An Econometric Approach of Modeling the Manufacturing System Performance in Machining Shafts

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ABSTRACT

Monitoring and controlling input and output parameters of a manufacturing system is a critical problem in optimizing the system. Performance of a manufacturing system covers a very broad spectrum of technological and management activities. Performance measurement for a manufacturing system is essential for the management system to understand its status and take appropriate decisions in order to maintain competitiveness. This paper proposes to develop an econometric model of the relationship between performance and the system parameters of a manufacturing system, model that will help to optimize the decision making system.

KEYWORDS: manufacturing system, performance, econometric model, product cost estimation

1. Introduction

The continuous increase of the competitiveness in the world has forced organizations to carry out only high quality products in a short time, at more and more competitive costs [2]. To achieve these high levels of competitiveness, the manufacturing enterprises are forced to become more flexible to market demands. However, since the initial and operating costs are very high, users of manufacturing systems are concerned with getting a system at full capacity utilization.

Despite the advantages of having a high degree of flexibility and production of high quality products, without a mechanism to calculate the cost as close to reality, these systems can not be competitive [1,5].

Monitoring and controlling input and output values of a manufacturing system is an important task to optimize energy consumption, saving human resources, effective technological flows. Performance of a manufacturing system covers a broad range of technologies and management activities. By definition, a manufacturing system performance is tied to past events and present events, and can be monitored and quantified [10]. Performance measurement of a manufacturing system is essential for the management system to understand its status and take appropriate decisions in order to maintain competitiveness. The way that the manufacturing systems are led affects their performance. Besides the driving influence on accuracy indicators, it is also registered a strong impact on economic indicators. This paper proposes to develop an econometric approach of modelling the manufacturing system performance due to market parameters for a shaft manufacturing chain.

2. Manufacturing System Parameters

The manufacturing system that we want to improve is a shaft manufacturing chain that is achieved cellularly because the processing of parts passes through several steps on different flow cells. Figure 1 shows a processing flow chart of a shaft chain identified by the current Value Stream Map. The Value Stream Map is tool used for identifying the wastes that appear during a technological flow. The manufacturing process has a frequency production process of 300 parts per month; the stocks are of 150 parts/2months. A first design of the Value Stream Map is done according to the initial data collected in the manufacturing process, for each workstation.

