MATEC Web of Conferences **94**, 06006 (2017) DOI: 10.1051/matecconf/20179406006
CoSME'16

Model for determining and optimizing delivery performance in industrial systems

Flavia Fechete[1, *], *and Anișor* Nedelcu[1]

[1]Transilvania University of Brașov, Department of Manufacturing Engineering, Mihai Viteazu No.5, Brașov, Romania.

Abstract. Performance means achieving organizational objectives regardless of their nature and variety, and even overcoming them. Improving performance is one of the major goals of any company. Achieving the global performance means not only obtaining the economic performance, it is a must to take into account other functions like: function of quality, delivery, costs and even the employees satisfaction. This paper aims to improve the delivery performance of an industrial system due to their very low results. The delivery performance took into account all categories of performance indicators, such as on time delivery, backlog efficiency or transport efficiency. The research was focused on optimizing the delivery performance of the industrial system, using linear programming. Modeling the delivery function using linear programming led to obtaining precise quantities to be produced and delivered each month by the industrial system in order to minimize their transport cost, satisfying their customers orders and to control their stock. The optimization led to a substantial improvement in all four performance indicators that concern deliveries.

1 Introduction

Industrial systems performance plays a crucial role for their survival and maintaining on the market, given the fierce competition which led to the disappearance from the market of those who are not progressing and therefore do not obtain high performance.

The current economic environment is no longer confined to strictly economic performance targets, it also requires a global vision of what the entity's performance really means.

Therefore it is no longer sufficient an exclusively economic approach to assess the financial performance of an organization, it requires a global vision that may relate to product and processes quality, entity's costs, on time delivery of their products or even to employees satisfaction. Delivery performance requires a special attention because it is closely related to customer satisfaction, the size of future orders, customer loyalty, and it may have a major implication on the revenue and expenses budget of the company.

[*] Corresponding author: fechete_flavia@yahoo.com.

In this regard it is imperative to meet the precise quantities to be produced so that delivery is made on time, according to the customer orders, and at the same time the delivery fits in the planned transport costs.

The present work aims to help the company to improve decision management system, to create a decision model that will contribute to improvement. The major objective of this paper is to create a model for the delivery performance of an industrial system, a model that will help the managers to make the best decisions on production optimization.

For this purpose, there will be used the linear programming to obtain the precise quantities to be produced and delivered each month by the industrial system in order to minimize their transport cost, satisfying their custormers orders and to control their stock.

Modeling and optimization techniques are used not only in the traditional supply chain management, but also in other functional areas of organizations as finance, accounting, marketing [1].

The problem of the delivery performance lies in the attention of many other researchers [2 - 4], though the delivery optimization focuses particularly on cost reduction, without taking into account other important factors.

In this regard, it was made a brief introduction to the theory of mathematical programming, following with a case study in order to develop the linear programming used to determine an optimal production program. The case study was conducted on an industrial system that produces and sells outer rings for cam follower rollers. The research was focused on delivering the products manufactured by the organization, it was intended to determine the optimal production program that satisfies customers orders and also minimizes the transport cost. Thus, it was determined the objective function and its constraints and using the linear programming module of the software Quantitative Management (QM), we were able to determine the amount of each product that must be manufactured in order to minimize the costs of delivery.

2 Method

The decision process involves evaluating several decisional alternatives based on economic indicators, in order to choose the optimal variant. For choosing the optimal decision it is necessary to hierarchy available variants, depending on the desired criteria. One of the most used methods in this regard it is economic modeling by linear programming.

Linear programming problem is within the general mathematical programming models and it is characterized by the fact that both the objective function and the constraints are expressed mathematically by linear functions [5].

The linear programming problem contains restrictions, as well as a criteria of "performance" to assess the effectiveness of each activity. Depending on the purpose, we can choose as a criterion of efficiency an indicator measuring the effort, one that measures the result or an indicator expressed as a ratio of result and effort (or effort and result) [6].

