Economic Aspects of Robotization of Production Processes by Example of a Car Semi-trailers Manufacturer

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A constantly growing competition in world economy results in an increasing demand for solutions enhancing both the effiiency of enterprises and the quality of goods produced. A solution which meets both requirements is robotization of production processes, i. e. replacing human labour with the work of industrial robots on the positions where tasks are monotonous, onerous or dangerous. The paper presents the economic analysis of the use of robots in production processes, as well as its technological conditioning. On the example of robotization of processes in the enterprise producing semi-trailers, the method of calculating the re-turn on investment was presented and an analysis of the labor costs of the worker and the robot at a given workplace was made.

Keywords: robotization, industrial robot, production processes, semi-tailer

1 Introduction

Contemporary market can, undoubtedly, be described as highly competitive. Therefore, time and cost are becoming the main criteria of production objectives. Enterprises, which want to meet customers‘ requirements, have to be efficient as far as performing production processes is concerned, and, at the same time, guarantee minimal production costs. Such requirements trigger a constant development and upgrading of processes, as well as a change in the attitude towards designing production systems [9, 10, 19].

Apart from progressing globalization and an increased pressure of the market, the main element influencing the manner and direction in which production systems develop is an unprecedented advance in engineering and technology in terms of machines, devices which perform assisting functions, and systems of communication and directing a production chain. A watershed moment which has had an impact on the direction of production systems development is the advent of industrial robots which today are used not only in big corporations but, more and more frequently, can be found in medium and small manufacturing companies [1, 15].

Growing significance of robotics is linked to the benefits resulting from its impementation, such as [2, 11] celerity of a given procedure, precision, repetitiveness, reliability, increased efficiency and, finally, the elimination of tasks which may pose a certain danger for a human.

A global trend which facilitated the advent of the next revolution was largely the growth in the amount of available data and computing capabilities [7].

In a modern, highly competitive production environment, enterprises are confronted with multiple challenges, such as large amounts of data to be dealt with, the strain of making proper decisions under the pressure of time, or change of production processes into more flexible ones. Particularly, the aspect of production flexibility is significant, as, nowadays, the character of production is shaped by changes of the paradigm from mass production to demand production, directed at the client's demands [11]. Such undertakings result in a shorter life cycle of products, an increased assortment, as well as a change of processes to those with high efficiency and the change of devices and machines to more flexible ones [14]. The development of a technological process leads to an increased complexity in all areas of the company's operations. Thus, an increased demand for innovation in terms of new materials and technologies, innovative production processes as well as new business models appears [3, 17]. The discussed additional aspects; processing of large amounts of data and decision-making; pose a challenge and contribute to a technological leap, which both have to be faced by an enterprise. The challenge is to provide innovative platforms and tools for mutual cooperation of all areas of the company's operations [18, 20]. Nevertheless, manpower is still irreplaceable, for example when assembling complex products. This is due to the fact that a human being is marked with high flexibility of action, and can deal with a variety of atypical situations in a much more efficient way than robots. On the other hand, a human is the most unreliable element in the production system. Additionally, different conditions on the market and various social changes can significantly hinder the recruitment of employees with high level of process competence. The development of autonomous systems, robots, and transport systems significantly influences the change of man-hour costs and machine man-hours. Currently, there is a tendency to increase the costs of human labor and reduce the cost of the machine's working hours [5]. Within a short time span, a situation when equating the costs of machine and human work is possible will be achieved. However, the introduction of robotics requires an investment not only in terms of the purchase of a robot, but also the execution of a robotic station and often adaptation of the transport system.

