Determining the Economic Effect from Automation in Production

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Abstract: The article is about determine the economic effect from automation in Production. The transition from current engineering to the complex automated and highly mechanical production is inevitable. The problem is mainly in the organization of such process grandiose by its nature so that no social aspects contravened the economic ones. Declarations that mechanization and automation are important instruments to eliminate manual work are often one-sidely explained. Automation is understood to be the process of making a man free of its participation in servicing any production instruments that basically remain unchanged.

Key words: automation, economic effect, productivity and reliability, competition

Introduction

Declarations that mechanization and automation are important instruments to eliminate manual work are often one-sidely explained. Automation is understood to be the process of making a man free of its participation in servicing any production instruments that basically remain unchanged.

1 Determining the Economic Effect - Methodology

Lots of failures to automate production processes can be explained by the fact that when designing, the attention was paid to the development of mechanisms and devices that were supposed to substitute human activity. Whereas the question of production quality, productivity and reliability were not taken into consideration. That resulted into the development of such mechanisms that are not competitive on demanding foreign markets. Therefore the knowledge of economic regularities is especially timely for the companies and business entities when decision-making on the modernisation of production.

Economic effect from automation is only possible when:

- increasing the productivity of production,
- improving quality,
- decreasing work expenditure on service.

Non-automated and automated production are both possible to be qualtitatively compared by following characteristics (related to production per unit):

- by proportional amount of quality products to total amount of products – index of proportional increase in share of quality products:

$$\Delta = \lambda_2 - \lambda_1 \tag{1}$$

where λ_2 and λ_1 are index of quality products share in automated (2) and non-automated (1) production.

- by absolute amount of quality products produced within one technological equipment unit per time unit:

$$\frac{p_2}{p_1} = \varphi' \qquad \frac{\lambda_2}{\lambda_1} = \varphi \tag{2}$$

where φ' an φ are index of proportional increase in the productivity of total and quality production,

p_1 and p_2 – productivity of non-automated and automated production unit (piece. $\min^{-1}$),

- by number of servicing workers and their wages – index of proportional decrease in the number of workers:

$$\varepsilon = \frac{M_1}{M_2} \tag{3}$$

where M_1 and M_2 is annual wage-fund for the service of a production facility unit in consideration with shifts in consideration as well as all sorts of extra pays in non-automated and automated production (€/ $year^{-1}$),

- by the price of production resources (basic technological equipment, auxiliary equipment, managing resources etc.) – the index of proportional increase in the price of equipment:

  $$\delta = \frac{k_2}{k_1} \tag{4}$$

  where k_1 and k_2 is the price of production resources and non-automated and automated production.

If the implementation of *automated equipment to production* (semi-automated machines and automated machines, automated production sections and lines) does not satisfyingly increase the quality of production $(\Delta \leq 0$ and the increase in productivity $(\varphi \leq 1)$, consequently purchase costs will be higher and can not be paid $(\delta$›1). In other words, reached social effect expressed by decrease in service work expenditure (ε›1 is always effective at automation) contravenes economic results. This implies that in the given case, the technical economic conditions for automation are insufficient or that the process of automation is just being in progress.

For a producer, the criterion of effective investment into a new technology can be the *annual economic effect E* known as the division of costs into compared alternatives. If the annual economic effect is defined by the index of non-automated production and aforementioned technical economic index, we get:

$$E = k_1(\varphi - 1).(E_n + \alpha_1 + \alpha_2) + M_1\,(\varphi - \frac{1}{\varepsilon}) + m_1\varphi(1-\delta) + \Delta M_s p_1 \tag{5}$$

where:

E_n - is normative index of effectiveness of investments to a new technology,

α_1 - index of annual write-offs,

α_2 - index of operating costs (share of annual costs on repair and maintenance to the mechanism price),

m_1 - annual costs on tools, electricity, auxilliary material in non-automated production,

δ - index of proportional costs on tools, electricity etc. related to a production unit,

M_s - price of raw material (semi-products) related to a production unit.

Technical instruments in non-automated production (for example universal machines with manual control) have certain *inovation index* – improvement od characteristics φ, λ, ε reached by modernisation, improvement of utilization etc. The possibilities are not very big becasue a worker remains the immediate participant of a technological process. Only automation of technological process, implementation of automated production machine allows to significantly increase the quality of production and its productivity and to decrease the number of service attendants.

