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# PRODUCT TIME AND COST IN MANUFACTURING SYSTEM-MARKET RELATIONSHIP

Assoc. Prof. Daschievici Luiza
Assoc. Prof. Ghelase Daniela
“Dunarea de Jos” University of Galati

## ABSTRACT

*This paper presents a product time and cost estimation method taking into account the market dynamics and manufacturing system competitiveness. The method is based on the behavioral modeling using on-line unsupervised learning. On one hand, it is modeled the interaction between task and manufacturing system, and, on the other hand, the interaction between task and market, finally resulting the behavioral modeling of the market-manufacturing system relationship to substantiate the strategic component of the competitive management thus ensuring extension in time of the high performance.*

*KEYWORDS*: *behavioral modeling, cost estimation, product time, manufacturing system.*

## 1. INTRODUCTION

The dynamic changes and the overall progress of society are reflected at company level by many orders in number, small in volume, very diverse, obtained through frequent auctions with short- term response, which leaves no time for a relevant analysis of the said orders.

To be competitive, enterprise should be able to produce a variety of components at low costs and in a short time. In order to achieve this goal, during the negotiation process, the manager, based on the product time and cost estimation, has to decide quickly and correctly if the order is competitive. It is very important in winning an order if the response time requested by the client is short. A slow response can determine the loss of the order because the client may choose the offer from another competitor that submits a quotation faster.

The cost estimation is used in price determination. If the price estimation is less than product cost then there can be financial losses for the enterprise. On the other hand, if the price estimation is much higher than the product cost it is possible that the client to place his order with another company that offers a better price. The product time estimation is used to determine the date of the delivery. It is known that any delays in the product delivery can lead to financial loss.

The classification of the different methods and estimation models used to obtain a reliable quotation is presented in [5] as follows:

*1) qualitative estimation methods;*

*2) quantitative estimation methods.*

The study [5], which is a review of the different types of the product cost estimation, concludes that qualitative estimation methods are based on the analysis of the new product as compared to products developed previously. On the other hand, quantitative estimation methods are based on the analysis of detailed product design, its features and manufacturing process.

Qualitative estimation methods include:

a) Intuitive methods - based on the use of previous experience. There, can be observed case-based methodology and decision support systems.

b) Analogical methods - based on the similarity between the new product and past cases. These methods can be classified as regression analysis and artificial neural networks.

Qualitative estimation methods include:

a) Parametric methods - derived from the application of statistical methods to define the cost as a function of different product variables. These methods provide fast estimation.

b) Analytical methods - based on the breakdown of the product into elements. Product cost is calculated as a sum of all of the components. Of these methods that are amongst the most reliable can be cited the following: operation-based, breakdown-based, tolerance-based, based on the product feature, ABC method (activity-based-costing).

Note that there is a classification of the traditional estimation methods as:

- Detailed breakdown methods;
- Simplified breakdown method (designed for estimation during the initial design phases);
- Methods based on the technological group (based on similarity);
- ABC method.

Manny researchers [2] consider that the use of a single estimation method is not enough to generate a estimation in the case of the initial phases because of the detailed information they require.

In this paper it is proposed a product time and cost estimation method taking into account the market dynamics and manufacturing system competitiveness, based on the behavioral modeling (term introduced by the authors).

The rest of the paper is structured as follows: section II presents the problem formulation, section III describes the behavioral modeling method, section IV contains a case study and section V summarizes the main conclusions.

## 2. PROBLEM FORMULATION

The interaction between the economic environment and the manufacturing system is a major source of knowledge about the economic environment and the manufacturing system themselves. Product prices have a strong informational load.

They inform producers about the economic profit margin that they may receive by producing the products.

In determining a price of the product must be know the production cost.

In market economy conditions, a product cost estimation and time for achieving it are problems of concern to any enterprise manager.

The manager of an enterprise is in the situation that has to make a quotation of price for elaborating an offer in order to negotiate. Thus, the question that occurs is: What price must product have to win the auction? For this, the manager is obliged to establish a link between task and market in terms of customer requirements.

The manager develops an action of exploiting and an action of exploration in order to choose the best in the future. In order to face these situations, the manager has set specific goals, can realize the different aspects of the economic environment and can make choices after which selects the efficient actions. The result of the actions provides information on how the action effective was.

Consequently, the aim of this research is to develop a behavioral modeling technique of the market-manufacturing system relationship to substantiate the strategic component of the competitive management thus ensuring extension in time of the high performance.