2 Conditions and analysis of the profitability of investments in robotization

According to 2018 World Robotics report, the sales of industrial robots are constantly growing. In 2017, it increased by 30% to 381,335 units and reached the new peak for the fifth year in a row. The main drivers of this exceptional growth in 2017 were the metal industry (+ 55%) and the electrical/electronic industry (+ 33%). Robots sales in the automotive industry increased by 22%. The automotive industry is still the forefront of the purchase of industrial robots with the share of 33% of their total supply in 2017. This is a definite evidence of a considerable, and constantly increasing demand for industrial robots around the world. The experience so far reveals that repetitive processes related to a large scale of production and, at the same time, a demand for flexibility are best suited for automation and robotics. An important element is the social aspect related to a drop of employees' interest in manual labour. Nowadays, a phenomenon of labour shortages can be witnessed, as well as reluctance of employees concernig the implementation of automated systems which is connected with the fear of being made redundant. However, such an apprehension is unfounded as an IFR report [5] indicates that robotization, in a way, contributes to the creation of new jobs in industry, while other research results [13] indicate that one additional robot per one thousand employees reduces the employment rate by only 0.16-0.20 percentage points.

Currently, the prices of industrial robots are regularly falling, while the costs of human labour are growing. Both the minimum wage and the average pay are increasing, and, still, there are problems with obtaining new human resources. The analysis of market trends relveals that labour cost of robots will be lower than the cost of human labour. In the analyzed enterprise which deals with producing specialized semitrailers, the initial analysis of labour costs showed that the equilibrium point would have been reached between 2021 and 2023 (Figure 1).

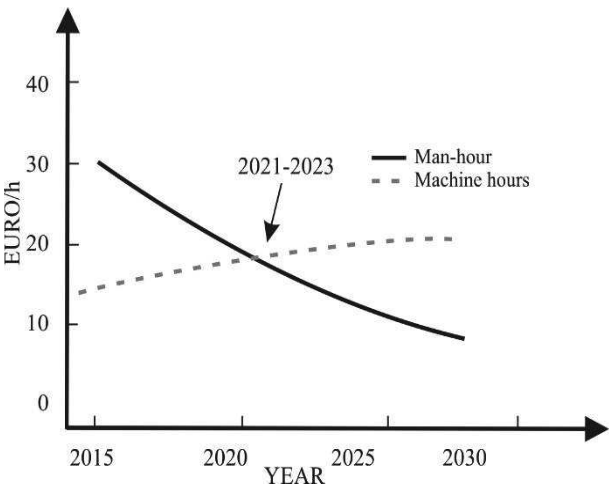

Fig. 1 *Comparison of estimated man-hour costs and machine hours in an enterprise producing car semi-trailers*

While analysing the production costs for conventional and robotic processes in a company producing car semitrailers, a different amount of initial expenditure on starting production must be acknowledged. In the case of conventional production, the expenditures are lower than in the case of robotic production. The costs of production process can be presented in a form of a linear relationship (Figure 2). In the analysed company, the return on investment is taken from 1-4 years.

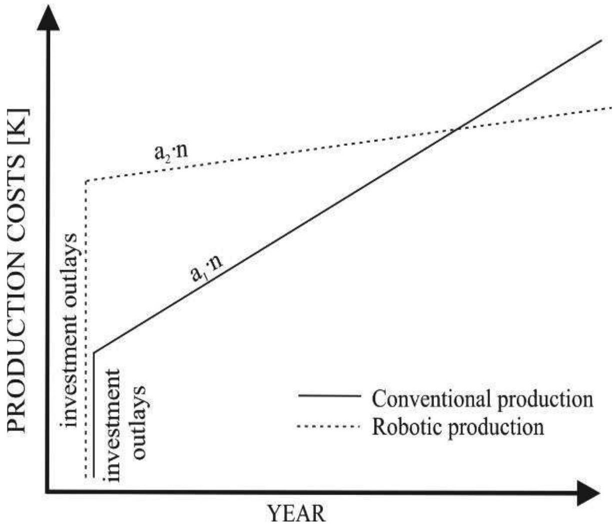

Fig. 2 *Comparison of production costs for conventional and robotic processes; a_1-proportional costs conventional production, b_1- investment outlays for starting conventional production, a_2-proportional costs of robotic production, b_2- investment outlays for launching robotic production, n-size of production, K-cost of production process*

The time of investment return depends on many factors, such as: complexity of the process, which is a subject to automation, difficulties with implementation of application security, time needed to execute the position and materials required for the implementation, type and sophistication of the peripheries used, time needed for programming, and many other factors. When the rate of return on investment is calculated, the cost of hardware and software, additional accessories, work integrators, the number of hours a robot is working, and other expected costs of adapting the line to the robot must be taken into consideration. A proper tool for the initial calculation of the time in which the investment in robotisation will be reurned is the ROI calculator prepared by the American Robotic Industries Assocation.