It is necessary to follow the dependance of annual economic effect on all the three elements and keep on thinking on the costs of automation. If the result of automation is the decrease of operators (ε ›1) while the amount of productivity is unchanged (φ=1) and the quality of production is the same ($\gamma_2 = \gamma_1, \Delta = 0$), then the economic effect is very small. (Tab. 1, Figure. 1)

φ=	2,2	2,0	1,8	1,6	1,4	1,2	1,0
ε	φ=2,2	φ=2,0	φ=1,8	φ=1,6	φ=1,4	φ=1,2	φ=1,0
1,0	42,05	35,63	29,21	22,80	16,38	9,97	3,55
1,1	44,77	38,36	31,94	25,53	19,11	12,69	6,28
1,2	47,05	40,63	34,21	27,80	21,38	14,97	8,55
1,3	48,97	42,55	36,14	29,72	23,31	16,89	10,47
1,4	50,62	44,20	37,79	31,37	24,95	18,54	12,12
1,5	52,05	45,63	39,21	32,80	26,38	19,97	13,55
1,6	53,30	46,88	40,46	34,05	27,63	21,22	14,80
1,7	54,40	47,98	41,57	35,15	28,73	22,32	15,90
1,8	55,38	48,96	42,55	36,13	29,72	23,30	16,88
1,9	56,26	49,84	43,42	37,01	30,59	24,18	17,76
2,0	57,05	50,63	44,21	37,80	31,38	24,97	18,55
2,1	57,76	51,34	44,93	38,51	32,10	25,68	19,26
2,2	58,41	51,99	45,58	39,16	32,75	26,33	19,91
2,3	59,00	52,59	46,17	39,75	33,34	26,92	20,51
2,4	59,55	53,13	46,71	40,30	33,88	27,47	21,05
2,5	60,05	53,63	47,21	40,80	34,38	27,97	21,55

Table 1

Economic effect from automatization

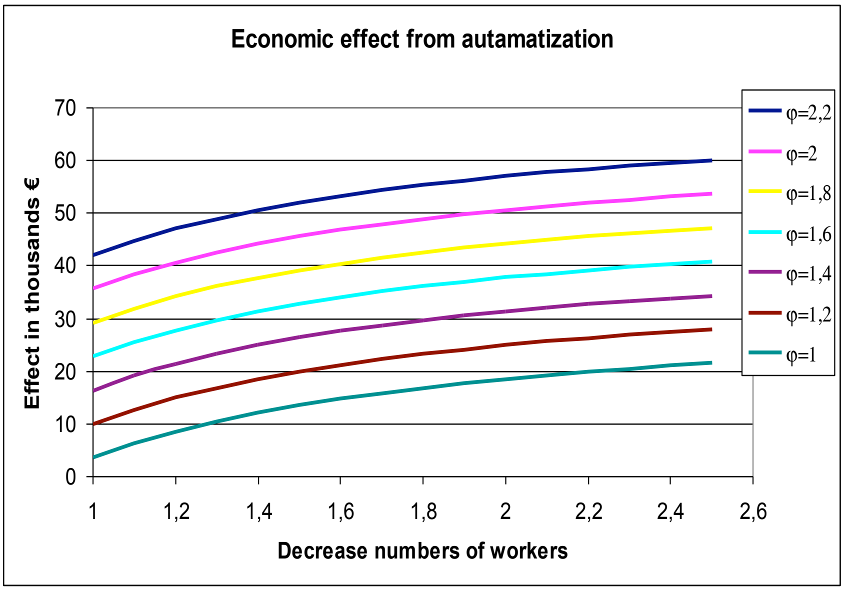

Figure 1
Dependance of annual economic effect from automation on the decrease of operators and on the increase in machine productivity

The higher price of automated mechanism (control devices), the smaller (when other conditions unchanged) economic effect. At optional concrete combination of reached technical characteristics (φ, ε, Δ), there is always maximum approved price of a machine ($\sigma = \sigma_{max}$) at which the economic effect equals zero. The increase in costs over the approved limit ($\sigma \geq \sigma_{max}$) leads to the situation when more complicated sets of machines are little effective and the economic effect is in contradition with the social one.

Before, the abovementioned relation evaluates the importance of each element to achieve goals of the economic effect. For example, if the price of automated devices is 1.5 times higher than the price of non-automated devices and when automated devices are put into practise, the productivity will increase doubly, the need of manpower will decrease doubly and the share of quality products will increase in 5% (it means φ=2, ε=2, Δ=0,05), consequently the calculation due to the introduced relation shows, that the final economic effect is made of increase in productivity by 71%, decresse in using manpower by 15% and the improvement in quality by 14%. Relatively little effect from the increase in quality of production can be explained by the fact that in the conditions of mechanical production the percentage of faulty pieces is relatively little (quality products´ share is 85 – 90%) and that is why the possible excess is $\Delta_{max} = 0{,}05$ to 0,1.