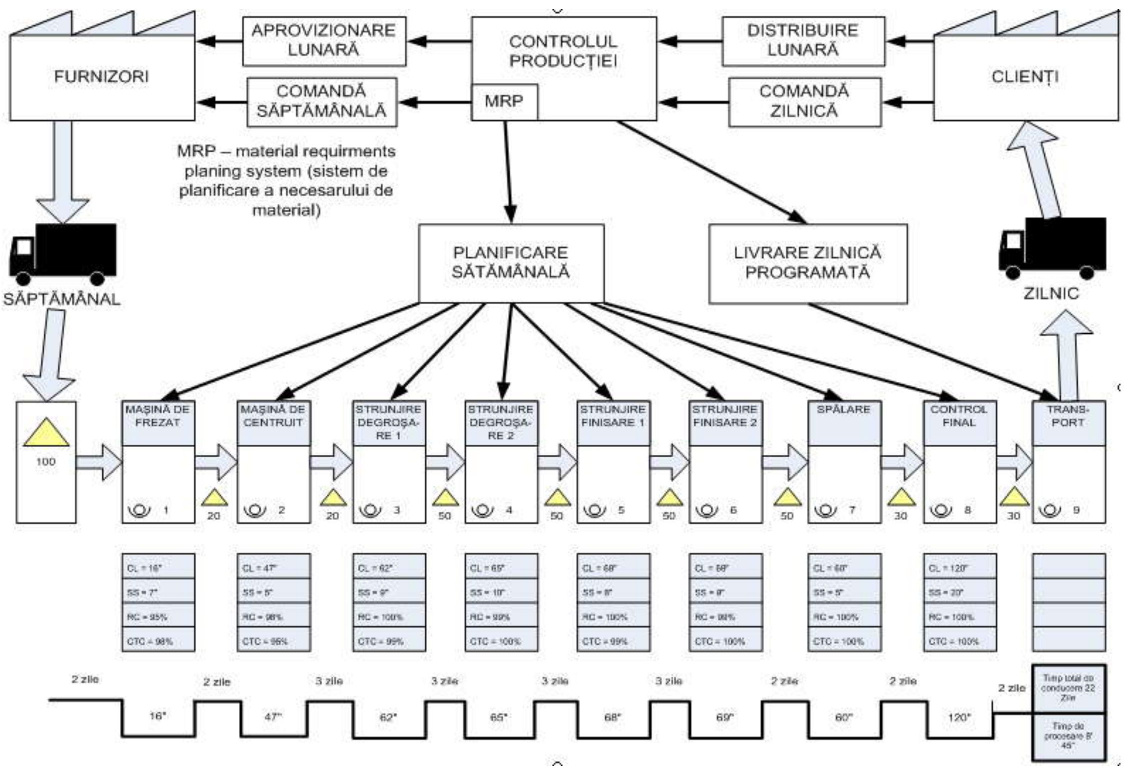

Fig. 1. *Current Value Stream Map for the technological flow*

In the manufacturing system described above there have been identified system parameters:

1) Production cost, Cp, is comprised of four components: C_{mp} is the cost of raw materials and of the orders already made; C_{em}, the cost of manufacturing items that is calculated due to the processing costs depending on each part; C_{tc}, cost of transport control from producer to customer; C_{pil} represents the total cost for storing parts being processed in the system and is estimated as the average cost of parts stored per each hour (lei/ unit / unit time).

$$C_p=C_{mp}+C_{em}+C_{tc}+C_{pil} \quad (1)$$

$$C_{mp}=\lambda \bullet b+K \bullet c_K \quad (2)$$

$$C_{em}=p \bullet DC \quad (3)$$

$$C_{tc}=c \bullet K \quad (4)$$

$$C_{pil}=h \bullet WIP \bullet l \quad (5)$$

where: λ is the crossing rate production in working through each workstation (units / time units) and represents the product of the processing rate on each workstation and the use of the station work at the maximum capacity; b is the supply cost per unit (lei / part); K, number of Kanban cards; c_K, cost for each Kanban card (lei / Card); p, processing cost per unit (lei / unit); Dc, rate request from a client (units / time units); c, the maintenance cost of transport; h, storage cost per unit (lei / unit / unit time); WIP, production in progress at any time (units); l, leading time. Thus the total production cost will be:

$$C_p=[\lambda \bullet b+K \bullet c_K]+[p \bullet DC]+[c \bullet K]+ +[h \bullet WIP \bullet l] \quad (6)$$

2) Standard manufacturing time, T_{sm}, represents the value added time and is the sum between the total processing time and the total leading time.

3) Manufacturing system efficiency, E_f, is the output combination of efficiency and utilization of the factors of production depending on the economic effects on a finished product made to obtain a minimum cost of production. Efficiency can be

expressed in terms of profitability, assets, factors of production, investment and the costs and represents the ratio between the total production and the expenditure. For the manufacturing system to be effective, the system's efficiency should be Ef> 1.

4) Market evolution, E_p, helps calibrating the enterprise performance and default of the manufacturing system. Analysis of the market behavior is based on demand-supply relationship, customers, and on competition appeared on the market.

3. Manufacturing System Performance

Performance measurement is a critical factor for evaluating the effectiveness of the manufacturing system. In many cases, the maximum level of performance measurement tends to be distorted by faulty equipments. Ignoring safety equipment when trying to model a manufacturing system will overestimate the occurrence of the level measurement performance.

A more precise performance evaluation of a manufacturing system is absolutely necessary for an enterprise. Performance indicators reflect the competitiveness of a manufacturing system, the default of an enterprise and, therefore, must be carefully identified during the evaluation process. The traditional indicators of performance evaluation system production capacity within an enterprise are production cost, inventory value, cost and quality production value.

