THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE XIV MECHANICHAL ENGINEERING, ISSN 1224-5615
2011

# ON-LINE ASSESSMENT OF THE MANUFACTURING SYSTEMS COPETTIVENESS

Assoc. Prof. Dr. Daniela Ghelase,
Assoc. Prof. Dr. Luiza Daschievici
"Dunarea de Jos" University of Galati

## ABSTRACT

*A company is competitive on a certain market when it succeeds in reaching, up to an acceptable level, some economic indicators: turnover, profit, market share comparable or superior to that of other competing companies acting on the same market. Many approaches to the problem of competitiveness show that, today, competitiveness is defined by the economic factors and indicators and is more a suggested/induced notion than a numerically evaluated one. The approaches are of economic and managerial nature, while the relationship with the technical aspects of competitiveness is less noticeable. At this point there is no algorithm to evaluate the technical and economic competitiveness, moreover, the technical factors are not considered, although consumption and costs incurred by the manufacturing processes are generated by technical actions. In this context, the notion of competitiveness gains new valences, including factors and policies that determine the ability of the enterprise to get a favourable place on the market, to maintain that place and to continuously improve its position. In this paper, competitiveness will be understood as the capacity (potential) to provide performance (compared with other similar elements), in a very punctual way, within a macroeconomic concrete context and at a certain time. A case study referring to the assessment algorithm is presented, showing the use of the algorithm in the on-line management of the manufacturing system to obtain maximum competitiveness.*

**KEYWORDS:** competitiveness, manufacturing system, behavioural modelling

## 1. INTRODUCTION

All over the world, companies are faced with increasingly accelerated and unpredictably dynamic changes. This is influenced by the scientific and technical progress, the dynamics of customers' demands, the scientific approach to management and the mathematical focus on economy [13]. Changes lead to aggressive competition on a global scale, which calls for the establishment of new balances between economy, technology and society. The characteristic aspects of the present-day market, in particular case of mechanical components market, are the following:

i) continuously decreasing the current orders, leading to the design of small series production;

ii) the strong tendency to personalize the products leads to a pronounced diversity of shapes, sizes and other characteristics of the mechanical components required on the market;

iii) flexibility, responsiveness and especially an efficient system management tend to become the characteristics that determine competitiveness on the market of components manufacturers and mechanical constructions. The current dynamics of the industrial and business environment is the great global challenge which must be faced. To a new global challenge the scientific community responds by a new conceptual paradigm, which in this case is the knowledge- based economy (KBE), [10]. In order to progress in the present-day complex and unpredictable environment, the company must feature abilities of quick response [5] and favorably reposition itself on the market. Acquisition and preservation of this capacity is the most difficult step for companies as it involves many endogenous and exogenous factors and the process is continuous, dynamic and hardly predictable. In this context, three elements are highlighted by their relevance: competitiveness, the manufacturing system and the knowledge system.

a) Competitiveness

According to the literature, a company is competitive on a certain market when it succeeds in reaching, up to an acceptable level, some economic indicators: turnover, profit, market share comparable or superior to that of other competing companies acting on the same market.

Many approaches to the problem of competitiveness [1, 4, 6, 7, 11, 14] show that, today, competitiveness is defined by the economic factors and indicators obtained and is more a suggested/induced notion than a numerically valuated one. Approaches are of economic and managerial nature, while the relationship with the technical aspects of competitiveness is less noticeable.

At this point there is no defined algorithm to evaluate the technical and economic competitiveness, moreover, the technical factors are not considered at a practical level, when defining competitiveness, although consumption and costs incurred by the technological processes are generated by technical actions. In this context, the notion of competitiveness gains new valences, including factors and policies that determine the ability of the enterprise to get a favourable place on the market, to hold that place and to continuously improve its position. Only in this way can competitiveness fully and synthetically characterize the enterprise viability.

