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# Modelling Technical and Economic Parameters in Selection of Manufacturing Devices

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***Abstrakt* – Sustainable science and technology development is also conditioned by continuous development of means of production which have a key role in structure of each production system. Mechanical nature of the means of production is complemented by controlling and electronic devices in context of intelligent industry. A selection of production machines for a technological process or technological project has so far been practically resolved, often only intuitively. With regard to increasing intelligence, the number of variable parameters that have to be considered when choosing a production device is also increasing. It is necessary to use computing techniques and decision making methods according to heuristic methods and more precise methodological procedures during the selection. The authors present an innovative model for optimization of technical and economic parameters in the selection of manufacturing devices for industry 4.0.**

***Keywords* – Manufacturing Devices, Technical and Economic Parameters, Industry 4.0.**

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## 1. Introduction

The development of technology, in particular electric drives, tires, hydraulics and electronics, has enabled construction of single-purpose machines with a high degree of concentration of technological operations. In addition to increasing productivity, such machines also deliver higher production quality due to the elimination of component clamping.

An increased level of technology can be used to create combined automatic machines that combine several technologies. There were constructed, for example, multi-position carousel lathes which also perform induction hardening of components. In practice, devices work successfully that combine chip machining, welding and metal deposition on the surface of a component.

Modular single-purpose machines are used in a perspective. The new concept is based on use of small standard mechanical, hydraulic and pneumatic units which are separate machines and provide technological processing. An integrating element of the modular machine is a device for clamping and transporting components. Transporting devices operating in rotation (rotor and drum configurations) and in a linear manner are very widespread. An advantage of the modular construction of the single-purpose machines is a reduction of machine costs, a shortening of the development and realization of the single-purpose machine as well a possibility of re-utilization of some units.

The highest degree of integration is achieved by single-purpose machines equipped with automated operating devices and central computer control.

The further projected development of single-purpose machines in connection with Industry 4.0 will mainly be related to creation of new structures of highly automated production lines and integration of technological, handling and control functions which will also be transferred to economic parameters [1], [6].

A program management of production machines has a special meaning in practical conditions with a predominant unit and small-lot production. This enables to solve important tasks such as: increasing labour productivity, a quick switch of the machine on new products and introducing high-productivity manufacturing device under small-lot and unit production conditions.

## 2. Development trends in industrial production

The trend of the current development in all areas of economic activities is an intensification of mutual corporate transactions and new quality of deployment of resources on the global market territory. The driving forces are those aspects [2],[3]:

- Transition from regional to global markets.
- Increasing openness in flow of capital, know-how, people.
- A phenomenon of relocating production to customers or to favourable conditions.
- An international standardization of business parameters.
- A possibility to compensate local turbulence.
- Practice of clustering companies and creating strategic partnerships.
- A trend of improving the production in terms of the environment and technical level.

Benefits of globalization in general are:

- Broadening economic scale.
- Diversity and a customer approach.
- It overcomes protection (customs, import limits, etc.)
- It balances different timing of innovation cycles.
- It enriches system with the best experience from the regions.

## 3. Approaches to selection of production devices

When selecting production devices, it is necessary to clarify the overall concept of the production technology. A degree of detail of the technology depends on whether the selection of the production devices is done:

- When creating the technological process in existing production.
- When solving technological project of a new or reconstructed, or modernized production.
- When renewing production devices.

As minimum input data for the selection of production devices, consideration should be given to:

- A production program and a production volume.
- Determination of methods and structures of technological processing, handling and management.
- Technological and organizational structure of production, specified in particular by series, degree of automation and flexibility.

At present, there are elaborated general methodological principles that can be assigned to certain types of production devices in a frame in a specified manner. In category of production machines, the assignment is based on the nature of component base, a degree of production series and degree of automation.

In the category of industrial robots and other handling devices, the assignment is based on the nature of material flow, dependence on technological devices, flexibility and degree of automation.

In the category of control devices, the assignment is based on a hierarchy of control functions and dependence of technological and handling devices.

