DOI: 10.37394/232024.2022.2.5


# About the Order Fulfillment Stage of the Manufacturing System

# Part 1

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*Abstract:* - Competitiveness fully and synthetically characterizes the viability of an enterprise. In the economics literature competitiveness is analyzed in particular in economic and managerial terms with almost no insight into the analysis of the technology role in ensuring and developing competitiveness. Hence the need for manufacturing systems based on behaviour modelling and on line learning. The behavioural approach is based on a continuous awareness of the situations and decisions in real time on activities. Thus it can provide solutions to make manufacturing systems develop and be competitive. From theories of knowledge and complexity, we can design a flexible system that will lead to manufacturing processes, flexibly responding to any environmental demand. The behavioural management is characterized by the ability to perceive the environment, to take decision in time, as a result of interaction, with no specific procedures. The system environment provides on-line data on the actions undertaken which, properly analyzed and correlated, will further generate solutions in order to develop said system and make it competitive. The paper aims, in the field of manufacturing technologies, at approaching issues of manufacturing systems, in order to develop a new concept of management, which is in line with the current market dynamics: the concept of competitive management. The concept of competitive management can offer solutions even to make competitive and develop enterprises as a whole. However, improving competitiveness is not a short-term process of exploiting advantages, but appears as a complex process of establishing and sustaining an economic structure based on capital investment, on research and knowledge, on development and innovation.

*Key-Words:* - competitiveness, manufacturing system, behaviour modelling, competitive management, knowledge based economy, on-line learning.

## 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 [14]. 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 of the current orders, leading to the design of small series production

ii) 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 the efficient management of the manufacturing system 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 this global challenge the scientific community responds by a new conceptual paradigm, which in this case is the knowledge- based economy (KBE)**,** [15].

Thus, in the U.S., this new orientation is considered a strategic priority, as results from [16], and the Lisbon European Council [17] has marked the EU objectives for the most competitive and dynamic 'knowledge based economy' in the world. The need to adapt technology to the knowledge society is reflected in the EU research projects in order to strengthen the competitiveness of European economy and its technological power. In addition, the concept of eEurope was launched intended for development of information technologies, for and beyond 2010, and integration of knowledge based society and economy.

This paper is related to manufacturing system management, so as to maximize their technical and economic performance. The proposed performance indicator for the management of these systems is to be both holistic (in the sense that it takes into account not only the economic but also the technical performance) and synthetic (in the sense that it reflects key aspects of the manufacturing system functionality, namely those that are closely related to the reason for which they were created). In the paper, the competitiveness is considered an indicator, both holistic and synthetic, of the technical-economic performance and is used as a criterion for the management of manufacturing systems. 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 structured 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 batches, but not in mass manufacturing, when all of the technological components of manufacturing system remain unchanged for a long time.

In the world three conceptual approaches in the field of manufacturing systems management are known.

- The first approach is based on Petri network, which aims at optimally ordering in time the technological operations that the system has to execute. Although it is well known and applied, this approach does not lead to a significant increase in efficiency, because it completely ignores the actual product manufacturing process, considering that the data about this process as permanently constant [1], [25].
- The second approach is based on the holon structuring of the manufacturing systems, which, like the first, completely ignores the process [9], [10], [11], [12], [13], [18] [31]. Although not yet applied in industry, experimental implementations of [10] and analysis of results reported in literature (which are comprehensively presented in [11]), show that it could be applied only to higher levels of process-machine systems (for example at department or enterprise level) and especially in auxiliary issues (such as inter-operational transport, off-line quality control or others).
- A third approach is based on the flexible integration of the system components, which led to the concept of reconfigurable manufacturing system, developed since 1999, by Prof. Yoram Koren from the University of Michigan (Ann Arbor), [12] and considered in many research centres in the world (such as Porto-Portugal, Germany-Hanover, Leuven-Belgium, to give a few examples). The management is exclusively technical and is based on numerical control. No economic issue is taken into consideration. Researchers' interest is oriented only towards the reconfiguration aspects, especially hardware and software, and control reconfiguration.

Our new concept seems to be important because: i) the competitive management of the manufacturing systems meets the demands generated by the extraordinary dynamics of both industry and business environments, which is regarded as the present-day big global challenge ; ii) the way of managing that will be developed in the paper has four key attributes - is on-line, adaptive, optimal and predictive – which means that it obviously implements the new conceptual paradigm by means of which the scientific community responds to the challenge, i.e. the knowledge- based economy, and, moreover, iii) our approach is comprehensive, because it considers both technical issues (related to the process), economic ones (related to cost and time) and also commercial issues (such as price, market competition) and finally, iv) the system of competitive management, proposed in the paper may be, without any difficulty, generally implemented beyond the approaches outlined above, as it operates with its own elements, alone.

## 2 Manufacturing system competitiveness

In order to survive in the present-day complex and unpredictable environment, the company must feature abilities of quick response [18] and favourably 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.

