OPTYMALIZACJA PROCESU REALIZACJI ZAMÓWIEŃ

PROCESS OPTIMIZATION OF ORDER FULFILLMENT

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Streszczenie: Przedmiotem pracy jest opis narzędzia optymalizującego kolejność realizacji zamówień w przedsiębiorstwie produkcyjno-dystrybucyjnym. Model został stworzony w oparciu o aplikację Microsoft Excel wraz z zastosowaniem dodatku Solver. Szczególną uwagę poświęcono analizie przydatności narzędzia w przypadku zmian funkcji celu, które podlegały zoptymalizowaniu. Omówiono problem minimalizacji opóźnienia w realizacji zamówień oraz minimalizacji kosztów, które wynikają z tych opóźnień.

Abstract: The aim of the article is a description of the tools that optimize order fulfillment in the enterprise of production and distribution. The model was created based on the Microsoft Excel application with Solver. Particular attention has been paid to the utility analysis at the time of the goal function changes that were optimized. The issue of minimizing delays in order fulfillment and minimizing the costs that result from these delays is discussed.

Słowa kluczowe: logistyka, przedsiębiorstwo, optymalizacja, realizacja zamówień.

Key words: logistics, enterprise, optimization, order fulfillment

INTRODUCTION

In the area of distribution one of the important elements of logistics decision optimization is proceeding in accordance with the principle of Just In Time. If the orders are not made on a regular basis by the customer, it is difficult to create a schedule of production and supply, and hence compliance with deadlines. Tool to optimize order fulfillment through the use of linear programming model provides information that the customers when to be hosted (Szymczyk, 2011).

The aim of the article is to present three possible variants in which the optimization of the order fulfillment process, where the most important assumptions relate:

- total delay of orders is minimized,
- maximum delay is minimized,

- costs resulting from the possibility of delays are minimized.

The use of Solver application can provide the basis for efficient and execution production and distribution in many companies.

1. METHOD OF OPTIMIZING THE ORDER FULFILLMENT PROCESS

All decisions taken in respect of ongoing business processes associated with the consequences of the in terms of profit and loss. Therefore, before it will take getting analysis of the situation, the criteria for the selection decision and seeking solutions to optimal. The methods used to solve decision problems using specialized computer techniques are helpful. In operational research, this means choosing one of the optimization package modules. A detailed analysis of the decision problem makes it possible to isolate its components. The decision-making process consists of the following actions to (Trzaskalik, 2008; Szymanowski, Bieńkowska-Lipińska i Twardowska, 2001):

- determining the purpose or objectives on which decisions will be made,
- defining the objectives of the sub-tasks that contribute to the achievement of the goal. Partial tasks are called decision variables and result from the priorities adopted by the decision maker,
- determining the preferences of the decision maker in the implementation of the target by the decision variables by means of a specific relationship between them in the form of a function of the target,
- determining parameters describing the technological and organizational conditions of activities within the production system. Parameters are usually determined on the basis of engineering or statistical methods,
- collect data describing the parameters and their verification,
- defining the dependence of decision variables describing technological and organizational conditions of activity in the form of balance limits,
- model verification by simplifying or synthesizing it by eliminating unnecessary constraints and variables,
- verification of the completeness and correctness of the data set so that their changes do not affect the model solution and ensure their stability.

Tool to optimize order fulfillment is a model used in enterprises operating on the basis of the principle of Just In Time. They do not have their own warehouses and produce the goods immediately after receipt of orders from customers. The following study is presented to the application of the model in a company producing and distributing furniture, which at one time had the accumulation of orders from five customers at one time. Application of the proposed tools will allow you to avoid the long delays the implementation of production and delivery to the client, will also pollute the costs related to the possible occurrence of delays.

The aim of the analysis is the planning of production and supply, in order to minimize the delays resulting from the cumulation of orders. This way the company can:

- minimize total delay, which will increase the level of customer service,
- minimize the maximum delay, so that you can determine to what extent it is meet the timeliness of supply and improve the ability to determine the time of the real execution of the contract,
- minimize the costs resulting from the production and delivery delays, which may involve the incurring a loss, having to pay a contractual penalty, or the granting of a discount.