## 3. BEHAVIORAL MODELING

By competitive management adaptation takes place of the manufacturing system for the purpose of profit maximization. To achieve adaptation, it is necessary to achieve modeling of the interaction between all elements of manufacturing system - market assembly, which shall be called behavioral modeling from now on. The term of behavioral modeling is introduced by the authors of this paper and, for presenting this notion, we shall consider two elements H1 and H2, which interact with each other (Fig. 1. a). Model H1 of the first element establishes a connection between the input x and output y. If x and y are at the same time input and output of another element, whose model is H2, then the two elements interact with each other.

Modeling their interaction (behavioral modeling) means setting the pairs of values (x, y) which satisfy the transfer functions H1 and H2. The multitude of solutions which satisfy both transfer functions H1 and H2 represent the behavioral model because they describe the behavior of the elements during their interaction.

For instance, under the theme concerned, H1 could stand for the manufacturing system while H2, for the market .

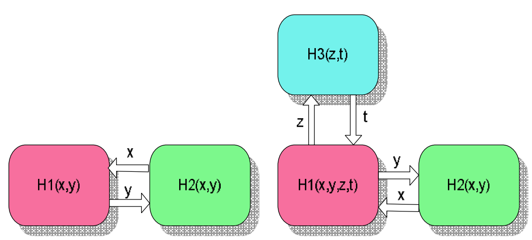


Fig. 1. Behavioral modeling

Behavioral modeling becomes increasingly complex as the number of interacting elements is growing too.

For example, in case of Fig. 1.b, three elements interact and behavioral model represents the relationship between the values of x, y, z and t for which the three elements can interact.

Considering elements H1 and H2 with the following transfer functions:

$$\begin{cases} H1(x,y)=0 \\ H2(x,y)=0 \end{cases} \quad (1)$$

then, the solutions of the system (1) represent the behavior model of H1-H2 assembly. If the solution is unique, then the behavioral model is reduced at one operational point. Considering H1(x,y) and H2(x,y) as being two lines, then the solution of the system is the intersection point H0 (Fig. 2).

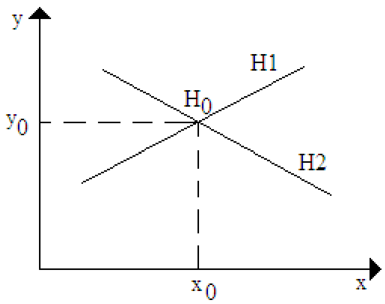


Fig. 2. Behavioral model with unique solution

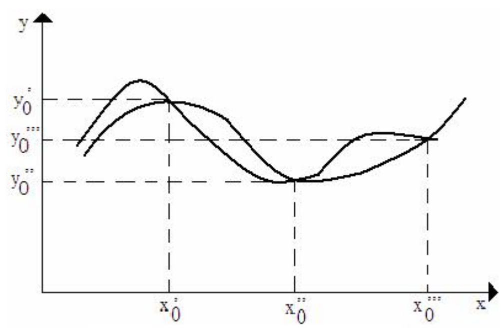


Fig. 3. Behavioral model with multiple solution

If there is a values string $x_0$ and $y_0$ as solutions of the system (1), then the behavioral model includes all these points (Fig. 3): ($x_0'$, $y_0'$), ($x_0''$, $y_0''$), ($x_0'''$, $y_0'''$).

If the system (1) is incompatible, then there isn't any behavioral model that meets H1 and H2 assembly. In the case of Fig.1.b, the case of the interaction of three elements H1, H2, H3, the behavioral model is given by ($x_0$, $y_0$, $z_0$, $t_0$), the system solution:

$$\begin{cases} H1(x,y,z,t)=0 \\ H2(x,y)=0 \\ H3(z,t)=0 \end{cases} \quad (2)$$

As the number of variables is more then equations, we expect the system (2) to be indeterminate. The model will include an infinite points number.

The behavioral modeling method of the manufacturing system-market assembly is developed on these assumptions:

- elements H1 (manufacturing system) and H2 (market) operate and are monitored on-line;

- during operation, elements H1 and H2 pass through different states, that means they operate with various values of the state parameters. For example, H1, the manufacturing system, processes various products with various machining parameters and with various time, materials consumptions. Element H2, market, operates similarly, selling various products with various prices in various supply conditions.

- elements H1 and H2 interact, but not throughout their operation (the manufacturing system can interact with other markets).

The algorithm used for modeling is based on states clustering and consists of the following steps [1]:

Step 1: clustering of variables based on the causal relationships;

Step 2: states clustering;

Step 3: building of the mathematical model corresponding to the states cluster and variables cluster set.