A specific approach is required if individual production devices are a part of production complexes, in particular:

- Production lines.
- Integrated production departments.
- Flexible production systems.
- Robotic systems.
- Integrated computer-generated production groups.

In this case, priority is given to mutual compatibility of production devices and their classification into generational development classes. A high proportion of the production means applied in production clusters is currently mainly in manufacturing of higher grades.

In the perspective of the choice of types of production devices, it is important to have a dynamic approach to determining selection parameters for their detailed analysis and appropriate extrapolation [2],[9].

There is an assessment of the parameters of production devices systems which determine the nature of production operations and stimulate the introduction of progressive technological principles and production structures mainly with a higher degree of automation in the forefront of interest.

## 4. Methodology of selection of production devices based on analysis of technical parameters

From the point of view of assessment of production devices and systems, an analysis of the so-called metrics which in addition to traditional parameters, also operates with rarely used parameters, is important. In the forefront of interest an assessment of the parameters of the production means and systems that determine a nature of production operations and stimulate an introduction of progressive technological principles and production structures, in particular with a higher degree of automation, flexibility and intelligence [2], [5],[6].

In the solution, it is advantageous to start from the so-called technological and system concept of production means and systems according to the model in Fig.1.

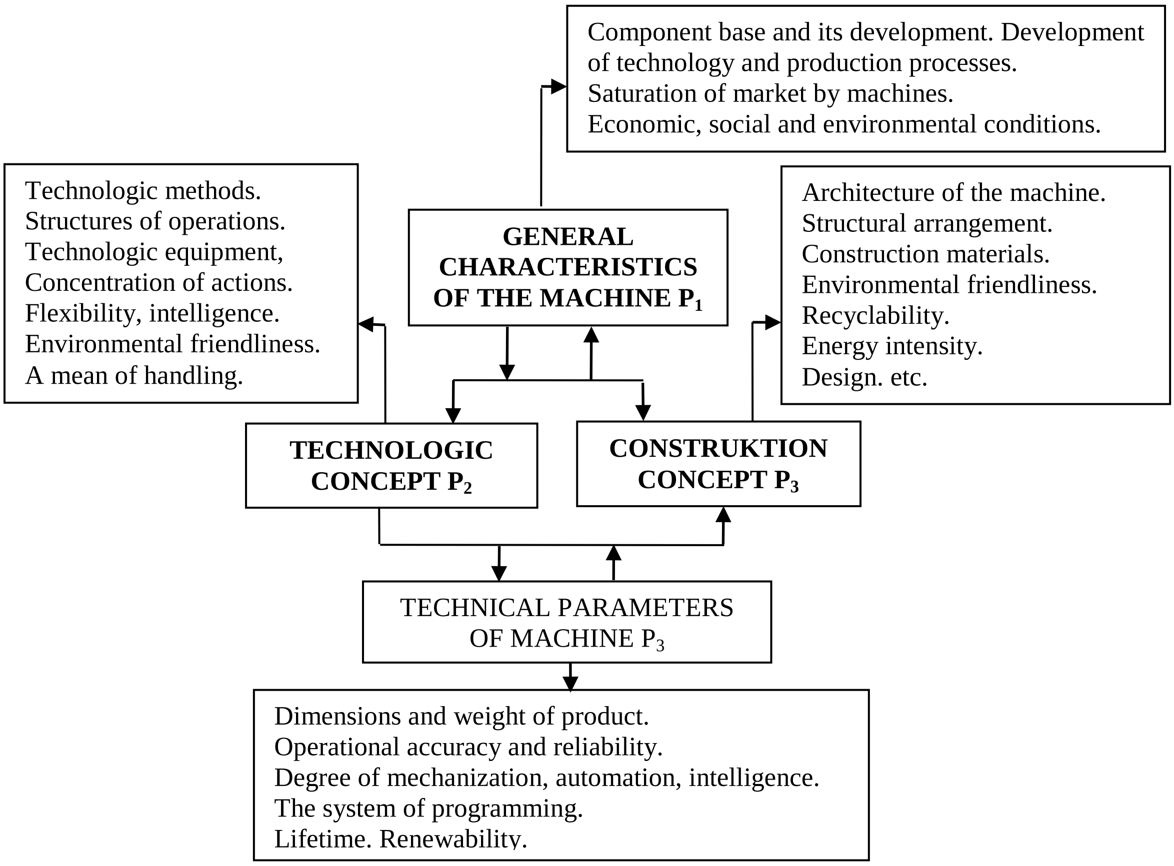


*Figure 1. Selection of technologic and system concept of production means*

In the proposed approach, production means and systems are characterized by sets of parameters that evaluate them not only from a construction aspect, but also from a functional, structural, environmental or from another point of view. The following levels can be recommended:

- Basic parameters describing external system environment, e.g. social, economic and environmental conditions, availability of resources and systems of the given category, etc.
- A technology concept that characterizes basic user features of the production means and systems and their immediate link to active elements of the manufacturing process.
- A design concept indicating basic features from the point of view of the maker of the production means and systems and their manufacturers.
- Detailed technical parameters that specify the previous quantitative data.

It is possible to recommend an analysis based on the parameter that most influences its function while other parameters are analysed at a level of limiting conditions, for practice. In particular, technological requirements linked to production and technological operations with the technical characteristics of production means and systems are to be compared [2].

It is advantageous to formulate a set of technical and technological possibilities of the production system G whilst its elements are sets of limiting conditions according to the selected parameters ($G_i$).

