Economic Modelling of the Manufacturing Machines Competitiveness

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Abstract: - The paper refers to a method of competitive management of the machines of the manufacturing systems in the conditions that they execute small series works to order. In practice, order acceptance decisions and production planning are usually taken separately. The sales department makes decisions regarding the acceptance of orders, while the production department is responsible for production planning for the fulfillment of accepted orders. In most cases, the decision to accept the order does not involving the production department and the information about the planning of available production capacities is incomplete. In this context, the purpose of the paper is to highlight the econometric correlations between technique-technology and competitiveness, to study the role of the parameters related to them in the acquisition, and increase the manufacturing machines' competitiveness.

Key-Words: - manufacturing machines system, monitoring and control of manufacturing process, manufacturing machines' competitiveness, performance of the manufacturing system, profit rate, market, customer requirements.

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1 Introduction

Ensuring permanency competitiveness is the main objective of any management system. The specialized literature concerning competitiveness does not involve the term innovation except at the level of management policies, but the innovation-competitiveness relationship studied in a technical and technological context is much more important. Innovation can be seen as a main component of competitiveness that causes continuous improvement, which is the engine of the total quality system, the foundation of competitiveness. That's why, in this context, innovation gets the certification of analysis parameters and competitiveness evaluation indicators. In an enterprise, the managerial solutions and technical solutions are the ways to stimulate innovation. A company's technological strategy is the path it chooses for the development and use of technologies. Technologies represent a complex set of knowledge, means (equipment), and procedures used in a local context in advantageous economic conditions. In the concrete conditions of companies, the priority is precisely the technological strategy with all that it implies. Even if the value of the investments is high, the amortization is slow, a courageous approach to the problem is necessary.

In conclusion, from the analysis of the literature, [1], [2], [3], [4], [5], [6], an asymmetric or one-sided approach to the competitiveness of industrial enterprises, and especially those with mechanical specifications, results, proving necessary to reconsider in the context of "technical competitiveness" inextricably linked to quality through innovation.

The performance of the manufacturing system depends on how it is managed. In several specialized works, for example, [7], [8], [9], [10], references are made to the relationships between the parameters of the processing regimes and the technical performance of the manufacturing system (purely technical aspects), and in others, just as many, [9], references are made to the relations between the product made by the manufacturing system and the market (that is, relations of an economic nature) and which require us to intervene in the manufacturing system to obtain economic effects favorable.

There is no known management algorithm for the entire manufacturing system - the market, [9], [11], [12].

2 Cost and Price Estimation

The main aspects of assessing the level of performance of an enterprise that refers to the overall efficiency of economic activity are economic efficiency, realized/planned performance, product competitiveness, or company excellence.

The competitiveness of an enterprise is determined by various factors that have a decisive influence on the competitive power of the company, such as production factors, managerial and marketing capabilities, and financial, technical, and creative resources.

The internal conditions available to an enterprise contribute to its ability to obtain an advantage over competitors, both in terms of costs and diversity, quality, and renewal of the offer.

Any enterprise is made up of manufacturing sections which, in turn, are divided into workshops. This structure forms the manufacturing system of an enterprise. Structurally, the workshop is made up of independent manufacturing machines. To order a product, manufacturing machines are grouped in the manufacturing system specific to the product.

In industry, the manufacturing operations on CNC machines (machine tools with numerical control) allow controllable processing times, [4]. For example, for a CNC turning machine, there is a nonlinear relationship between the cost of the manufacturing and the time of required processing, [7]. The simultaneous objectives on a single CNC machine are considered total manufacturing cost (F1) and total weighted completion time (F2). Also, the decisions for processing time are as critical as decisions for job sequencing. F1 subject to a given F2 level, is given an effective model for the problem of minimizing. For this problem, in [7], it is deduced some optimality properties and then, it is proposed a heuristic algorithm to generate an approximate set of efficient solutions.

In [8], the authors show that they can generate alternative reactive schedules considering the manufacturing cost implications in response to disruptions if they have the flexibility to control the processing times of the jobs. They consider that processing times of the jobs are compressible at a certain manufacturing cost which are represented with a convex function of the compression on the processing time in a non-identical parallel machining environment. By reassigning the jobs to the machines and compressing their processing times, in rescheduling, it is highly desirable to catch up with the original schedule as soon as possible.

3 Economic Modelling Method Proposed

Currently, the machines of manufacturing systems are controlled by the programs of the machine tools with the program command that composes the system, [10]. Management is exclusively technical, because there is no economic variable, although this would represent the final goal of the processing processes. The dynamics of the changes and the general progress of the society are translated at the company level through orders many in number, small in volume, very varied, obtained through frequent auctions with answers in short terms, which do not provide time for the pertinent analysis of the orders. As a result, it is no longer possible to manage in the long term. A fluctuating type of management (just like the market), online, with prompt, quick reaction, but still ephemeral, must be imposed.

The manufacturing system receives contracts following auctions (competitions) generated by market requests. Obtaining maximum competitiveness through instructions and intervention on how to develop the manufacturing process. The evaluation of competitiveness generates a competitive management system. This competitive management must enable the development of competitive offers that will enter the auction. This is done by using two learning techniques: reinforcement learning technique to learn about the market and unsupervised learning technique to learn about the manufacturing system.

3.1 Modeling Algorithm

Starting from the contractual specifications, based on the monitoring of the operation of the technological systems, the consumption and costs of the technological operations are established. A set of data is formed and, through data-mining, the process of discovering relationships and combinations, generally knowledge, is carried out, and the results found can be included in an automatic decision support system.