The analysis will be carried out based on linear programming with designated to function. Production and transport can be treated as performing a number of tasks on two machines in which the sequence is strictly defined. The purpose of the model is the lineup to tasks to the time they perform the least deviate from the established requirements. The algorithms are solved using Microsoft Excel with Solver.

2. ASSUMPTIONS OF THE OPTIMIZATION MODEL

As a result of a series of analyzes, building model were adopted assumptions about the production time, delivery and the cost of order delays for individual customers were (table 1).

Tabele 1. Input data model

customer number *j*	**time of production (h)**	**time of delivery (h)**	**time for order fulfillment (h)**	**cost of order delay (zł/h)**
1	20	16	48	20
2	10	16	72	30
3	8	24	72	35
4	18	12	48	10
5	12	16	48	15

Source: Own elaboration based on (Szymczyk, 2011)

Calculations for the three variants are carried out in a similar way. They differ from each other by the purpose function and the need to make minor modifications to the constraining conditions in the second case.

Linear programming using application Solver is based on the appointment of the individual purpose function, determining what program size to consider as variables, and adding restrictive conditions.

At the time of the analysis of the following parameters::

- $t_{j,1}$ – time of manufacture of products for the customer *j*, (j=1,2,….,n),
- $t_{j,2}$ – time of delivery to the customer *j*,
- d_j – required time of order fulfillment

The following variable sizes were defined:

- x_j – moment of starting production of products for the customer *j*,
- y_j – moment of starting of delivery of the goods to the customer *j*,
- $x_{i,j}$ – the binary varible is equal to 1, when the production of the customer *j* is later than the production of the customer *i* and 0 otherwise,
- $y_{i,j}$ – the binary varible is equal to 1, when the delivery to the customer *j* is later then the delivery to the customer *i* and 0 w otherwise,
- $X_{i,j}$ – matrix production variables,
- $Y_{i,j}$ – matrix of the distribution variables,
- L_j^+ – exceeding the total time of production and delivery to customer *j* in relation to the required time of order fulfillment,
- L_j^- – reduce the overall production time and delivery to the customer *j* in relation to the required time of order fulfillment,
- K_l – logistic cost due delays in total production time and delivery to customer *j* in relation to the required time of order fulfillment.

3. MATHEMATICAL MODEL OPTIMIZATION TOOLS

During the construction of the model, the variable cells are allocated in the form of a matrix, in which the appearance of volume 1 in a row means that customer takes precedence over the one that is indicated by the number column (figure 1, 2 - the size variables are marked with a gray background). This assumption in practice should be interpreted as meaning that if the described line x1 in the column x3 there is number 1, the customer order 1 to be produced before releasing to order customer 3 (figure 2).

9									
10	M	1000			x1	x2	x3	x4	x5
11					0	0	0	0	0
12									
13				Xij					
14	x1	0			0	0	0	0	0
15	x2	0			1	0	0	0	0
16	x3	0			1	1	0	0	0
17	x4	0			1	1	1	0	0
18	x5	0			1	1	1	1	0
19									
20					y1	y2	y3	y4	y5
21					0	0	0	0	0
22									
23				Yij					
24	y1	0			0	0	0	0	0
25	y2	0			1	0	0	0	0
26	y3	0			1	1	0	0	0
27	y4	0			1	1	1	0	0
28	y5	0			1	1	1	1	0
29									

Figure 1. Matrix before applying the Solver application
Source: Own elaboration

9									
10	M	1000			x1	x2	x3	x4	x5
11					22	0	64	42	10
12									
13				Xij					
14	x1	22			0	0	1	1	0
15	x2	0			1	0	1	1	1
16	x3	64			0	0	0	0	0
17	x4	42			0	0	1	0	0
18	x5	9,999999999			1	0	1	1	0
19									
20					y1	y2	y3	y4	y5
21					44	12	72	60	28
22									
23				Yij					
24	y1	44			0	0	1	1	0
25	y2	12			1	0	1	1	1
26	y3	72			0	0	0	0	0
27	y4	60			0	0	1	0	0
28	y5	28			1	0	1	1	0