Maximum efficiency means minimizing the effort and maximizing the outcome and the optimal concept is defined in this case as a program that minimizes or maximizes an objective function and simultaneously satisfies all technical and economic restrictions [7].

In order to determine the optimal production program that satisfies customers orders and also minimizes the transport cost there will be used the following objective function [1, 6, 8]:

$$min\left[\sum_{i=2}^{n}\left((c_i \times x_i + c_i^s \times x_i^s + d \times s_i) + c_1 \times x_1 + c_1^s \times x_1^s\right)\right], \tag{1}$$

With the following constraints:

$$\sum_{k=1}^{i}(x_k + x_k^s) - s_{i+1} = \sum_{k=1}^{i} R_k\,, \tag{2}$$

$$i=1,2,\ \dots,\ n-1 \tag{3}$$

$$x_n + x_n^s + s_n = R_n \tag{4}$$

$$0 \le x_i \le y_i,\ i=1,2,\ \dots,\ n \tag{5}$$

$$0 \le x_i^s \le y_i^s,\ i=1,2,\ \dots,\ n \tag{6}$$

$$s_i \ge 0,\ i=1,2,\ \dots,\ n, \text{ where} \tag{7}$$

n – number of months;
y_i,i =1,2,...,n - monthly production volume achievable on normal program;
y_i^s , ,i =1,2,...,n - monthly production volume achievable overtime;
c_i,i =1,2,...,n- monthly cost of production on normal program;
c_i^s , i =1,2,...,n - monthly cost of production overtime;
d - unit cost of storage;
x_i, i =1,2,...,n – quantities that must be monthly produced on normal program;
x_i^s, i =1,2,...,n - quantities that must be monthly produced overtime;
s_i, i =1,2,...,n – quantities that must be monthly stored.

In order to achieve the minimum costs of production and storage, variables x_i, $x_i^s s_i$ will be determined.

Determining the optimal production program is one of the major concerns of managers because it is closely related to the economic performance of the organization, deciding the success of the organization [9].

This paper presents below a study case of modeling and optimization the delivery performance of an industrial system by using linear programming. There is considered an industrial system that must sell their product during a period of 12 months, based on the customer orders. The paper objective is to analyze the current situation of delivery and to determine an optimal production program by using linear programming in order that shipping costs to be minimal.

3 Results

The delivery area is one of the most important aspect for each company, it may influence the customer behavior, the number of orders and the sales. The industrial system shows a major interest on this particular area, desiring to satisfy customer needs and minimizing their transportation expenses.

In order to identify the optimizing area, there will be first analyzed the main key indicators monitored in the delivery, as we proposed below. These indicators are:

A. On-Time Delivery - OTD

This indicator measures the percentage of all orders delivered by the requested delivery date, as indicated in the PO/contract during a defined period of time.

$$OTD = \frac{Nrct}{Nrcl} \times 100, \text{ where} \tag{8}$$

OTD = On-Time Delivery;
Nrc_t = Number of orders delivered at requested date;
Nrc_l= Number of orders.

B. Supplier Lead-Time Variability - SLT

This indicator is the average of the absolute percentage differences (APD) between the supplier's forecasted lead time and the actual lead time for each order placed with the supplier. This indicator can be calculated for any supplier that supplies products to the requesting facility. It can be measured over any time period, but one year is typical; usually measured in days.

$$SLT = \frac{\sum APD}{Nrc} \tag{9}$$

$$APD = \frac{Iprg - Trl}{Trl}, \text{ where} \tag{10}$$

SLT = Supplier Lead-Time Variability;
APD = Absolute percentage differences between the expected time delay in delivery of the supplier and real time delivery;
Nr_c = Number of orders;
I_{prg} = Expected delay;
T_{rl} = Real time delivery.

C. Backlog efficiency - BE

This indicator measures the performance of the backlog comparing 2 consecutive months.

$$BE = \frac{Rlc}{Rt} \times 100, \text{ where} \tag{11}$$

BE = Backlog efficiency;
R_{lc}= Total value of backlog delivered this month;;
R_t= Total value of backlog this month;.

