RESEARCH ARTICLE OPEN ACCESS

The Effects of Offline Simulation on Return on Investment for Robotic Investments

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ABSTRACT
In this study, the parameters affecting the investment cost were investigated with offline simulation during the projecting stage of industrial production robots and in the light of these parameters, the calculation of the return on investment of a robot was examined systematically. In the parametric examination, the parameters that affect the robot investment such as the return on investment in the industrial robot investment, the effects of the robot according to years, installation and commissioning are taken into consideration. Approaches were also compared with manual operating costs. Today, factories are expected to produce more products in a short time and the cost of these products is expected to be at the lowest level. It is desirable to reduce manpower, reduce accidents and minimize downtime. At this point, robotic systems started to enter the circuit. Industrial robots are increasing rapidly in the industry and it is aimed to minimize the labor cost with such systems. These objectives are aimed at maximizing the return on investment. This is where offline programming and simulation come into play. It is seen that in the installation of robotic systems, it contributes greatly to the return on investment by minimizing the continuous production downtime in offline programming commissioning processes..
Keywords – Industrial robots, return of investment, investment analysis on robotics, roi

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DATE OF SUBMISSION: 15-01-2020 DATE OF ACCEPTANCE: 31-01-2020

I. INTRODUCTION

Robots are autonomous or electro-mechanical devices capable of performing pre-programmed tasks. In this case, the robots are machines or devices which are composed of a number of mechanical and also electronic units, which can be programmed. Robots are engineering products and they have the ability to move physically with a number of abilities.

In order for a machine or device to be perceived as a robot, four different elements are essential. Sensors, ie sensors, detect some data from the environment. Some electronic circuits for controlling incoming data, a program that performs the necessary logic operations and the mechanical structure that gives the necessary action as a result of all this. [1]

According to the definition of ISO TR 8373, the industrial robot is an automatically controlled, programmable, multi-purpose machine with three or more programmable axes, used in industrial applications with fixed standing or wheels. [2] According to another definition, the robot is "programmable, capable of carrying multiple functions, products, parts, and special devices and performing various tasks by performing various programmed functions". [3].

II. INDUSTRIAL ROBOT STATISTICS

Particularly in the mass production industry, the number of industrial robots in the world, which have more effective uses in mass production lines, is rapidly increasing. According to the 2018 IFR-International Federation of Robotics data, an average of 90 industrial robots are allocated per 10,000 employees worldwide. Singapore is in the lead with 831 units, followed by South Korea with 774 and Germany with 328. [4]

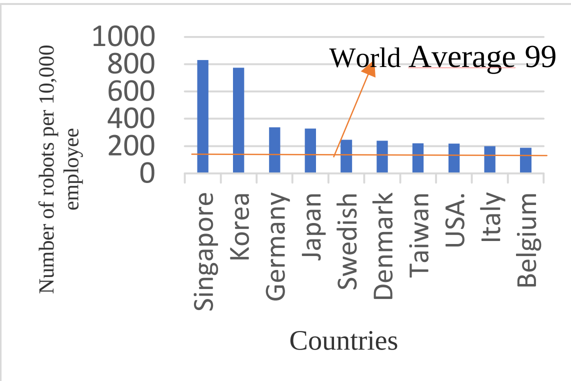

Figure 1: Top 10 countries in the number of robots per 10,000 employees in 2018 [4]

In 2018, approximately 422,000 robots were sold in all countries around the world. In these sales, there are 5 supermarkets with a large proportion. These are China, Japan, USA, South Korea and Germany. These countries account for 74% of the total number of installed robots in the world. China ranks first with 154,000 robots, followed by Japan with 55,200, USA with 40,400, Republic of South Korea with 37,800 and Germany with 26,700. [5]

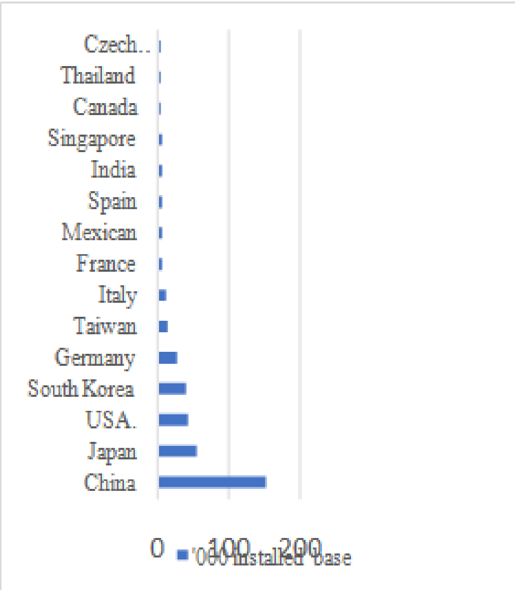

Figure 2: Top 15 country data for the number of robots installed in 2018 [5]

Turkey has 2267 sales of units situated as 18th and 19th place is followed by Brazil 2196 and 20th place in Malaysia with 1860 robots.