$$G = \{G_i\}, \quad i = 1,2, ..., n$$

Where:

i- parameters of the production device
n- the number of considered parameters of the selection
$G_1$- a set of applicable technological methods
$G_2$- a set of applicable technological structures
$G_3$- maximal dimensions of the product
$G_4$- permitted dynamic effects of the product (kinetic energy)
$G_5$- permitted statistical effects of the product (weight of the product)
$G_6$-construction and technological parameters
$G_7$- accessories and special devices (tools)
$G_8$- achieved quality of technological processing
$G_9$- economically acceptable number of pieces of products in a batch
$G_{10}$ - environmental performance

Typical product data (e.g. geometric shape, position of functional surfaces, dimensions, tolerances, additions, material, surface layer condition, required surface quality, etc.) and data on production method and structure are important for selection of suitable types of the production means [8].

When using a system approach, it is also necessary to focus on new parameters of production system metrics, such as:

- Ability of the system to survive changes. It depends on a degree of adaptation of the system to new conditions - intelligence. An ability to change elements, linkages, structure, behaviour without interrupting major functions is represented.
- Minimum of the system. It characterizes achievement of objectives in relation to minimization of resources, functional elements and links (JIT systems).
- System reality. It expresses a likelihood of achieving the set objectives over time.
- A level of structuring. It expresses an assessment of system-building relationships. A strong system is characterized by strong dependence a part on the whole.

A detailed analysis of the technical parameters of the types and typos of the production devices is linked to determination of the particular type of the production device based on general production conditions. It is recommended a selection of a type of production device based on the parameter that most influences its function while other parameters are analysed at the level of limiting conditions. According to the mentioned sets and limitations, an algorithm for the selection of the typos of the production machines can be compiled (Fig. 2).

The algorithm is generic and it can be used both in a classic way of designing technological processes and in the automated way on a computer [7].

The selection of suitable types of production machines is based on component data (e.g. geometric shape, position of functional surfaces, dimensions, tolerances, additions, material, surface layer condition, required surface quality, etc.) and on a proposed method and structure of technological processing. An own selection of suitable typos will be carried out by sequentially comparing the suitability of each machine parameter. This methodology gives good results when selecting suitable types of production machines, provided that the selection parameters will be adjusted to specific conditions of the production unit. In new production projects and in modernization and reconstruction, the selection parameters should be expanded in particular by:

- A degree of automation.
- A degree of flexibility.
- Reliability.
- Working life.
- Level of control.
- Software.
- Requirement of best available technique (BAT).