D. Transport efficency - TE

$$TE = \frac{Crt - Cpt}{Crt} \times 100, \text{ where} \tag{12}$$

TE = Transport efficency;
C_{rt} = Actual cost per transport;
C_{pt} = Forecasted cost per transport.

Table 1 presents the results obtained from the industrial system for each performance indicator.

Table 1. Data used to calculate delivery indicators.

Month	Number of orders delivered at requested date	Number of orders	Forecasted cost per transport (euro)	Actual cost per transport (euro)	Backlog (Pieces)	Real time delivery (days)	Expected time delay in delivery (days)
Jan	252	357	3500	14645,1	235805	6,5	5,5
Feb	211	416	3500	18375,8	219434	6,8	6,2
Mar	253	495	3500	7690,0	116117	6,9	7,1
April	238	431	3500	7924,9	37888	7,0	8,9
May	260	408	3500	6867,8	91333	6,5	6,3

June	294	404	3500	3427,2	48175	6,3	6,1
July	338	390	3500	2455,8	36523	6,0	5,9
Aug	346	370	3500	6873,0	63181	5,9	5,4
Sept	346	393	3500	6590,1	30351	5,7	4,9
Oct	345	383	3500	2844,8	52786	5,9	6,1
Nov	386	418	3500	2867,2	49517	5,5	4,7
Dec	274	290	3500	1646,4	12379	13,0	12,3

Using the data from Table 1 the delivery indicators were calculated; the evolution of the four performance indicators over the period of 12 months, it is presented in Table 2.

Table 2 Indicators evolution during months January-December.

Month	OTD (%)	SLT (%)	BE (%)	TE (%)
January	70,588	94,714	90,75	-318,43
February	50,721	97,473	91,40	-425,02
March	51,111	99,408	95,76	-119,71
April	55,220	95,009	98,49	-126,42
May	63,725	99,202	96,68	-96,22
June	72,772	99,295	98,16	2,08
July	86,667	99,374	98,64	29,83
August	93,514	97,492	97,54	-96,37
September	88,041	95,761	98,76	-88,29
October	90,078	99,328	98,24	18,72
November	92,344	95,981	98,21	18,08
December	94,483	98,055	99,45	52,96

As it can be seen, the risk is on having an efficient transport, namely, that the delay in delivery of the ordered pieces increases the transportation expenses for the backlog products. Indicators evolution and graphic analysis is provided in Fig. 1.

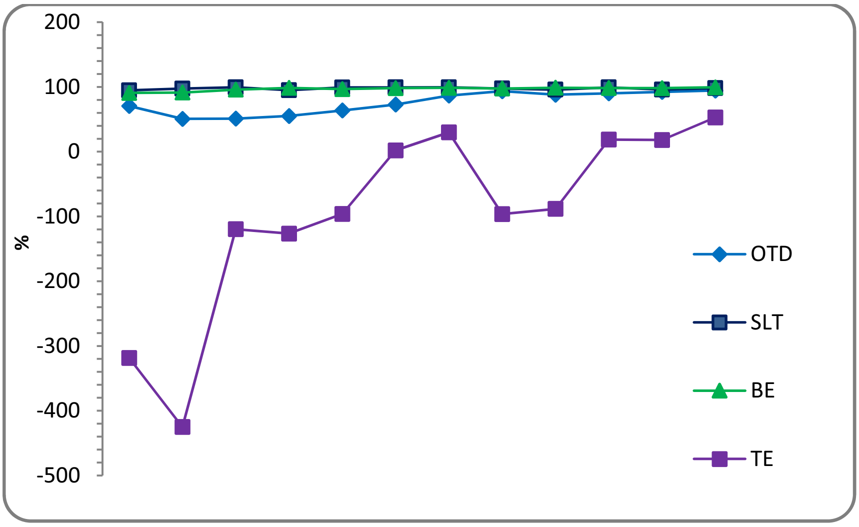

Fig.1. Delivery indicators: OTD, SLT, BE and TE.