Figure 2. Matrix after applying the Solver application
Source: Own elaboration

For the first variant in which the total delay is minimized, the purpose function and the restrictive conditions take the following form:

$$\sum_{j=1}^{n} L_j^{+} \rightarrow \min \tag{1}$$

$$x_i - x_j + Mx_{i,j} \leq M - t_{i,1} \tag{2}$$

$$y_i - y_j + My_{i,j} \leq M - t_{i,2} \tag{3}$$

$$x_{i,j} + x_{j,i} = 1 \tag{4}$$

$$y_{i,j} + y_{j,i} = 1 \tag{5}$$

$$y_i - x_j \geq t_{j,1} \tag{6}$$

$$y_j - L_j^+ + L_j^- = d_j - t_{j,2} \tag{7}$$

$$x_j, y_j, L_j^+, L_j^- \geq 0 \tag{8}$$

$$x_{i,j}, y_{i,j} \in \{0,1\} \tag{9}$$

where:

$i = 1,2,\ldots,n$

$j = 1,2,\ldots,n$

$i \neq j$

For the second variant, where the minimum maximum delay is calculated, the constraint conditions are the same as in option 1 (patterns 2-9) and the purpose function take the following form:

$$L_{\max} = \max_j \{L_j^+\} \to \min \tag{10}$$

With this purpose function assignment, the task is not a linear programming task and requires linearization. Therefore introduced an additional variable that reflects the maximum delay:

$$z = \max_j \{L_j^+\} \tag{11}$$

After modernization constraints conditions and the purpose function, you can build a linear programming equivalent to a task whose purpose function is described by the pattern 11. To do this, a set of constraints with one additional condition:

$$L_j^+ \leq z \tag{12}$$

and redefine the purpose function:

$$z \to \min \tag{13}$$

In the third variant, only the change in the purpose function, and the constraint conditions are assumed as for the first case.

$$\sum_{j=1}^{n} K_l \to \min \tag{14}$$

4. SOLUTION AND INTERPRETATION OF RESULTS

After solving the algorithm using Solver, the following results were obtained:

• for the first variant (figure 3):

10	M	1000			x1	x2	x3	x4	x5
11					12	52	70	32	0
12									
13				Xij					
14	x1	12			0	1	1	1	0
15	x2	52			0	0	1	0	0
16	x3	70			0	0	0	0	0
17	x4	32			0	1	1	0	0
18	x5	0			1	1	1	1	0
19									
20					y1	y2	y3	y4	y5
21					32	62	78	50	16
22									
23				Yij					
24	y1	32			0	1	1	1	0
25	y2	62			0	0	1	0	0
26	y3	78			0	0	0	0	0
27	y4	50			0	1	1	0	0
28	y5	16			1	1	1	1	0
29									
30									
31									
32					**SUMA**	50			

Figure 3. Solution of the linear programming tasks in the first variant
Source: Own elaboration

By interpreting the obtained results it was found that the goods ordered by the customer 1 must be produced before the goods for clients 2, 3 and 4. This is evidenced by the generated values 1 in the first row (customer 1) of the matrix Xi, j respectively in columns 2, 3 and 4 (customer 2, 3 and 4). Similar reasoning is carried out for other customers. Finally, from the proposed matrix, can read the following order of production: customer 5, 1, 4, 2 and 3.

In Figure 3, also shows the generated by the program the variables Xj, on the basis of wich we can determine the precise moment of the start of production for individual customers. For customer 5 should begin immediately (time 0), for customer 1 after 12 hours, for 4 after 32 hours, for 2 hours after 52 hours and for 3 after 70 hours. In the same way, you can define the starting of delivery, which should begin to turn for the customer 1 after 32 hours, for 2 after 62 hours, for 3 after 78 hours, for 4 after 50 hours and for 5 after 16 hours.

The Solver minimizing the total delay generates what delays are created for each customers (figure 4).