Evaluating performance of a manufacturing system is viewed as a multiple criteria decision making to select a specific option from a data set. Generic functions of manufacturing performance measurement system are designed: i) to reflect the current state of the system, ii) to monitor and control operations efficiency, iii) to implement improving programs, iv) to calibrate the effectiveness of manufacturing decisions.

4. The Proposed Econometric Model

It was developed an econometric model of manufacturing performance measurement system based on its parameters. Measuring the manufacturing system performance helps to improve the quality of output value and expectations. The mathematical modeling of the manufacturing system is done through an econometric model. In this model, on the one hand are the parameters that enter the manufacturing system and on the other hand, the parameters that get out of the system, that means the market connection.

The proposed econometric model has as input values the characteristics of the manufacturing process, speed of the production process (v_p), total leading time (T_{tc}), total processing time (T_{tp}), the number of orders (N), number of workstations (n) and as output values the total production cost of production (C_{op}), the standard manufacturing time (T_{sm}), manufacturing system efficiency (E_f) and market evolution (E_p). Thus, the proposed model has the following form:

$$x_0+x_1v_p+x_2T_{tc}+x_3T_{tp}+x_4N+x_5n= y_0+y_1C_p+y_2T_{sm}+y_3E_f+y_4E_p, \quad (7)$$

where: x0, x1, x2, x3, x4, x5 are input variables and y0, y1, y2, y3, Y4 output variables, for which the manufacturing system performance reaches a maximum value at minimum costs. For the technological flow in the manufacturing system observed during 2006-2009 there were registered a number of values for the model parameters (Fig. 2).

	Input parameters	Output parameters	Performance
2006	v_p=10[parts/change] ; T_{tc}= 10 days ;T_{tp}= 22 min/part ;N=20 ; n=8 ;	C_p=100 lei ;T_{sm} =11 days ;E_f>1 ; E_p=20%;	50%
2007	v_p=15[parts/change] ; T_{tc}=9 days ;T_{tp}=20 min/part ;N=30 ; n= 6;	C_p=120 lei ;T_{sm} = 10 days ;E_f>1; E_p= 30%;	52%
2008	v_p=20[parts/change] ; T_{tc}=8 days ;T_{tp}=18 min/part;N= 40; n= 5 ;	C_p=130 lei ;T_{sm} =9 days ;E_f>1 ; E_p=40% ;	60%
2009	v_p= 25[parts/change]; T_{tc}=7 days;T_{tp}=15min/part;N=50; n=4;	C_p=135 lei ;T_{sm} =8 days ;E_f>1 ; E_p=50% ;	70%

Fig. 2. *Parameters of the proposed econometric model for the manufacturing system*

Taking into account the market evolution, the proposed econometric model, relation (7), allows identifying the polynomial coefficients, represented by C_p, T_{sm}, E_f, E_p. The way to predict these values or to determine the variation was done by training a neural network. To train this network the input variables are T_{tc}, T_{tp}, N, P and the output variables C_p, T_{sm}, E_f, E_p. Having a trained neural network NNMODEL, we can predict a value for T_{sm}, for example, in conditions of known and imposed performance. Based on these estimated ranges of output parameters, in order to join the market in terms of policy performance, a genetic algorithm was applied to determine the values of xi, i=0,5 and yi, i=0,4, in terms of polynomial optimization with restrictions.

5. Conclusions

This paper proposed the developing of an econometric model able to describe the relationship between the manufacturing system performance and the market parameters.

During the four analyzed years 2006-2009, we can see that the manufacturing system was improved so the production volume has increased and the total leading time as well as the standard manufacturing time has recorded lower values. The production cost has increased with the production volume, but the manufacturing system performance has increased from 50% in 2006 to 70% in 2009. The manufacturing system is continuously improved in order to reach a maximum value of the performance in the next years.

Using the econometric modelling the effects of the production planning and control marketing functions on manufacturing costs can be observed and improved. Controlling these cost functions is very important because they play very important roles in the value manufacturing chain. Any action that takes place in a cycle time, even if it has a direct or indirect contribution to the manufacturing part, is strictly associated to a cost. By applying optimizing and control functions, these actions can be transformed into direct contributions at the total production costs.

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