As far as Poland is concerned, sectors which are to greatest extent open for robotisation are such production sectors in which high costs are accompanied by extremely high requirements of contractors, including terms of quality or repeatability of production. These include car manufacturers as well as Tier 1 and Tier 2 suppliers, representatives of the metal and machine industry, as well as companies operating in the field of manufacturing of electric and electronic products or in the chemical industry. In Poland, as well as in other parts of the world, the most popular among manufacturers are robots for tasks commonly referred to as "handling", that is, for transferring, translating and servicing products. Such robotic applications are found in all industries at every stage of production. Manufacturers also willingly order assembly and welding works as well as robots dedicated to palletizing application.

To roughly evaluate the cost-effectiveness of an investment connected with the ourchase of robots, the return on investment period can be used, which can be calculated as follows (1) [6, 16]:

$$\boldsymbol{OZ} = \frac{\Delta I}{\Delta K} = \frac{I_a - I_k}{\Delta K} \quad (1)$$

Where:

ΔI - the difference between investment expenditures on the launch of automatized production I_a and conventional one I_k.

ΔK - annual manufacturing cost savings.

The shorter the return on investment span is, the greater the profitablity of an investment. Taking into account the character of robotic processes as well as an aggregate value of an investment outlay, discount rate, and amortization, it can be described in the following manner (2) [8, 12]:

$$\boldsymbol{OZ} = \frac{I_n}{l_z(l_p - \frac{l_o}{k_p} - (r+p)l_n} \quad (2)$$

Where:

I_n - the value of investment outlays,

l_z – the number of working shifts,

l_p – the number of workers on one shift replaced by a robot,

l_o – the number of workers manning a robotized workstation,

k_p - annual cost per hire,

r - discount rate,

p – the share of an annual exploitation cost as an interest on capital (amortization).

Annual costs per hire of *kp* workers which were replaced by robots constitute savings and correspond to a return on investment. When outlays and revenues are variable over time, a Net Present Value method (NPV) can be used. It belongs to discount methods for assessing the effectiveness of investments which means that it takes into account the change in the value of money over time. This meter has both advantages and disadvantages. One disadvantage is certainly a high degree of subjectivity when determining the level of the discount rate. The advantages, however, include all the cash flows related to the investment, the ability to ensure the comparability of investments and permitting easy aggregation of investments (the NPV value of the investment portfolio is equal to the sum of NPVs value of investments included in its composition). In addition, this criterion is fully in line with the principle of maximizing company value. NPV in the discussed case makes it possible to compare the expenditures expected for the implementation of the investment to the sum of expected and achievable cash surpluses (reduction of employment, efficiency increase) from the designed robotic position in subsequent years of its operation, but after checking their future value to the current level including the cost of capital employed [6, 16].

$$\boldsymbol{NPV} = \sum_{t=1}^{n} \frac{CF_t}{(1+r)^n} \quad (3)$$

Where:

CFt – projected net cash flows that can be achieved in subsequent operational periods *t*

r- discount rate.

Formula 1 is applicable only when all the necessary expenditure is incurred at the beginning of the investment. In a situation where expenditures are incurred during an investment project, the NPV can be calculated as follows:

$$\boldsymbol{NPV} = \sum_{t=1}^{n} \frac{P_t}{(1+r)^n} - \sum_{t=1}^{n} \frac{I_t}{(1+r)^n} \quad (4)$$

Where:

Pt- revenues from subsequent periods

It- expenditures of subsequent periods.