	L+	L-
	0	0
	6	0
	30	0
	14	0
	0	16
SUMA	50	

Figure 4. Delay implementation of the orders for individual customers
Source: Own elaboration

From the figure above, delays in order fulfillment, for customers 1-5 go to 0, 6, 30, 14 and 0 hours respectively, giving a total of 50 hours;

- for the second variant (figure 5):

9									
10	M	1000			x1	x2	x3	x4	x5
11					22	0	64	42	10
12									
13				Xij					
14	x1	22			0	0	1	1	0
15	x2	0			1	0	1	1	1
16	x3	64			0	0	0	0	0
17	x4	42			0	0	1	0	0
18	x5	10			1	0	1	1	0
19									
20					y1	y2	y3	y4	y5
21					44	12	72	60	28
22									
23				Yij					
24	y1	44			0	0	1	1	0
25	y2	12			1	0	1	1	1
26	y3	72			0	0	0	0	0
27	y4	60			0	0	1	0	0
28	y5	28			1	0	1	1	0
29									
30									
31					z	24			
32									

Figure 5. Solution of the linear programming tasks in the second variant
Source: Own elaboration

The results are read in the same way as in the first variant. On this basis, customers will be served in order of 2, 5, 1, 4 and 3. Order delays are for customers 1-5 in turn 12, 0, 24, 24 and 0 hours respectively. The start of production should be for customer 2 immediately (0 hours), for 5 after 10 hours, for 1 after 22 hours, for 4 after 42 hours and for 3 after 64 hours. The distribution of furniture should be appropriate for the customer respectively 1 after 44 hours from the moment of execution of the orders, for 2 after 12 hours, for 3 after 72 hours, for 4 after 60 hours and for 5 after 28 hours.

- for the third variant (figure 6):

9									
10	M	1000			x1	x2	x3	x4	x5
11					8	48	0	30	58
12									
13				Xij					
14	x1	8			0	1	0	1	1
15	x2	48			0	0	0	0	1
16	x3	0			1	1	0	1	1
17	x4	30			0	1	0	0	1
18	x5	58			0	0	0	0	0
19									
20					y1	y2	y3	y4	y5
21					32	60	8	48	76
22									
23				Yij					
24	y1	32			0	1	0	1	1
25	y2	60			0	0	0	0	1
26	y3	8			1	1	0	1	1
27	y4	48			0	1	0	0	1
28	y5	76			0	0	0	0	0
29									
30									
31									

Figure 6. Solution of the linear programming tasks in the third variant
Source: Own elaboration

It should be concluded that customers will be supported in the sequence 3, 1, 4, 2, 5. Order processing delays (figure 7) are for customers 1-5 go to 0, 4, 0, 12 and 44 hours. The total cost associated with instance of delays is 900 pln. Start of production should take for customer 3 immediately (0 hours), for 1 after 8 hours, for 4 after 30 hours, for 2 after 48 hours and for 5 after 58 hours. Distribution of furniture should be appropriate for the customer 1 after 32 hours from the execution of the orders, for 2 after 60 hours, for 3 after 8 hours, for 4 after 48 hours and for 5 after 76 hours.

Kl	L+	L-
0	0	0
120	4	0
0	0	40
120	12	0
660	44	0
SUMA	900	

Figure 7. Delay implementation of the orders for individual customers and the associated costs in the third
Source: Own elaboration

CONCLUSION

The article presents a tool for optimizing order fulfillment. For this purpose, an application was created and described, which enables it to run smoothly and an accurate way to determine the optimal time of the start of production and distribution for individual customers. Analyzed and presented examples of creating a mathematical model to minimize the maximum delay in customer order fulfillment, minimizing total delay and minimizing logistics costs resulting from these delays. Presented the development allows the conclusion that procurement order optimization model is a useful tool that can be used in the planning of production and delivery schedule in case of orders. An additional advantage of the tools presented is the fact that it can be used to solve problems of different features to the restrictive terms and conditions, as well as the variable number of customers and their parameters with delivery and production time, order fulfillment.

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