Analogously, we can state that if automation with triple increase in costs increases productivity 3.5 times, decreases the amount of service twice, improves the quality by 5% (it means φ=3,5, ε=2, Δ=0,05), up to 88% of total economic effect is achieved by the raise in productivity.

2 Discuss about mathematical of application

Complex calculations realized in a wide range of standardized conditions in machinery industry show that the results are regular and the most important source to obtain the economic effect when implementing automation is the decrease in the number of operators and the increase in productivity. Both the effects are reached by the *stimulation of technological processes,* especially by covering operations and by acceleration of additional processes when applying a new technology.

Automation and mechanization are both complex contructional technological task that results in the development an the implementation of a new technology that on principle differs from the technology used in non-automated production. In the conditions of non-automated production the technological preparation of production consists mainly from working out technological processes by the means of appropriate production facilities with traditional methods and practices.

Technological preparation in automated production requires to work out new technological methods and processes with the use of covering operations, their differencies and concentrations regardless technological system of machines that in a moment given, is usually not available. *Automated technological sets* usually contain technological and additional machines and developed systems of automated control mainly different from universal machines. Their designing requires to deal with automation of essential technological and additional processes and control processes complexly. An automated technological set with multiple-pole and multi-machine sets have the highest efficiency and that enables to machine tenths of components by tenths of machines at the same time. Develpment of automated technological sets is associated with significant varibility of construction solutions, especially in the beginning of designing (technical task and technical proposal) when principal project solutions and structural schemes are being chosen.

Automated systems to machine the same work-piece can be differed by methods, by a procedure, cutting conditions, the degree and the character of differenciation of technological procedure, the number of opeator positions, by the type of production facility and the degree of its unification, by the sort of transport system, by control system, the number of machines – twins etc.

When solving concrete construction tasks, many technologically realizable and engineering carefully worked-out alternatives arise and those can differ in costs, surface, productivity and reliability. They can be the source of choosing the alternative for future designing in the stage of technological designing.

Other stages of designing automated production differ from the non-automated one, too. In the case, not only traditional technological mechanisms, devices must be worked out, but on principle also new mechanisms for transportation, orientation and elimination of waste, devices and control systems.

When making provision for specifications of automated production systems, it is necessary to deal with *scientific technological basis of complex automation.* Scientific technological basis of complex automation is knows as the set of mutually connected scientific tendencies that have their own scientific methodical basis and mathematical apparatus. It mainly concerns:

- Theory of controlled technological processes that deals with questions of differential and concentration of operations, adaptive control of technological conditions etc.,
- Theory of productivity of machines – automatic machines and their systems,
- Theory of reliability of machines – automatic machines and their systems,
- Engineering theory of technical economic efficiency of automation,
- Theory of functional and structural analysis of automated production,
- Scientific basis of calculation and construction of automated mechanisms and devices according to the speed and reliability standards,
- Theory of automated control and regulation as the scientific basis for machine control system,
- Theory of optimal machine designing – automatic machines and their systems,
- Scientific basis of highly effective exploration.

Important criteria to accept a technological solution when implementing automation are indicators of productivity, reliability and economic efficiency. Attribution to the increase in productivity is the basic source of economic effect.

The level of reliability is the important factor on which the real value of technological, economical and social effect is dependant when implementing automation. The more often stoppages and longer time for their elimination, the higher work expenditure on technical service and the lower utilization of a device. That is why the level of reliability has the direct impact on all the sources of economic effect. The lower indicators of reliability, the lower productivity while technological and constructional parametres unchanged, thus when indicators of reliability are low, the production of technologically difficult and expensive automatic devices is significantly lower than when usual devices are used, and at the same time the number of workers increases.

When making provision for all the successes so far in the sphere of increase in lifetime and reliability of machines, the problem can not be considered definitely solved because continually with the development in case of new, more perfect mechanisms, devices and control apparatus, the demands increase continually as well. On one hand, the increase is conditioned by constructional complicacy of machines and devices, the increase in number of continually working devices, mechanisms and control apparatus, and on the other hand there is the progress in technology, stimulation of machining and other factors increasing the intensity of machine work.