According to the literature, a company is competitive on a certain market when it succeeds to reach, 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 [2], [3], [4], [5], [6], [7], [8], [19] show that, today, competitiveness is defined by the economic factors and indicators obtained and is more a suggested/induced notion than a numerically evaluated one. In the world there are prestigious competitiveness research centres, such as: Center for International Development-USA Harward University, European Institute of Technology with its research center in Cambridge, Geneva, Oxford and Organizational Competitiveness Research Unit of Sheffield University Halle-UK which deals with competitiveness at the global, regional down to enterprise/company level.

However, 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- economic competitiveness and the management of the manufacturing system is performed to obtain maximum competitiveness.

The manufacturing system performance depends on how it is run. In more specialized papers [20], [21], reference is made to the relationships between the parameters of the processing regimes and the technical performance of the manufacturing system (purely technical aspects), while in others, equally numerous [14], [15], references are made to the relationship between the product made by the manufacturing system and the market (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 [5], [23], [24] and tools of economic management of the relationship between the enterprise as a whole and the market [7], [8], [9], [15].

Nowadays, the manufacturing systems are controlled by means of numerically programmed machine tools which are part of the system [23], [24]. The control is exclusively technical because there is no economic variable, although this is actually the ultimate goal of any processing process. 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 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 [25].

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 [13].

# 3 Key ideas

Key ideas the paper construction is based upon at 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 an 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 based 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 (publication), to be applied.

The circuit is too long and knowledge reaches the manufacturing system late and indirectly. The project 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. Manufacturing system behaviour 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 management of the manufacturing systems will be developed based on behaviour modelling, which will describe the interaction between elements (technological system, manufactured products, the market).

# 4 Technical-economic modelling of the manufacturing system

The technical-economic model of the manufacturing system is shown in Figure 1.

The competitiveness is assessed by profit rate of the manufacturing system, $P_{max}$.

Analyzing Figure 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 *Rc* and the productivity curve, *q* has a maximum point for which the process intensity has the value *Rp.* Because analytically, *Rc* is different from *Rp*, it follows that it is never possible to simultaneously achieve minimum cost and maximum productivity.

The question arises: to achieve a profit as higher as possible, which is the best way to produce? more and costly or less and cheaper, because more and cheaper, as seen in Figure 1, is not conceptually possible. To answer the question, let us follow the spatial evolution of the maximum profit rate (*Pmax* curve), depending on product price *p*, and the intensity process, *R*.

Let us consider two levels $p^{(1)}$ and $p^{(2)}$ of product price. The researches conducted by the authors have shown that, as product price *p* is higher, productivity becomes more important (*q* curve) than the cost (curve c) and therefore the optimal process intensity (that for which the profit is maximum) is approaching (asymptotically) the *Rp* point (follow the route $p^{(1)}$-*E*-*B*- $P^{(1)}_{max}$), which represents the process intensity for maximum productivity (without ever reaching it!).

For $p^{(2)}$ value of product price (which is lower), the cost becomes more important and the optimal process intensity is approaching the point *Rc* which is the process intensity corresponding to the minimum cost $c_{min}$ (follow the route $p^{(2)}$-*D*-*V*-$P^{(2)}_{max}$). In both cases, the maximum profit rate takes the values $P^{(1)}_{max}$, $P^{(2)}_{max}$, respectively. In limit case, when 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 *Rc* (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 product price between the *Rc* and *Rp* limits without reaching any of them.

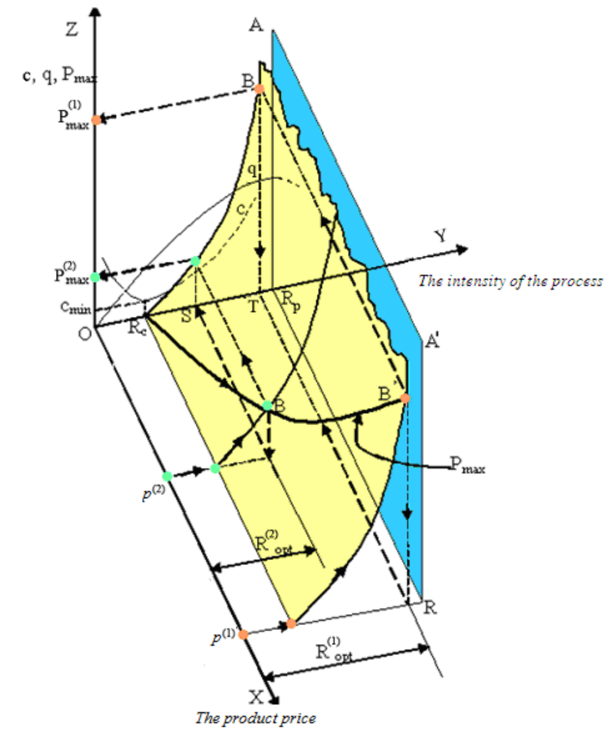


Fig. 1. Curve of maximum profit

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

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

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:

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

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 reshaping;
$c_{mat}$ – 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:

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

## 5 Conclusions

We propose to give managers a model so that they can interact with the economic environment (market). 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. Develop a methodology for mathematical assessment of the technical-economic competitiveness of the manufacturing system.

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