Then the causality relationships between parameters are identified. Based on these relationships, clusters of independent variables are established. Further, based on the dataset to be used for the model fitting, a cluster of neighbouring states is made up, at the centre of which there is the state to which the respective input data are related. Finally, a linear model whose variables are the variables of one of the clusters of identified variables is fitted on the manufacturing system states cluster. These input data are the ones which have been previously considered in the procedure of enclosing the manufacturing system states cluster.

It can be noted that, according to the proposed method, the model construction and its operation are accomplished within an integrated algorithm which is run through upon each interrogation of the manufacturing system model. At the operational level, the variable clustering is based on the "*best NN model*" facility which is offered by the neural networks technique applied to a data set recently obtained from monitoring the manufacturing system. The states cluster construction, the linear model is fitted to, first implies the use of the 2nd rank Minkowski distance for the classification of states, in the increasing order of their distance to the state to be used for model interrogation.

That is why only the variables representing these input data will be considered in the calculation of Minkowski distance.

The states cluster is to be obtained either by restricting the value of the distance or by restricting the number, *k*, of retained states or using both conditions. The construction of the mathematical model is made by linear regression. It can be noted that this is a local model, as it is valid only in the vicinity of the state for which the model is interrogated. This model is meant to be used just once as, after the interrogation, we give it up.

In conclusion, the aim of the proposed method is to develop a cost estimation for the required product in terms of time required by the customer.

To be sure of winning the product auction, the manager must apply an attractive price.

In determining the price of the product it is necessary to know the product cost. Thus, for a specific task required and in imposed time conditions, through modeling are obtained the relations as:

$$\text{Cost} = f(\text{task}) \tag{3}$$

$$\text{Time} = f(\text{task}) \tag{4}$$

At the same time, the manager must have a model of the product markets by monitoring the auctions.

Auctions provide data on market price quotation.

By modeling of market data it is obtained a relationship of dependency as:

$$\text{Market} = f(\text{task}) \tag{5}$$

The method proposed for the achievement of the three models (fig.4) consists of monitoring and recording the relevant state variables of the manufacturing system in a database.

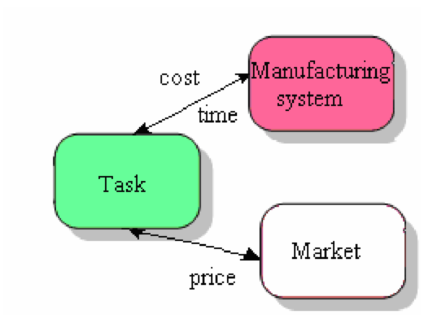


Fig. 4. The interaction between task-manufacturing system and between market-task

## 4. CASE STUDY

In today's economic context, the corporations and the business environment in general are producing data in enormous quantity and on daily basis.

During the experiment data have been collected with regard to the manufacturing machines that had been used for manufacturing some important parts in the construction of dump truck bins, namely the attachment plate of the supplementary chassis of the dump truck bin (fig. 5).

Data regarding the actual work times, data referring to the modes of operation, data regarding the amounts of resulted wastes, data regarding all types of consumption, as well as data regarding the orders for the delivered products were collected.

We use the database of a cutting process that has the following parameters: type of the material, length of cutting, cutting width, cutting speed, feed rate, number of pieces, machining time, energy consumption, cost of operation and waste quantity, table 1. Identification algorithm uses as input data a set of monitored variables, between which it exists an implicit relationship.

In order to succeed in demonstrating the viability of the solution to the problem of product time and cost estimation running of the modeled manufacturing systems, a practical database resulted from process measurements was obviously required.

For this, measuring and monitoring of the cutting process were made, whose results are summarized in table 1.

Analysis of cluster is a descriptive technique used for grouping similar entities from a data set or equally for entities that present evident substantial differentiation from the group. Clustering technique is based on algorithms from the neural networks.

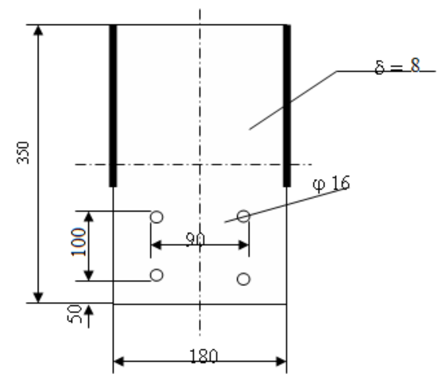


Fig. 5 Attachment plate of the supplementary chassis of the dump truck bin

A. Clustering variables

Clustering variables consists in grouping variables which are variables in dependence. Thus using "best NN model", choosing of many consecutive columns and determination of the best links with the 1, 2 or i variable we determine the cluster of variables which are in the best relationship of dependency.