If this criterion is used, making the right decision depends on the NPV result. If NPV <0 - project to build a robotic station should be rejected, NPV> 0 - the project can be implemented, NPV = 0 the investment does not affect the value of the enterprise.

3 Costs of maintaining employees vs. robot

The average wage in Poland in the production sector in 2018 amounted to approximately EUR 1,100 gross. The cost of maintaining an employee replaced by a robot means cost-effectiveness and corresponds to a return on investment. A sample comparison of the labor costs of an employee and a medium-sized robot (Standard Robots) in 2018 in Poland is shown in Table 1.

Tab. 1 *Comparison of the labor costs of an employee and a robot of standard robots type (Statistics Poland, Eurostat, ria -Robotics Industry Association, Wielton S.A.)*

Employee	Robot-(Standard robots)
Average gross monthly salary in 2018. 1132 Euro Including: Pension contribution 9.76% Disability contribution 6.5% Accident contribution 1.67% Labor Fund contribution 2.5% Guaranteed Employee Benefits Fund contribution 0.1%	Service, once a year 500 Euro General overview and replacement of worn components, once every 5 years 5,000 Euro General overhaul after 10 years 30,000 Euro Average costs on an annual basis of 4 500 Euro
The employer, in addition to the gross remuneration, bears an additional burden of approx. 20% of the gross remuneration. 227 Euro	7.5 kVA energy - consumption about 6kWh The average price of 1 kWh in Poland is 0.12 Euro The cost of energy per working hour is 0.72 Euro 4.32 Euro for 8 hours of work
Total cost Monthly: 1,359 Euro Annual: 16,308 Euro	Total cost with the assumption of work for one shift 365 days a year. Annual: 6,076.8 Euro Two shifts. Annual: 7,653.6 Euro

The presented analysis shows that the costs of work of a robotic station are significantly lower as compared to an employee's labour costs. However, the analysis does not take into account the outlays incurred on investments. It is also necessary to consider the increase in wages in the near future and the reduction of costs of investment outlays for the creation of robotic positions. In the factory producing semi-trailers, the analysed station was equipped with an industrial robot to facilitate the assembly process of structural elements of semi-trailers. Up to now, two employees have worked in the same scope. The investment costs incurred for the implementation of the system amounted to around 150,000 Euro. Two work scenarios were adopted for one and two shifts, a 50% reduction of operators on the position was assumed, and an increase in wages of 5% year-on-year, expected increase in productivity at 35% level, labour retained to operate system per shift of 10%. The obtained results are presented in Table 2 and Figure 3. All the calculatios were made on the basis of data which were made available by WIELTON S.A, with the use of ROI -Robot System Value Calculator (general overview and replacement of worn components are based on the Robotics Industry Association methodology).

***Tab. 2** A summary of operating costs of the robot system for a two-shift system (Wielton S.A.)*

Year	System Costs [Euro]	Maintenance Costs [Euro]	Operating Costs [Euro]	Labor Savings [Euro]	Productivity Savings [Euro]	Yearly Cash Flow [Euro]	Cumulative Cash Flow [Euro]
1.	150,000	500	3,000	30,600	10,710	-112,190	-112,190
2.		500	3,060	31,212	10,924	38,576	-73,614
3.		500	3,121	31,836	11,143	39,358	-34,256
4.		500	3,184	32,473	11,366	40,155	5,899
5.		5,000	3,247	33,122	11,593	36,468	42,367
6.		500	3,312	33,785	11,825	41,797	84,164
7.		500	3,378	34,461	12,061	42,643	126,807
8.		500	3,446	35,150	12,302	43,506	170,314
9.		500	3,515	35,853	12,548	44,386	214,700
10.		30,000	3,585	36,570	12,799	15,784	230,484
11.		500	3,657	37,301	13,055	46,200	276,683
12.		500	3,730	38,047	13,317	47,134	323,817
13.		500	3,805	38,808	13,583	48,086	371,904
14.		500	3,881	39,584	13,855	49,058	420,962
15.		500	3,958	40,376	14,132	50,049	471,011
Totals:		**41,500**	**51,880**	**529,179**	**185,212**		