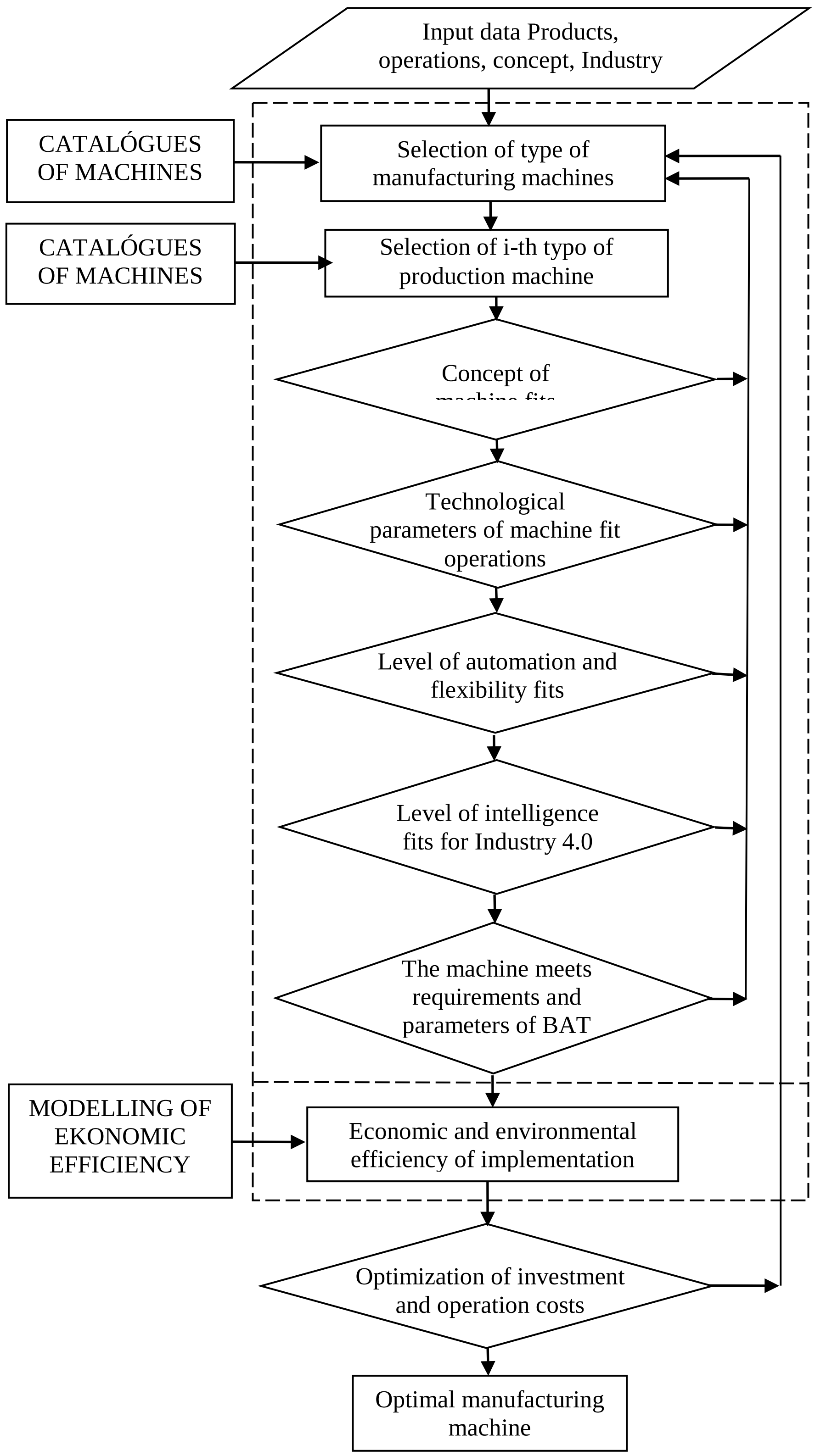


*Figure 2. Algorithm of selection of manufacturing machine*

## 5. Economic efficiency of the selection of production devices

The basis for an economic assessment of selected machine options is the costs of manufacturing a type product ($N_0$) per this machine. They can be easily identified from the formula:

$$N_0 = N_m + \sum_{i=1}^{n} \left[ N_z \ (1 + 0{,}01\, N_r) + N_{ost} \right] \quad (1)$$

