed by the phase of thickening plane, where wood is tailored to the proper thickness. This workshop has 2 machines: a newer and an older type. The difference between the machines can be measured by comparing the operation costs and the manufacturing waste. The next activity is the planning of the already thickened wood. Similarly to the previous stage, there are two operating machines here. In the last but one production phase, the sawing of the processed product into the final width and size takes place. The last activity in the production is the assembly of the processed wood to make wooden boxes. This production system can be seen in Figure 1.

During the research, we were shown around the production area, where we could become acquainted with the production processes, while cost figures related to each workshop were provided by the company's financial department. Table 1. demonstrates these data.

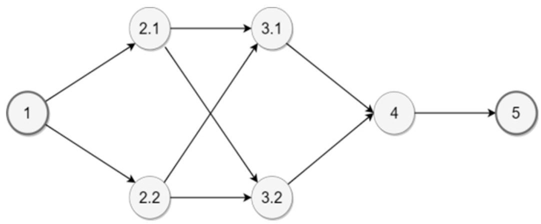

Figure 1. *Production model of the company*

Table 1. *Basic information*

Activity	Production cost (HuF)	Setup cost (HuF)	Yield
1-2.1	500	45	80%
1-2.2	570	60	83%
2.1-3.1	350	35	60%
2.1-3.2	390	35	65%
2.2-3.1	400	40	90%
2.2-3.2	420	55	95%
3.1-4	350	46	100%
3.2-4	330	62	100%
4-5	700	0	100%

3.2. Results

3.2.1. The optimization of material flow based on the objective of minimal production cost

In accordance with the data provided by the company and measured during the research, the variables of the model were the material flow between the workshops. The aim of the first calculation was to optimize the material flow by minimal production cost. Production cost was included in the network model:

$$500x_{1,21} + 570x_{1,22} + 350x_{21,31} + 390x_{21,32} +$$
$$+ 400x_{22,31} + 420x_{22,32} + 350x_{31,4} + 330x_{32,4} + 700x_{4,5} \Rightarrow min \quad (1)$$

The constraints of the model were the following:

$$\sum_{j=1}^{n} x_{ij}\,\lambda_{ij} - \sum_{i=1}^{n} x_{ij} - I_i \geq 0 \qquad (2)$$

Where, x_{ij} indicates the gross material flow, λ_{ij} stands for yield value, and Ii marks the inventory in the i. node. The objective coefficients of the calculated model can be seen in the **Table 2.**

Table 2. *Objective coefficients related to the minimal production cost model*

From	To	Gross Flow	Net Flow
1.	2.2.	15.22	12.63
2.2.	3.2.	12.63	12.00
3.2.	4.	12.00	12.00
4.	5.	12.00	12.00

The production cost related to this variant is 26 339 HuF, while the total setup cost is 2351 HuF, so the total cost of the manufacturing is 28 691 HuF. The optimal material flow is realized through the following machines: (1)-(2.2)-(3.2)-(4)-(5).

3.2.2. The optimization of material flow based on the objective of minimal setup cost

The second model was calculated by the objective of minimal setup cost. The formula is as follows:

$$45x_{1,21} + 60x_{1,22} + 35x_{21,31} + 35x_{21,32} + $$
$$+ 40x_{22,31} + 55x_{22,32} + 46x_{31,4} + 62x_{32,4} \Rightarrow min \qquad (3)$$

With the given constraints:

$$\sum_{j=1}^{n} x_{ij}\,\lambda_{ij} - \sum_{i=1}^{n} x_{ij} - I_i \geq 0 \qquad (4)$$

Production cost of the second variant is 27 090 HuF, while the setup cost in this model is 2049 HuF, therefore, the total production cost of the manufacturing comes to 29 139 HuF. The optimal material flow according to the second objective is: (1)-(2.2)-(3.1)-(4)-(5).

Objective coefficients calculated by the second model are presented in **Table 3.**

Table 3. *Objective coefficients related to the minimal setup cost model*

From	To	Gross Flow	Net Flow
1.	2.2.	16,06	13,33
2.2.	3.1.	13,33	12,00
3.1.	4.	12,00	12,00
4.	5.	12,00	12,00

3.2.3. Compromise model

According to the results, it is obvious that both objectives cannot be optimized simultaneously. In order to create a compromise solution, distribution ratios are assigned to both models with 0.5-0.5 weights. The objective coefficients of the alternative optimum can be seen in **Table 4.**

Table 4. *Objective coefficients related to the compromise model*

From	To	Gross Flow	Net Flow
1.	2.1.	0	0
1.	2.2.	15.64	12.98
2.1.	3.1.	0	0
2.1.	3.2.	0	0
2.2.	3.1.	6.66	6.00
2.2.	3.2.	6.32	6.00
3.1.	4.	6.00	6.00
3.2.	4.	6.00	6.00
4.	5.	12.00	12,00

The production cost of the process in the compromise model is 26 714 HuF, setup cost equals 2201 HuF, which comes to 28 915 HuF in total. This material flow differs from the former two models, because in the last version both machines work in the third workshop.

3.2.4. Evaluation of the models

The lowest production cost is achieved by the first model, while the lowest setup cost was provided by the second model. In the case of compromise solution, the total process cost is the highest; however, focusing on the continuity of the production it is advisable to schedule the production according to this compromise model. Considering that model, two machines are working in the third workshop, so the production can be shared, or in the case of machine outage, the other machine can take over the full production, which results in safer production.

4. Conclusion

Material flow optimization opportunities were examined in this article at a wooden box manufacturing company. The following results were concluded:

In spite of the higher operations costs, this company should apply the compromise model with a greater production security.

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