For example, in table 1, considering the cutting process variables that denote $V_1$, $V_2$, ..., $V_{10}$ and using the "best NN model" facility, results the column $V_7$ - time of cutting, as the most influential variable in determining the time of operation. There are the best relationships with dependent columns $V_2$ and $V_4$.

B. Clustering states

Suppose that the manufacturing system is required to execute an operation that $V_2 = 150$, and $V_4 = 3$, which you don't find in our experiment.

Clustering states consists in identifying groups of related records that can be points of departure for further exploration of relationships. In the process of grouping elements it is necessary to estimate the minimum distance between those elements with the function:

$$d = \sqrt{\left(V_2 - 150\right)^2 + \left(V_4 - 3\right)^2} \qquad (6)$$

C. The mathematical model

Mathematically it can be written a linear relationship:

$$V_7 = a \cdot V_2 + b \cdot V_4 \qquad (7)$$

Retaining the first 2 states, so for k = 2 according to k-NN algorithm can be written:

$$\begin{cases} a \cdot 158,25 + b \cdot 1,2 = 8201 \\ a \cdot 158,25 + b \cdot 9,25 = 8835 \end{cases} \qquad (8)$$

which represents a system of two equations with two unknowns. By finding system solutions, are obtained the values for *a* and respectively *b* which are replaced in the relationship (7) resulting relationship (9).

$$V_7 = 51,225 \cdot V_2 + 78,75 \cdot V_5 \qquad (9)$$

Linear model so determined will be used in modeling task-time relationship. This is a local model, that is only valid in the vicinity of the state in connection with which it is interrogated and ephemeral because after the query is dropped.

Taking the reasoning again we modeled the relationship between task and cost. In this case we found that the influence variable is variable $V_8$, using the "best NN model". Similarly we determine:

$$V_8 = 0,05 \cdot V_2 - 1,08 \cdot V_4 \qquad (10)$$

Returning to the our example above, $V_2 = 150$ and $V_4 = 3$, it follows the same steps as in modeling of relationships: task-time and task-cost and we obtain a mathematical relationship for model task-market model, taking $V_9$ as the influence variable.

$$V_9 = 5,78 \cdot V_2 - 116,52 \cdot V_4 \qquad (11)$$

In conclusion, if we introduce variations of the process parameters and a variable restriction we can get a table of solutions that will help to find common solutions through negotiation between the customer's requirements and possibilities of the economic and technical producer.

## 5. CONCLUSION

Note that we propose to give managers a model so that they can interact with the

Table 1 - Example of experimental data regarding the process variables collected for the cutting off process

| Item nr. | Type of material | Length of cutting (mm) | Cutting off width (mm) | Cutting off speed (mm/s) | Feed rate (mm/s) | Number of pieces | Machining time (s) | Energy consumption (kwh) | Cost of operation (Euro) | Waste quantity (Kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| - | **$V_1$** | **$V_2$** | **$V_3$** | **$V_4$** | **$V_5$** | **$V_6$** | **$V_7$** | **$V_8$** | **$V_9$** | **$V_{10}$** |
| 1 | OL 52 | 350,1 | 180,15 | 3,1 | 0,5 | 50 | 1200 | 14,74 | 1781,35 | 26,512 |
| 2 | OL 52 | 253,1 | 184,15 | 4,1 | 1,5 | 75 | 2254 | 18,24 | 2186,25 | 32,787 |
| 3 | OL 37 | 257,15 | 172,1 | 5,1 | 2,5 | 100 | 2011 | 24,84 | 2861,66 | 42,912 |
| 4 | OL 42 | 462,05 | 268,1 | 5,15 | 2 | 45 | 3201 | 18,45 | 2190,45 | 32,862 |
| - | | | | | | | | | | |
| - | | | | | | | | | | |
| - | | | | | | | | | | |

economic environment (market).

Practically, this happens before the actual work of manufacturing system, so we have to do with a function of anticipation.

The proposed method has the advantage of being applicable to any manufacturing system, regardless the physical nature of the process and the product features.

The method provides the extended modeling of the relationship between manufacturing system - market .

The level of extension is only limited by the number of the monitored state variables. The level of the modeling accuracy satisfies both the requirements specific to a contract negotiation and the ones specific to the operational management.

The developed method allows for the identification of the variables of one model that represents the relation between the output and the input model. The proposed method develops a cost estimation for the required product in terms of time required by the customer.

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