In the paper, competitiveness will be understood as the capacity (potential) to provide performance (compared with other similar elements), in a very punctual way, within a macroeconomic concrete context and at a certain time. Moreover, according to a meter of competitiveness (considered as an essential performance indicator) it will be assessed the extent to which the company achieves the purpose for which it has been created. Therefore the paper aims at making a numerical and on-line evaluation of the technical and economic competitiveness and the management of the manufacturing system is performed to obtain maximum competitiveness.

b) The manufacturing system

Within this paper, by manufacturing system we understand all the technological systems that are used to produce a specific product. Each of these technological systems is composed of machine-tool, tools, devices, parts, operator and carries out one of the operations of the technological process of making that product.

The manufacturing system is complete when the product is released for manufacture and remains there only until the end of the product completion. After this, when another product is released, the problem of structuring the manufacturing systems is taken from the beginning. This ad hoc structure of the manufacturing system is always present with manufacturing lots, but not in mass manufacturing, when all of the technological components of manufacturing system remain unchanged for a long time.

The manufacturing system performance depends on how it is run. In more specialized papers, eg [9], reference is made to the relationships between the parameters of the cutting processes and the technical performance of the manufacturing system (i.e. purely technical aspects), while in others, equally numerous references [10, 14] are made to the relationship between the product made by the manufacturing system and the market (i.e. economic relations).

In the literature no attempt to approach the whole manufacturing system–market assembly is reported; therefore, there are significant resources to improve performance which are not used because the technical and economic aspects are dealt with separately. Also, it is not known an algorithm for the management of the manufacturing system–market assembly, but only algorithms for the technical control of the technological systems-components of the manufacturing system [1, 3] and tools of economic management of the relationship between the enterprise as a whole and the market [8, 9, 10].

Nowadays, the manufacturing systems are controlled by means of numerically programmed machine tools which are part of the system [2].

The control is exclusively technical because there is no economic variable, although this is actually the ultimate goal of any activity.

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. As a result, a long-term management is no longer possible. A sort of fluctuating (just like the market) on-line, fastly responsive, prompt and rapid, however, ephemeral management is called for [2, 12].

c) The knowledge system

The market dynamics is further passed to the mode of operation and management. In a knowledge-based society and economy, operations such as determining the relevant information and aggregating them into pieces of knowledge must be automated, because in such a complex and unpredictable environment, they are indispensable tools for creating, searching and structuring knowledge.

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 [5].

The paper has the following structure: section 2 presents the key ideas, section 3 develops the new concept of manufacturing systems management, section 4 presents the competitive management algorithm and section 5 summarizes the main conclusions achieved.

## 2. KEY IDEAS

The key ideas the paper construction is based upon at a conceptual level, are:

1. Taking over the Competitive Exclusion Principle from Biology and applying it to the manufacturing systems-market assembly;

According to this principle, if the ecological system is stationary, then two species that consume the same food resources cannot coexist within a stable equilibrium. Permanently, one of the two competitors will win and the other will be excluded and will have to adapt itself to a different niche of food resources. It is noted that there is the isomorphism between the situation in biology and situation of the manufacturing systems-market assembly.

The manufacturing systems are similar to species, the market is similar to an ecological system and the contracts for the manufacture of some ordered quantities of products are the food resources, while the competition for these resources is taking place under the auctions or other similar commercial activities. By analogy, it is compulsory for the manufacturing systems to be conducted on the basis of competition and, moreover, according to this principle, the manufacturing systems must adapt to the conditions to be competitive, even when they still have enough orders.

It follows that, in general, competitiveness is a sine qua non condition, on which is based the very reason of the manufacturing systems to be.

2. The on-line learning management, to obtain promptitude and accuracy, hence efficiency;

Nowadays, the monitoring data of the manufacturing system are transformed into knowledge only in case of scientific research activities; knowledge is then disseminated through the dissemination channels (eg. publication) to be applied.

The circuit is too long and knowledge reaches the manufacturing system late and indirectly. The paper will pursue a permanent circuit to transform on-line the information into knowledge in order to generate actions able to be implemented immediately and directly inside the system.

3. Behavioural modelling, instead of element modelling, to get quintessence and completeness, hence simplicity and robustness in the act of management/control;

Models currently used in the management of the manufacturing systems, whether analytical, numerical or neural (or, in general, algorithmic), refer to the components of the systems.