$N_m$- costs for material
$N_z$- wages of employees
$N_r$- overhead costs

$N_{ost}$- other production costs
n- number of technological operations

In the total costs, a classical production is most marked by wages of the workers on the shop floor. Other costs components can be included in overhead costs in rough comparisons [4].

An important factor determining economics of production is the cost of production means and systems and technological rationality of their construction. Rationality is expressed by degree of complexity of production and assembly. In decision making, it is necessary to orientate, as far as possible to production means and systems, with high productivity and minimal production costs.

Comparing economic efficiency of two different variants and the other means linked to them can be done by comparing the costs of producing a complex of type products through an economic efficiency ratio – $k_{ef}$.

$$k_{ef} = \frac{N_1}{N_2} \quad (2)$$

$N_1$ – costs of producing type products option 1
$N_2$ - costs of producing type products option 2

In a case one-off (investment) costs of one option are higher and the own production costs are lower, the economic efficiency of the production device is determined by comparing savings to its own production costs with one-off costs:

$$k_{ef} = \frac{N_1 - N_2}{I_2 - I_1} \quad (3)$$

where:

$N_1$-$N_2$- the difference in own production costs (annual savings)
$I_2$-$I_1$- the difference of one-off (investment) costs
$K_{ef}$ = 0.15- neffective devices (payback time is greater than depreciation time)
$K_{ef}$ = 0.4- economically effective devices
$k_{ef}$ = (0.4 – 0.125)- bound effective devices

Costs of research, development, production and prototype testing are also included in the one-off costs for determining cost-effectiveness of the devices.

From the economic efficiency ratio, the payback time (D) of one-off costs can also be determined:

$$D = \frac{1}{k_{ef}} = \frac{I_1 - I_2}{N_1 - N_2} \quad (4)$$

When comparing more options of production devices, the economic efficiency needs to be judged under the condition:

$$( N_i + k_{ef} I_i ) = \min$$

When introducing innovated production devices into production (economically and environmentally more productive, more accurate with a higher degree of intelligence), it is necessary to determine the so-called economic price of production device.

The economic price of the production device is a limit that cannot be exceeded under the given production conditions:

$$C_n = \frac{Q_n (k_1 + k_2)_s \; . \; k_{3s} (N + k_{ef} I)_s}{Q_s (k_1 + k_2)_n \;\; k_{3n} (N + k_{ef} I)_n} \, . \, C_s \quad (5)$$

where:

C- costs of acquisition of the device (eur)
Q- production equipment production (pieces/h),
N + $k_{ef}$I- costs for operating the device (eur/h )
$k_1$, $k_2$ , $k_3$- correction coefficients assessing the performance of the production device (accuracy, environmental friendliness, degree of automation)

$$\frac{C(k_1 + k_2)\, k_3 \, (N + k_{ef} I)}{Q} = const. \quad (6)$$

Index s- values for obsolete production facilities
Index n- values for an innovated manufacturing facility

## 6. Conclusion

The proposed model of the technical, economical and environmental assessment of the options of the production devices in their production can be considered sufficient if the devices are at the same level. When evaluating devices with significant technical level differences (degree of automation, flexibility, intelligence, mobility, etc.), the economic assessment should be extended by other relevant indicators such as:

- Shortening the production run time (reduction in the volume of inventories inherent in inventories of incomplete production).
- Reduction in the number of workers on the shop floor (the profit that released workers can make).
- Increasing use of production devices by shortening preparatory times in transition to new production tasks and increasing the value.

- Reducing production preparation costs.
- Improving production quality by eliminating impact of human factor.
- Higher production flexibility economized by improving product sales, etc.

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