This paper aims to optimize the delivery area of the analyzed industrial company, which is a major problem for this company, owed to backlog in delivery and significant transportation costs because undelivered parts incur much higher costs.

Thus, knowing the amount of pieces that will be delivered for the next 12 months, according to the customer orders, the production capacity for each month, and the cost per piece, there will be determined the optimal production by using linear programming in order that shipping costs to be minimal.

The industrial system spends 25 euro/min for getting a piece of the outer ring and the cost of delivery of the backlog on a special transport is 5 euro/piece.

Annotations:
$x_1, x_2, x_3, \ldots, x_{12}$ = The quantity of parts to be delivered in 12 months.

It will thus obtain the following restrictions:

$$\begin{cases} x_i>0, \quad i=\overline{1,12} \\ x_1 \geq 2\,548\,556 \\ x_2+(x_1-2\,548\,556) \geq 2\,550\,855 \\ x_3+(x_1+x_2-5\,099\,411) \geq 2\,735\,389 \\ x_4+(x_1+x_2+x_3-7\,834\,800) \geq 2\,503\,787 \\ x_5+(x_1+\ldots+x_4-10\,338\,587) \geq 2\,750\,643 \\ x_6+(x_1+\ldots+x_5-13\,089\,230) \geq 2\,624\,632 \\ x_7+(x_1+\ldots+x_6-15\,713\,862) \geq 2\,682\,187 \\ x_8+(x_1+\ldots+x_7-18\,396\,049) \geq 2\,563\,748 \\ x_9+(x_1+\ldots+x_8-20\,959\,797) \geq 2\,451\,276 \\ x_{10}+(x_1+\ldots+x_9-23\,411\,073) \geq 2\,992\,994 \\ x_{11}+(x_1+\ldots+x_{10}-26\,404\,067) \geq 2\,761\,731 \\ x_{12}+(x_1+\ldots+x_{11}-29\,165\,798) \geq 2\,258\,991 \\ x_1 \leq 2\,700\,000 \\ x_2 \leq 2\,500\,000 \\ x_3 \leq 2\,700\,000 \\ x_4 \leq 2\,800\,000 \\ x_5 \leq 2\,800\,000 \\ x_6 \leq 2\,700\,000 \\ x_7 \leq 2\,800\,000 \\ x_8 \leq 3\,000\,000 \\ x_9 \leq 2\,800\,000 \\ x_{10} \leq 3\,000\,000 \\ x_{11} \leq 2\,800\,000 \\ x_{12} \leq 2\,100\,000 \end{cases} \tag{13}$$

The data used to optimize the delivery performance are presented in Table 3:

Table 3. Required data for the optimization process.

Month	Customer orders (pieces)	Production capacity (pieces)	Expenses (euro/min)
January	2548556	2 700 000	25
February	2550855	2 500 000	25
March	2735389	2 700 000	25
April	2503787	2 800 000	25
May	2750643	2 800 000	25
June	2624632	2 700 000	25
July	2682187	2 800 000	25
August	2563748	3 000 000	25
September	2451276	2 800 000	25
October	2992994	3 000 000	25
November	2761731	2 800 000	25
December	2258991	2 100 000	25

Considering the cost of production and transport, the objective function becomes:

$$f(x) = 25\,x_1 + 25\,x_2 + \ldots + 25\,x_{12} + 5\times(x_1 - 2\,548\,556) + 5\times(x_1 + x_2 - 5\,099\,411) + 5\times(x_1 + x_2 + x_3 - 7\,834\,800) + 5\times(x_1 + \cdots + x_4 - 10\,338\,587) + 5\times(x_1 + \cdots + x_5 - 13\,089\,230) + 5\times(x_1 + \cdots + x_6 - 15\,713\,862) + 5\times(x_1 + \cdots + x_7 - 18\,396\,049) + 5\times(x_1 + \cdots + x_8 - 20\,959\,797) + 5\times(x_1 + \cdots + x_9 - 23\,411\,073) + 5\times(x_1 + \cdots + x_{10} - 26\,404\,067) + 5\times(x_1 + \cdots + x_{11} - 29\,165\,798). \quad (14)$$