The fundamental orientation of the theory of machine (automatic machine) reliability is in the monitoring constructional elements function of machines and their systems while considering various interactive impacts of environment. The important task is to *elaborate mathematical models* of interaction of machines and devices reliability indicators with the indicators of productivity and economic efficiency. Practical orientation of the reliability theory is based in the elaboration of calculation methods and designing from the point of reliability with bringing it to such a level as kinematic and strength calculations.

The initiatory stage of formation the theory of reliability characterized the development of scientific-methodical basis that are based in the elaboration of statistical methods of describtion of stoppages in concrete technological systems. It results in qualitative indicators of reliability and their relations. When sorting out similar problems, the approximation was made. The theoretical basis of reliability is in this first stage of the theory of probability and mathematical statistics and related theories (theory of mass control, correlation of random functions).

According to experiences, the description of stoppages has been topical no more and the new approach has not been formed yet. By the means of mathematical approximation only limited number of practical tasks can be solved, especially those analytical ones but not synthetical systems. It is possible to go from the basis based in the first stage of theory of reliability (indicators of reliability, the method of their determination, mathematical models of stoppages etc.), to more difficult tasks of the theory of productivity and reliability that must become the basis for calculating practical counts, for constructing and using machines.

On principle, it requires a new methodical approach to reliability, a different mathematical apparatus, different criteria for evaluation of activities.

Potential possibilities of productivity, quality and economical efficiency, that are realized in concrete conditions of production, are fixed in various constructions and technological processes of machines and systems. The reliability of processing machines can not be considered purposelessly but as a degree of realizable possibilities for production, as the rate of losses in machine productivity.

High reliability is the problem of optimal designing and highly effective utilization of machines – automated machines and automatic lines. It is necessary to observe the increase in reliablity in interaction with its other ways to reach an increase, such as differentiation and concentration of operations, intensification cutting conditions, improvement in the organization of service and the increase in service qualification.

There are two options, that lead to the development of *highly productive and efficient machines*:

- Analysis of casual connections and dependencies, the formulation of principal conclusions and regularities, their mathematical description, it means the identification of physical core of effects related to reliability. By this, it is possible to formulate scientific and engineering opinion and to make preconditions for the development of processing machines with high technological economical indicators.
- Development of engineering methods that immediately solve concrete tasks on the high level – calculation, designing and the utilization of processing machines with high reliability, productivity and efficiency provided.

The first task is solved especially on the theoretical level and it results in working out mathematical dependancies of reliability indicators depending on technological, constructional, structural and operating indicators of machines with regard to externalities. The process of working out such dependancies is difficult because until now the qualitative indicators of reliability have been evaluated by statistical methods. The important task of fundamental theory of productivity and reliability is to work out mathematical models of reliability indicators interaction. On one hand, the results are the parametres of machines and on the other hand, there are their target functions (productivity, quality of work-pieces, economical efficiency).

Engineering tasks in the theory of reliability are connected with the choice of such constructional, technological and operating marameters of machines, that would provide their high technical economical indicators with considering their operational reliability. It is reasoned by various processing machines and various types of production.

The problem of reliability can be considered the problem number one especially in automated production where the requirements on reliability are high and the real reliability is often very low.

The problem of reliability of universal machines is very often modified into the problem of deterioration and operational life of mechanisms and knots (control, head stocks, trains of gears). At automated machines and automated lines, the problems are more significant if taking into consideration the high intensity of work, constructional complication etc. One of the most important tasks of the theory of productivity and reliability of automated machines and automated lines is the choice of principal and construction schemes of mechanisms, devices and control apparatus. When comparing characteristics of relability of various alternatives, it is possible to choose the most reliable one.

Conclusion

When comparing characteristics of relability of various alternatives, it is possible to choose the most reliable one. When comparing the real reliability of the best alternative on required level, it is possible to evaluate the stage of its suitability and perspective for another applications. Analogically, it is possible to evaluate the reliability of new machines and devices according to their laboratory and operational tests. The task relates the forecast of productivity and reliability level of designed automated lines. The lower reliability of constructional elements from which the automated production system is made of, the more elements the system needs to be separated on.

The theory of productivity and reliability of automated lines solves such problems as the choice of the most appropriate number of system service operators, rational system of instruments exchange, the calculation of reserves to increase productivity of existing automated lines etc. The methods of the theory of productivity and reliability change into solving tasks of complex optimalization of designing production machines.

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