Building models in all cases is based on off-line experimental investigation of an element, making up a set of experimental data and using it to select, out of a given family of data, the most appropriate model.

There are no cases reported in literature of behaviourally modelled systems where, by monitoring the current operation of the manufacturing system concerned, to extract on-line knowledge which relates to the interactions taking place in said manufacturing system, although, for a competitive management, it is in fact required to model the interaction between the system components.

The new concept of control/management of the manufacturing systems will be developed based on behavioural modelling, which will describe the interaction between elements (technological system, manufactured products, the market).

## 3. DEVELOPING A NEW CONCEPT OF MANUFACTURING SYSTEMS MANAGEMENT

Competitive management is a concept that the authors propose in this paper, starting from the principle of competitive exclusion taken from Biology. The concept development is based on the results obtained so far by the authors, in terms of rigorous and general analytical description of the econometry of a generalized technological system consisting of machine-tool, devices, piece and tool.

The obtained results for the machining process will be presented. So, analyzing fig. 1, which, in ZOY plan, presents the cost curve, *c*, and productivity curve, *q*, depending on the intensity, *R*, it can be noted that *c* has a minimum point for which the process intensity takes the value $R_c$ and the productivity curve, *q*, has a maximum point for which the process intensity has the value $R_p$. Because analytically, $R_c$ is different from $R_p$, it follows that it is never possible to simultaneously achieve minimum cost and maximum productivity.

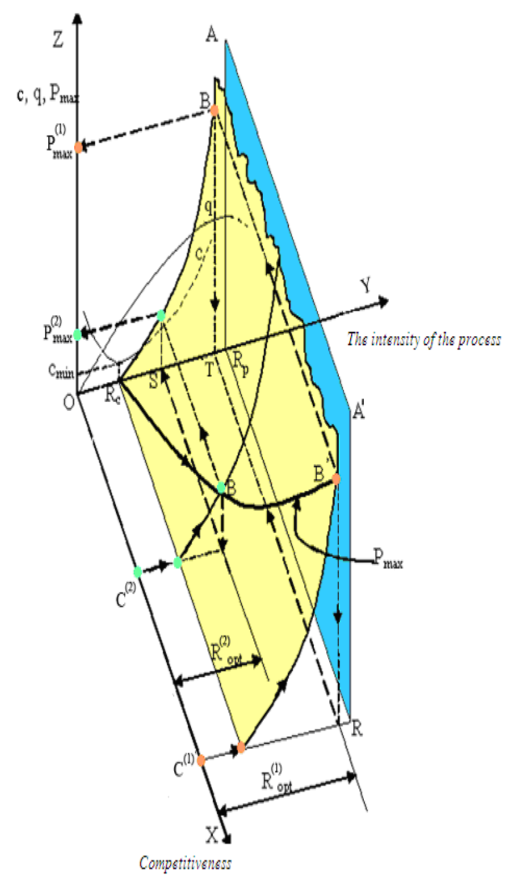


Fig. 1. Curve of maximum profit

The question arises: to achieve a profit as high as possible, which is the best way to produce? more and costly or less and cheaper, because more and cheaper, as seen in Fig. 1, is not conceptually possible.

To answer the question, let us follow the spatial evolution of the maximum profit ($P_{max}$ curve), depending on competitiveness, *C*, and the intensity process, *R*.

Let us consider two levels $C^{(1)}$ and $C^{(2)}$ of competitiveness. The researches conducted by the authors have shown that, as competitiveness, *C*, is higher, productivity becomes more important (*q* curve) than the cost (curve *c*) and therefore the optimal process intensity (ie that for which the profit is maximum) is approaching (asymptotically) the $R_p$ point (follow the route $C^{(1)}$-E-B-$P^{(1)}_{max}$), which represents the process intensity for maximum productivity (without ever reaching it!). For $C^{(2)}$ value of competitiveness (which is lower), the cost becomes more important and the optimal process intensity is approaching the point $R_c$ which is the process intensity corresponding to the min. cost, $c_{min}$, (follow the route $C^{(2)}$-D-V-$P^{(2)}_{max}$). In both cases, the maximum profit takes the values $P^{(1)}_{max}$, $P^{(2)}_{max}$, respectively. In limit cases, when competitiveness is null (ie all auctions are lost, but lost to the limit), then the maximum profit that can be obtained is zero (meaning that at best there is no profit at all) and this situation can occur only if the process intensity corresponds to point $R_c$ (for which the cost is minimal). It is obvious that the operation at minimum cost is a limit we do not want to reach. In conclusion, the process intensity changes according to competitiveness between the $R_c$ and $R_p$ limits without reaching any of them. Competitiveness, once established, will determine, for each separate element of the manufacturing system, the optimal level of the process intensity.