The minimum of the function:

$$f(x) = 25\,x_1 + 25\,x_2 + \ldots + 25\,x_{12} + 55\,x_1 + 50\,x_2 + 45\,x_3 + 40\,x_4 + 35\,x_5 + 30\,x_6 + 25\,x_7 + 20x_8 + 15\,x_9 + 10\,x_{10} + 5\,x_{11} - 172\,961\,230. \quad (15)$$

The final objective function will be:

$$\min f(x) = 80\,x_1 + 75\,x_2 + 70\,x_3 + 65\,x_4 + 60\,x_5 + 55\,x_6 + 50\,x_7 + 45\,x_8 + 40\,x_9 + 35\,x_{10} + 30\,x_{11} + 25x_{12} - 172\,961\,230. \quad (16)$$

To simplify calculations, data were inserted in the software Quantitative Management (QM) as shown in Fig. 2.

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12		RHS
Minimize	80,	75,	70,	65,	60,	55,	50,	45,	40,	35,	30,	25		
Constraint 1	1,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	>=	2.548.556
Constraint 2	1,	1,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	>=	5.099.411
Constraint 3	1,	1,	1,	0,	0,	0,	0,	0,	0,	0,	0,	0,	>=	7.834.800
Constraint 4	1,	1,	1,	1,	0,	0,	0,	0,	0,	0,	0,	0,	>=	10.338.590
Constraint 5	1,	1,	1,	1,	1,	0,	0,	0,	0,	0,	0,	0,	>=	13.089.230
Constraint 6	1,	1,	1,	1,	1,	1,	0,	0,	0,	0,	0,	0,	>=	15.713.860
Constraint 7	1,	1,	1,	1,	1,	1,	1,	0,	0,	0,	0,	0,	>=	18.396.050
Constraint 8	1,	1,	1,	1,	1,	1,	1,	1,	0,	0,	0,	0,	>=	20.959.800
Constraint 9	1,	1,	1,	1,	1,	1,	1,	1,	1,	0,	0,	0,	>=	23.411.070
Constraint 10	1,	1,	1,	1,	1,	1,	1,	1,	1,	1,	0,	0,	>=	26.404.070
Constraint 11	1,	1,	1,	1,	1,	1,	1,	1,	1,	1,	1,	0,	>=	29.165.800
Constraint 12	1,	1,	1,	1,	1,	1,	1,	1,	1,	1,	1,	1,	=	31.424.790
Constraint 13	1,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	<=	2.700.000
Constraint 14	0,	1,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	<=	2.500.000
Constraint 15	0,	0,	1,	0,	0,	0,	0,	0,	0,	0,	0,	0,	<=	2.700.000
Constraint 16	0,	0,	0,	1,	0,	0,	0,	0,	0,	0,	0,	0,	<=	2.800.000
Constraint 17	0,	0,	0,	0,	1,	0,	0,	0,	0,	0,	0,	0,	<=	2.800.000
Constraint 18	0,	0,	0,	0,	0,	1,	0,	0,	0,	0,	0,	0,	<=	2.700.000
Constraint 19	0,	0,	0,	0,	0,	0,	1,	0,	0,	0,	0,	0,	<=	2.800.000
Constraint 20	0,	0,	0,	0,	0,	0,	0,	1,	0,	0,	0,	0,	<=	3.000.000
Constraint 21	0,	0,	0,	0,	0,	0,	0,	0,	1,	0,	0,	0,	<=	2.800.000
Constraint 22	0,	0,	0,	0,	0,	0,	0,	0,	0,	1,	0,	0,	<=	3.000.000
Constraint 23	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	1,	0,	<=	2.800.000
Constraint 24	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	1,	<=	2.100.000

Fig. 2. Objective function and restrictions introduced in module Linear Programming of QM.

By solving the objective function in the QM program, it will obtain the results presented in Fig.3 and in Fig.4.