The data mining methods that will be used are unsupervised learning and supervised learning. Through unsupervised learning, using the Principal Components Analysis (PCA) technique, the pattern of state variables of technological systems will be discovered. According to the causal relationships between variables, they are grouped using the Cluster Analysis (CA) technique through unsupervised learning. For each group of variables, through supervised learning, knowing the data, on the one hand, regarding the dimensions of the part, the working regime, the precision characteristics, and, on the other hand, those regarding the consumption of time, materials, energy, the model will be built econometric of the manufacturing system. For example, cost and productivity could be

identified as functions that depend on the product and the intensity of the manufacturing process.
The performance of the manufacturing system can be evaluated by the profit rate P, according to the relationship:

$$P = (p-c)q \tag{1}$$

where: the price is noted with p, the cost is noted with c and q is the productivity.

Once the productivity and expenses curve has been drawn, the third variable, competitiveness, can be added and on this basis the intensity of the process can be adjusted, thus adapting the system to obtain maximum profit. By adjusting the intensity of the manufacturing process and through online learning, the model of the manufacturing system corresponding to the creation of competitive products is adopted. It is a behavioral modeling because it is based on monitoring the interactions between the component elements of the manufacturing system and the permanent circuit of information from inside and outside the manufacturing system.

3.2 Simulations of the Proposed Algorithm

To check the accuracy and applicability of the competitive management concept needed by results practically obtained, for a certain case.

Consequently, it will simulate and model a real manufacturing system of the pilot enterprise, which works in real conditions, on a real market, with real parameter values and, based on this modeling, will be realized as an experimental system.

In this frame, using the methodology will be introduced the attributes and values generated through online learning, which will determine the state of the system and respectively solutions of that carry out of the competitiveness optimum.
These will be applied to the model and will determine the solutions for the management policy. In the frame of the virtual enterprise, the manufacturing system will be materialized by the proof-of-concept stand. Through modeling, the physic parameters obtained on the stand will be introduced into the manufacturing process of the virtual enterprise, thus working as a complex system. The experimental stand will be realized by taking into account the case of the most simple manufacturing system, which contains one technological system. The technological system will be made up of machine tools with numerical control (CNC) and will be equipped as one monitoring system corresponding to a competitive management algorithm. The experimental manufacturing processes realized using the stand will be introduced into databases. This database will be used for implementation of the unsupervised online learning methods. Estimating the obtained results will conclude algorithm viability of competitive management.

In the presentation of the method, we start from the fact that we will have a series of inputs, considered as customer requirements, we will have a series of restrictions given by the work regime and the time of making the product, considered independent variables and we will have a series of variables dependent or output, one of which will be the main objective variable, against which we analyze the efficiency of the results. To understand the problem, we will use an example and we will first consider a random sequence from the database of the drilling operation, Table 1, in which we find the notations V_1, with i=1,...,10.

Drilling operation is modeled by a Neural Network technique or the best model provided by a neuronal network is a practical modality to find out causality relations between variables to be able to determine the variable clusters [9]. The variables are compared with each other with the help of the neural network to obtain clusters of variables that are in causal relationships. Obtaining the clusters is done through a computer application, practically training the network with the values from the database and determining those variables between which there are causal links.

Table 1. Example of experimental data regarding the process variables collected for the drilling process

Item nr.	Type of material	Diameter hole (mm)	Number of holes	Speed drilling (mm/s^2)	Advances in drilling (mm/s)	Number of pieces	Drilling time(s)	Power consumption (kw/hour)	Cost of operation (euro)	Amount of wastes (Kg)
-	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}
1	OL 52	12,5	3	1,1	0,7	70	7242	6,04	0,026	13,12
2	OL 42	15,55	5	4,1	0,3	28	12033	3,76	0,0268	13,54
3	OL 42	11,6	5	2,05	0,25	59	6255	4,41	0,0315	15,87
4	OL 42	25,6	2	5,05	0,35	104	3404	37,86	0,108	54,52
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Table 2. Table Arranged According to the Shortest Distances

-	v2	v3	v4	v5	v6	v7	v8	v9	v10	d	price
1	12,5	3	1,1	0,7	70	7242	6,04	1093,75	13,12	1,004988	0,285
2	15,55	5	4,1	0,3	28	12033	3,76	1128,41	13,54	1,044031	0,285
3	11,6	5	2,05	0,25	59	6255	4,41	1323,17	15,87	1,059481	0,285
4	25,6	2	5,05	0,35	104	3404	37,86	4543,82	54,52	2,015564	0,285
5	9,55	7	4,05	0,8	49	3998	2,48	1042,74	12,51	3,006659	0,285
6	17,55	8	3,2	0,75	77	2459	13,17	6324,31	75,89	4,002812	0,285

We consider that the input data, the client's requirements are V3 = 4, and V5 = 0.6, which you don't find in our experiment. We will choose from the database those lines for which the common distance will be the minimum, thus performing the clustering of the lines with the minimum common distance. In this way, a set of data will be selected that has the quality that they will be in the vicinity of the client's requirements and thus the mathematical model will be a linear one, Table 2.

$$d = \sqrt{\left(v_3 - 4\right)^2 + \left(v_5 - 0{,}6\right)^2} \quad (2)$$

For the experimental implementation of the modelling method proposed, an IT product was developed and designed in the Visual FoxPro programming environment, using the function libraries in Matlab and C++.

4 Conclusion

The developed program was tested with numerous sets of variables allowing the simulation of optimal adaptive management based on the continuous identification of the calculation model of the solution table. The behavior of the program was good, supporting the idea that this method is robust, giving viable solutions for use.

Following the analysis of the solution table and the use of the data set requested by the client in practical form, small differences were observed compared to the expressed requirements, actually confirming the accuracy of the method and the unlimited practical possibilities.

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Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.