III. INDUSTRIAL ROBOTS AND INVESTMENTS

The concept of robot encompasses many engineering branches. And there are many factors to consider when classifying. These include design and manufacturing, system dynamics, actuators, announceers, artificial intelligence and communication, algorithm applications, real-time systems and control system designs.
Based on these concepts, robots can be classified according to the following headings.

According to technologies; CNC Machine tools, automatic machines, tools, etc. According to the movement; Stationary robots, mobile robots. According to control methods; Continuous trajectory controlled, controlled from one point to point. According to their abilities; Sequentially controlled, playback, adaptive, etc.

III.1. Industrial Robot Programming

Every industrial robot needs to be programmed as a combination of on-line and off-line to be able to move and perform the desired job. In online programming, it is called og jogging rob to take the robot to the desired position. Jogging is done with the robot control called 'TeachPendant' [6] Program parameters can be manipulated via this device and the robot can be intervened in case of a problem. In online programming, the robot is simply moved to the desired position and this point is taught.

In offline programming, the robot is programmed using computer-based software. The advantage of off-line programming over online programming is that the field work is considerably reduced. Robot program is made in the program used on the computer. After the necessary data is collected in the computer program and offline simulation is performed, a large part becomes ready and commissioning is performed to reduce downtime in the field. Another plus of off-line robot programming is the ability to test the system's operability in real time before commissioning. Conventional programming methods for industrial robots are very complex for an inexperienced robot programmer, so external assistance is needed. [7] Offline programming packages offer an attractive alternative to reduce programming time and robot download time. [8]

III.2. Return of Investment on Robotic Investments

In the six major economies of the past century, economic growth has been strongly associated with machine investment, as in a larger group of countries since 1950. Both the macroeconomic models and the narratives of the history of technology show that they are causal. The high machinery investment rate appears to be a necessary prerequisite for rapid long-term growth. [9]

According to a report published by the Consulting Boston Consulting Group,, customers need to multiply the machine's price tag by at least three to achieve a robust cost estimate for robots. Let's say a six-axis robot costs $ 65,000; customers need to give a budget of $ 195,000 to invest. However, if the robot requires extensive equipment overhaul, such as adding auxiliary machines or conveyors, a total of four or five times the cost of the robot may be required. [10]

There is a lot of variable cost. These include the labor, energy, materials, continuous maintenance and production materials needed to get the most out of a robot. Due to the variable nature of production facilities, these costs vary dramatically depending on the industrial sector and the size of the operation. Furthermore, these costs are not always linear. For example, maintenance costs can vary considerably over the life of the machine. Producers can calculate the ROI only after determining the total purchase cost of the robot, ie the investment. Even then, manufacturers should consider some other elements, starting with the use of robots.

III.3. HYPOTHETICAL ROI MODELING IN INDUSTRIAL ROBOT INVESTMENT

Return on investment is obtained by deducting the investment cost from the profit arising from the investment and dividing the result by the investment cost. The return on your investment is usually expressed as a percentage and is always the most preferred metric system for measuring your company's profitability and comparing different investments. The positive return on investment gives us an idea about the investment.

Table 1: Input parameters

LC	Labor Cost	3006.12 ₺
CTFW	Cycle Time for Workers	5.5 s
DWH	Daily Working Hours	7.5 h
HDY	Human Daily Yield	85%
CTFR	Cycle Time for Robot	5 s
RLY	Robot Log Yield	95%
VA	Value Added	0.1 Euro
k	Occupational safety, quality, marketing and so on. coefficients	3%
RIC	Robotic Investment Cost	150,000 Euro
BL	Breakdown Loss	3 weeks
RE	Robot Expenses	5000 Euro
ACL	Annual Cost of Labor	5,672 Euro

According to the data of the Ministry of Family and Labor in 2019, the cost of a minimum wage employee to the employer is 3006.12 ₺ per month as shown in Table 2.