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12		RHS
Minimize	80,	75,	70,	65,	60,	55,	50,	45,	40,	35,	30,	25,		
Constraint 1	1,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	>=	2.548.556,
Constraint 2	1,	1,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	>=	5.099.411,
Constraint 3	1,	1,	1,	0,	0,	0,	0,	0,	0,	0,	0,	0,	>=	7.834.800,
Constraint 4	1,	1,	1,	1,	0,	0,	0,	0,	0,	0,	0,	0,	>=	10.338.590,
Constraint 5	1,	1,	1,	1,	1,	0,	0,	0,	0,	0,	0,	0,	>=	13.089.230,
Constraint 6	1,	1,	1,	1,	1,	1,	0,	0,	0,	0,	0,	0,	>=	15.713.860,
Constraint 7	1,	1,	1,	1,	1,	1,	1,	0,	0,	0,	0,	0,	>=	18.396.050,
Constraint 8	1,	1,	1,	1,	1,	1,	1,	1,	0,	0,	0,	0,	>=	20.959.800,
Constraint 9	1,	1,	1,	1,	1,	1,	1,	1,	1,	0,	0,	0,	>=	23.411.070,
Constraint 10	1,	1,	1,	1,	1,	1,	1,	1,	1,	1,	0,	0,	>=	26.404.070,
Constraint 11	1,	1,	1,	1,	1,	1,	1,	1,	1,	1,	1,	0,	>=	29.165.800,
Constraint 12	1,	1,	1,	1,	1,	1,	1,	1,	1,	1,	1,	1,	=	31.424.790,
Constraint 13	1,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	<=	2.700.000,
Constraint 14	0,	1,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	<=	2.500.000,
Constraint 15	0,	0,	1,	0,	0,	0,	0,	0,	0,	0,	0,	0,	<=	2.700.000,
Constraint 16	0,	0,	0,	1,	0,	0,	0,	0,	0,	0,	0,	0,	<=	2.800.000,
Constraint 17	0,	0,	0,	0,	1,	0,	0,	0,	0,	0,	0,	0,	<=	2.800.000,
Constraint 18	0,	0,	0,	0,	0,	1,	0,	0,	0,	0,	0,	0,	<=	2.700.000,
Constraint 19	0,	0,	0,	0,	0,	0,	1,	0,	0,	0,	0,	0,	<=	2.800.000,
Constraint 20	0,	0,	0,	0,	0,	0,	0,	1,	0,	0,	0,	0,	<=	3.000.000,
Constraint 21	0,	0,	0,	0,	0,	0,	0,	0,	1,	0,	0,	0,	<=	2.800.000,
Constraint 22	0,	0,	0,	0,	0,	0,	0,	0,	0,	1,	0,	0,	<=	3.000.000,
Constraint 23	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	1,	0,	<=	2.800.000,
Constraint 24	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	0,	1,	<=	2.100.000,
Solution->	2.634.800,	2.500.000,	2.700.000,	2.503.790,	2.750.640,	2.624.630,	2.682.190,	2.563.750,	2.564.990,	3.000.000,	2.800.000,	2.100.000,		$1.653.001.250,

Fig. 3. The optimized solutions obtained by solving the objective function.

As it can be seen in Fig. 4, to obtain optimal costs, the industrial company should deliver, respecting customer requirements and production capabilities, the following quantities: in January 2 634 800 pieces, in February 2 500 000, in March: 2 700 000 pieces, in April 2503790 million pieces, May: 2 750 640 units, in June 2 624 630 units, in July 2 682 190 units, in August: 2 563 750 pieces, in September 2 564 990, October 3 000 000 units, in November: 2 800 000 units, and at the end of the year, in December, 2 100 000 pieces.