In the concrete case of the manufacturing system, technical-economic competitiveness can be assessed by he profit rate, *P*, given by the relationship:

$$P = \frac{p - c}{\tau} \text{ [Euro/min]}, \quad (1)$$

where:
p is specific price, [Euro/cm$^2$],
τ - time for 1 cm$^2$ surface area machining [min/cm$^2$];
c - cost for 1 cm$^2$ surface area machining [Euro/cm$^2$], given by the following relation:

$$c = \frac{c_\tau}{10 \cdot v \cdot s} + \frac{\tau_{sr} \cdot c_\tau + c_s}{10T \cdot v \cdot s} + \frac{t \cdot c_{mat}}{10} + \frac{K_e \cdot c_e}{10000 \cdot v \cdot s} + \frac{C_M}{10 \cdot K_M} v^{\alpha-1} \cdot s^{\beta-1} \cdot t^{\gamma} \text{ [Euro/cm}^2\text{]} \quad (2)$$

where:

$c_\tau$ – it is the sum of all expenses directly proportional with the time;
$\tau_{sr}$ - time needed for the tool change and adjustment of the tool [min];
$c_s$ - tool cost between two successive reshapings;
$c_{mat}$ – tooling allowance cost;
$c_e$ – cost of 1Kwh electric energy;
$K_e$ - energy coefficient [wh/min];
$K_M$ - machine-tool coefficient;
$C_M$ - machine-tool cost [Euro];
v – cutting speed [m/min];
s – feed rate [mm/rot];
t – depth of cut [mm];
α, β, γ – coefficients.
T – tool durability, given by the Taylor relation.

The necessary time, τ, for 1 cm$^2$ surface area machining is calculated by means of the formula:

$$\tau = \frac{T + \tau_{sr}}{10T \cdot v \cdot s} \text{ [min/cm}^2\text{]} \quad (3)$$

Using the above relations, the cost curve (Fig. 2.) and profit rate for three levels of the price - $P_1$, $P_2$, $P_3$ (Fig. 3.) can be drawn.