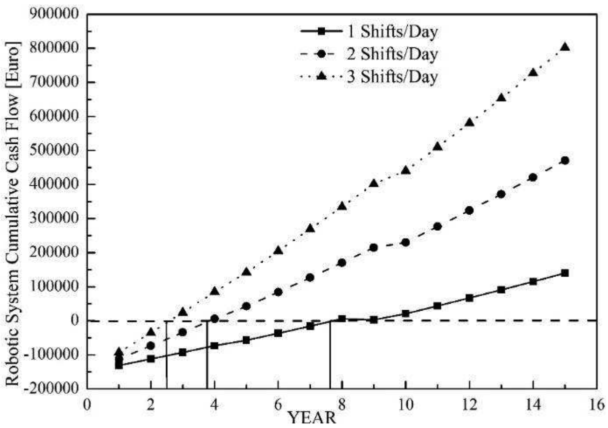

***Fig. 3** Robotic System Cumulative Cash Flow for one, two and three shift system in a factory producing car semi-trailers (Wielton S.A.)*

In the case of work of a robotic station in a one-shift system, the return on investment will take place after 7 years and 9 months. After 15 years of operation, 264,589 of labour saving and 92,606 Euro of productivity savings will be recorded. For a two-shift system, the return on investment will take place after 3 years and 11 months. After 15 years of operation, 529.179 of labor saving and 185.212 Euro of productivity savings will be observed. For three-shift production, the return on investment will occur after the shortest period, that is after 2 years and 8 months. After 15 years of operation, 793,768 of labor saving and 277,819 Euro of productivity savings will be recorded. It should be noted that the return on investment is significantly affected by the operating costs of the employee, in Poland it can be observed that a very dynamic increase in employee labor costs, which will significantly reduce the payback time of the investment in the robotic station.

Taking into consideration experts' forecasts and current trends on world industrial market, it should be expected that the demand for industrial robots, including welding robots which are the most frequently used in automated production systems, will rise not only among Polish entrepreneurs. The increase is thought to be the result of a pressure imposed by the competition. As numerous examples show, the use of robots has a positive impact on the enterprise effciency, improvement of production and lowering its cost, as well as on enhancing product quality. The growth of employment and and improvement of staff qualifications (e.g. weldnig staff), are additional assets. Robots also take the place of qualified presonell in jobs which are connected with difficult and dangerous conditions for human life and health.

4 Summary

Robotics of the industry is not only a change in the employment structure, but can also be perceived as a real asset for enterprises. Robotization allows to increase repeatability and quality of production, enables to obtain stable production parameters, high precision, and, thus, gives the possibility of producing quality products. Moreover, there is also productivity growth which is the nest argument in favour of robotics often mentioned by its advocates [19]. The latter allows to ensure reliability and efficiency of production, and, consequently, guarantees an increase in production efficiency. Additionally, lowering of production costs takes place, as in the long run robots allow to obtain savings related to staff costs. The return on investment time is also shorter. A very important factor determining the purchase of robots is the ability to solve the problem of staff shortages - entrepreneurs, especially in areas far from larger cities, often have problems with acquiring qualified employees. In such cases robots are sometimes the only alternative. Unfortunately, enterprises make mistakes in the robotisation of production processes. The most common mistakes include:

- lack of communication infrastructure synchronization and the ability to process large amounts of data,
- lack of synchronization with old solutions,
- the will to do everything right away - reloading the project,
- excessive complexity of implemented systems,
- no preparation (including training) of users,
- incomplete analysis of problems and needs.

The carried out analysis of the conditions of robotization of processes in the production of car semi-trailers was aimed at eliminating the last element, that is, the analysis of the needs and determining the cost-effectiveness and return of investments incurred for the investment.

Competitive mechanisms connected with a dynamic increase of the number of robots in world industry in the near future will result in more and more frequent decisions of entrepreneurs to implement robotization in the production process.

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