Variable	Value	Reduced	Original	Lower	Upper
X1	2.634.800,	0,	80,	75,	Infinity
X2	2.500.000,	0,	75,	-Infinity	80,
X3	2.700.000,	0,	70,	-Infinity	80,
X4	2.503.790,	0,	65,	60,	80,
X5	2.750.640,	0,	60,	55,	65,
X6	2.624.630,	0,	55,	50,	60,
X7	2.682.190,	0,	50,	45,	55,
X8	2.563.750,	0,	45,	40,	50,
X9	2.564.990,	0,	40,	35,	45,
X10	3.000.000,	0,	35,	-Infinity	40,
X11	2.800.000,	0,	30,	-Infinity	40,
X12	2.100.000,	0,	25,	-Infinity	40,

Fig. 4. The optimal quantities to be delivered by the industrial company.

After applying the new optimized variants for delivery it can be seen that the optimization led to a substantial improvement in all performance indicators that concern deliveries.

After optimization, the performance indicators OTD, SLT, BE and TE have values between 94 and 100 % (Fig.5), which means that deliveries are made according to the clients needs, without additional expenditure of special transport.

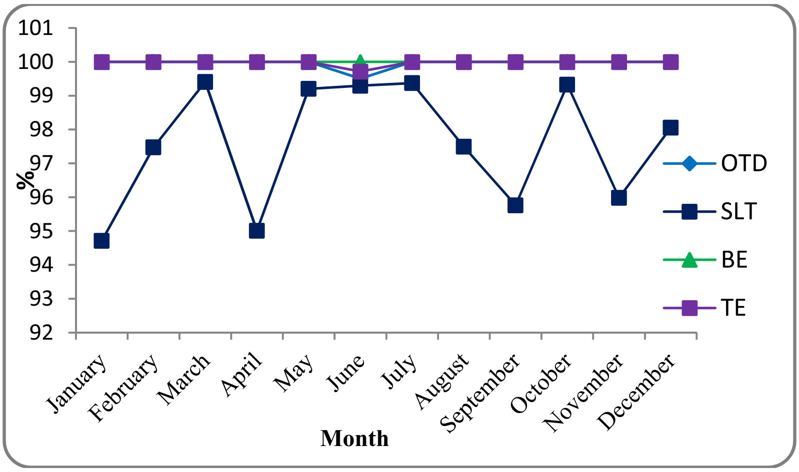

Fig. 5. Delivery indicators after optimization.

4 Conclusions

The main objective of business process modeling is to optimize decision-making process, as a determining factor in the transition from experience, intuition complex, to a scientific approach based on information-reasoning. Economic modeling process enables the manager making the best decision, giving it multiple ways to make an efficient agreement between human, material, financial with the main objectives of the organization.

This paper objective is to help managers to improve the delivery performance of the organization by determining and implementing an optimal production program. Modeling a manufacturing program using the QM software led to obtaining precise quantities to be produced and delivered each month by the industrial system in order to minimize their transport cost, satisfying their custormers orders and to control their stock.

Future research will focus on multi-criteria modeling methods, namely the multidimensional linear programming that allows to use the objective function as a utility function that will combine both criteria of maximizing profits and minimizing costs.

References

1. D. Lixandroiu, *Economic processes modeling* (Transilvania University Publishing House, Braşov, 2012).
2. A. Guiffrida, R. Nagi, Int. J. Production Economics **102,** 22–36 (2006).
3. A. Gunasekarana, C.Patelb, R.E.McGaugheyc, Int. J. Production Economics **87,** 333–347 (2004).
4. H. Shina, W.C.Bentonb, M.Junc, Comp & Op R **36**, 2462 – 2471 (2009).
5. M. Beldiga, Sci.Jur.S.Univ.Mold **7,** 34-39 (2012).
6. A .Nedelcu, *Technology and flexible manufacturing systems* (Lux Libris Publishing House, Brasov, 2000).
7. C. Anghelache, *Modeling and simulation of decision-making processes* - lecture notes (Artifex, Bucuresti, 2003).
8. M. Andrasiu, *Multi-criterion Decision Methods*, (Tehnica Publishing House, Bucuresti, 1986).
9. A. Rusu, *Operational Research* (Iasi, 2007).