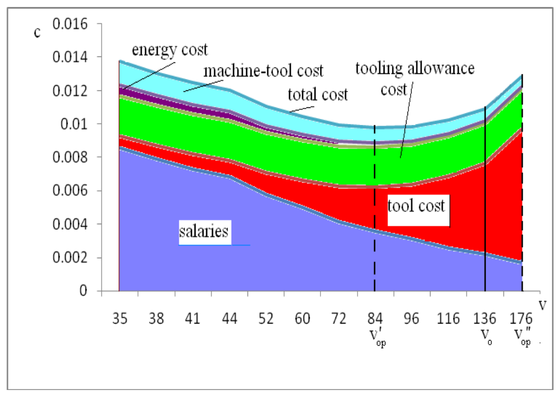


Fig. 2. Cost structure

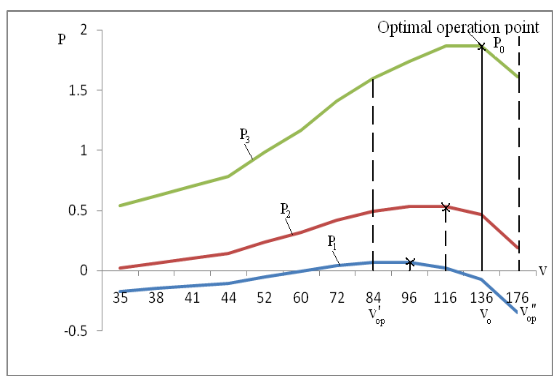


Fig. 3. Profit rate

where: $p_1$ = 0.0104 Euro/cm$^2$, $p_2$ = 0.0142 Euro/cm$^2$, $p_3$ = 0.0242 Euro/cm$^2$, $c_\tau$ = 0.45 Euro/min, $\tau_{sr}$ = 10 min, $c_s$ = 20, $c_{mat}$ = 0.008 Euro/cm$^3$, $c_e$ = 0.23 Euro/Kwh, $K_e$ = 150 wh/min, $K_M$ = 5400000 min$^{1/3}$cm, $C_M$ = 100000 Euro, s = 0.15 mm/rot, t = 3 mm, α = β = γ =0.5.

As shown above, by competitive management adaptation takes place, according to the principle of the exclusion to be found in Biology, of the manufacturing system for the purpose of profit maximization. To achieve adaptation, it is necessary to achieve modelling of the interaction between all elements of manufacturing system - market assembly, which shall be called behavioural modelling from now on. The term of behavioural modelling is introduced by the authors.

Behavioural modelling becomes increasingly complex as the number of interacting elements is growing too. By developing the concept of competitive management, the general architecture of competitive management systems shall be obtained, along with the general methods of implementing the concept.

## 4. DEVELOPING THE COMPETITIVE MANAGEMENT ALGORITHM TO BE APPLIED TO THE MANUFACTURING OF MECHANICAL CONSTRUCTIONS

The block schedule on which the competitive management algorithm is based is illustrated in Fig. 4.

The manufacturing system receives contracts after the tenders (competitions) generated by the market offer quotations. The competitive management system means competitiveness assessment, and based on it, an intervention on the manufacturing system through instructions regarding the progress of the manufacturing process in order to obtain maximum competitiveness.

On the other hand, after assessing competitiveness, the management system should enable to develop competitive bids for the tenders.

To achieve these two objectives, the competitive management system makes used the reinforcement learning to get to know the market and the non supervised online learning technique to get to know the manufacturing system.

As shown in 3., the behavioural system modelling is to be achieved, based on which the company management may intervene in order to elaborate the necessary instructions to adjust the technological process and elaborate the management policies.

Following each line of the competitive management algorithm in Fig. 4, the following can be noticed:

1) the algorithm for modeling the relationship market-manufacturing system implies using the data base from the economic environment (auctions), extraction of knowledge through data mining and model elaboration by reinforcement learning techniques;

2) to obtain the concrete indicators of competitiveness, database from the competitive environment shall be provided and knowledge shall be extracted in order to assess competitiveness;

3) the market offer quotations enter the competitive environment to generate the contracts for the manufacturing system;

4) the modeling algorithm of the manufacturing system is designed starting from the contract specifications and system identification. Using data mining techniques, data sets on the functional and economic parameters shall be obtained to be further used to obtain the model of non supervised learning techniques.

Based on the above learning processes the behavioural modelling of the manufacturing system - market assembly and the management system implementation are achieved.

The manufacturing system receives instructions on the development of the manufacturing processes in order to achieve the maximum level of efficiency (maximum profit).

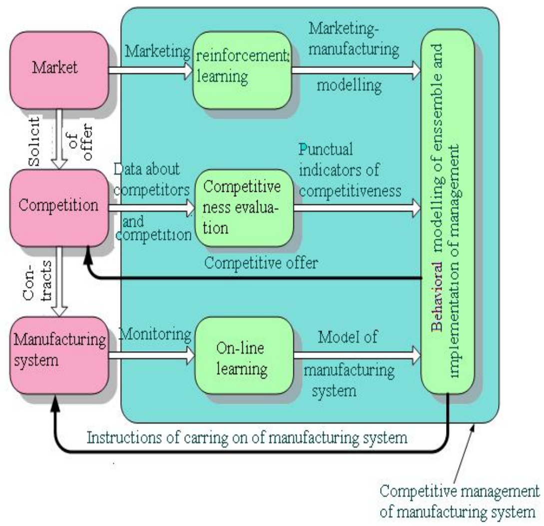


Fig. 4. Algorithm of competitive management

## 5. CONCLUSION

The present research contains a significant number of approaches, original techniques and methods, developed under a unitary concept. Out of these we can mention the following:

1. A new, original approach to the competitiveness issue in a company/enterprise by using modern methods of investigation that take into consideration all factors that contribute to ensuring, maintaining and increasing competitiveness of industrial enterprises;

2. It is developed a methodology for mathematical assessment of the technical-economic competitiveness of the manufacturing system;

3. It is developed a new concept of manufacturing systems management based on behavioural modelling of the market-manufacturing system assembly and on the implementation of the management to the manufacturing system, which is generally applicable and appropriate to the current market demands;

4. Using the reinforcement learning method to ensure enterprise adaptability to the market;

5. Development of behavioural modelling methods based on non supervised on-line learning, which enables adaptive-optimal and predictive control of the manufacturing systems.

## ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support of the Romanian Ministry of Education and Research through grant PN_II_ID_795/2008.

## REFERENCES

**[1] Chen, T.** *Evaluating the mid-term competitiveness of a product in a semiconductor fabrication factory with a systematic procedure,* Computers & Industrial Engineering, Volume 53, Issue 3, October 2007, pag. 499-513.

**[2] Cios, K., Pedryez, W., Siniarski, R., Kurgan, L. Wooldridge, J.** *Data Mining - A knowledge discovery approach,* Springer , ISBN 13-978-0-387-33333-5, 2007.

**[3] Epureanu, A., Virgil, T.** *On-Line Geometrical Identification of Reconfigurable Machine Tool Using Virtual Machining,* in Enformatica Journal, vol. 15, SPANIA, ISBN 975-00803-4-3, 2006.

**[4] Georgakopoulos, G. F.** *Chain-splay trees, or, how to achieve and prove loglogN-competitiveness by splaying,* in Information Processing Letters, Volume 106, Issue 1, 2008, pag. 37-43.

**[5] Koren, Y., Ulsoy, G.** *Reconfigurable manufacturing system having a production capacity method for designing and method for changing its production capacity*, in United States Patent, US 6, 349, 237 B1, 2002.

**[6] Lee, S. K., Mogi, G., Kim, J. W.** *The competitiveness of Korea as a developer of hydrogen energy technology: The AHP approach Energy Policy*, In Press, Corrected Proof, Available online 28 January, 2008.

**[7] Li, M.R., Chang, Y. L.** *On a particular Emden–Fowler equation with non-positive energy* $u''-u^3=0$*: Mathematical model of enterprise competitiveness and performance,* in Applied Mathematics Letters, Volume 20, Issue 9, 2007, pag. 1011-1015.

**[8] Christoph, H. L., Chick, S., Huchzermeier, A.** *Can European Manufacturing Companies Compete?: Industrial Competitiveness, Employment and Growth in Europe,* in European Management Journal, Volume 25, Issue 4, August 2007, pag. 251-265.

**[9] Özbayrak, M.** *Activity –based cost estimation in a push/pull advanced manufacturing system,* in International Journal of Production Economics 87 (1), 2004, pag. 49-65.

**[10] Rooney, A.** *Handbook on the knowledge economy,* Cheltenham: Edward Elgar, ISBN 1843767953, 2005.

**[11] Stewart, R. A.** *IT enhanced project information management in construction: Pathways to improved performance and strategic competitiveness,* in Automation in Construction, Volume 16, Issue 4, July 2007, pag. 511-517.

**[12] Wang, M., Wang, H.** *From process logic to business logic- a cognitive approach to business management,* in Information &Management, 43, 2006, pag. 179-193.

**[13] Wooldridge, J.** *Introductory Econometries: A Modern Approach,* Mason:Thomson South-Western, 2003.

**[14] Yeo, G.-T., Roe, M., Dinwoodie, J.** *Evaluating the competitiveness of container ports in Korea and China Transportation Research Part A: Policy and Practice,* In Press, Corrected Proof, Available online 14 February 2008.