Table 2: The cost of a worker to the employer [11]

Employer Cost	
Minimum Wage	2558,4 ₺
Empleyer Premium % 15.5	396.55 ₺
Unemployment Insurance Premium % 2	51.17 ₺
Total Cost to Employer	3006.12 ₺

Let's assume that the cycle time in the press feed process for 1 worker is 5.5 seconds. The total working hours per day is 7.5 hours and is 22.5 hours for 3 shifts. 22.5 hours is 81,000 seconds.

When we divide the number of parts printed per day by 81,000 into 5.5 seconds, we can find 14,228 pieces. Suppose an employee produces 12,518 products at 85% daily yield at best.

For a robotic system with a cycle time of 5 seconds, we can accept 95% efficiency. In this case, 15,390 pieces are printed per day.

Assuming that the value added for 1 product is 0.1 Euro, we are earning 287.2 Euro on a daily basis. In a single system over a period of 300 days, 86,160 Euros are earned. Let's add a 'k' constant to the elements that indirectly affect this gain. This 'k' value can include factors such as occupational safety, quality problems, replacement operator, consumables, and the effect on the sale of the product. Let this value affect 3% on plus or minus. If we take into consideration the robot yield in our estimated total earnings, it will be 88,744 Euros.

The average investment cost for one robot system is 150,000 Euros. When installing the robotic system, it will take at least 3 weeks to stop the existing system, switch to the robotic system and test the system.

3-week product profit is 12,518 units and in 20 days, from EUR 0.1 to EUR 25,036. Suppose that the average maintenance and breakdown costs for a 1 robot system is 5000 Euro. The annual cost of 1 operator to the employer is 108,220 TL, 5,672 Euros. [12]

Table 3: Output parameters

HPA	Human Production Amount	12,518 pcs
RPQ	Robot Production Quantity	15,390 pcs
EBD	Earnings by Day	287.2 Euro
ARE	Annual Robotic Earnings	88,744 Euro

From the hypothetical example above, the return on investment is negative for the first year. The second year shows a positive trend

III.4.THE EFFECTS OF ROBOT INVESTMENT ON A YEARLY BASIS

When analyzed on a yearly basis, annual operator earnings, annual parts per year, annual operating costs will increase cumulatively. However, there is a significant increase in the return on investment since the investment cost and the amount of stoppage during the investment will be one-off expenses.

In the hypothetical table below, when off-line programming is performed, the stance during investment is taken into account and reduced to half.

Table 4: Change of return on investment by years

	End 1st year	End of 2nd year	End of 3rd year
Annual Operator Earnings	€ 5,671.00	€ 11,342.00	€ 17,013.00
Annual Part Gain	€ 88,744.00	€ 177,488.00	€ 266,232.00
Investment Cost	€ 150,000.00	€ 150,000.00	€ 150,000.00
Annual Operating Fee	€ 5,000.00	€ 10,000.00	€ 15,000.00
Loss of breakdown	€ 25,036.00	€ 25,036.00	€ 25,036.00
Return on Investment (%)	- 0.475577107	0.020504118	0.490480751

III.5. The Effects of Installation and Commissioning on the basis of Days in Robot Investment

Off-line programming significantly simplifies installation and commissioning times in the field for simulation applications in the office environment.

It is very difficult to manually program the robot from the robot controller, to define the signals and to make the entire configuration in the field. One of the most important factors is not to interrupt production processes in engineering works. In this case, it is necessary to reduce the risks and ensure the faster installation of the systems. The basis for off-line programming is the commissioning as quickly as possible during production.

In the installation of robotic systems, pre-planning of all mechanical layouts, and simulating and writing the robot program greatly reduces the time spent in the field. [13]

Considering that in the example above, the profit from the production of a daily product by robot is 1539 Euros and the reduction of each day less than the 3-week stop will have a positive effect on the return on investment.

Table 5: The effect of decreasing downtime on the basis of days to return on investment

Decrease in stop by day	1 day	2 days	3 days
Return on investment (€)	283,247	283,247	283,247
Investment Expense (€)	198,497	196,958	195,419
Return on Investment (%)	0.426958594	0.438108632	0.449434292

Table 6: The effect of decreasing downtime on the basis of days to return on investment 2

Decrease in stop by day	4 days	5 days	6 days
Return on investment (€)	283,247	283,247	283,247
Investment Expense (€)	193,880	192,341	190,802
Return on Investment (%)	0.460939757	0.472629341	0.4845075

The hypothetical effect of a 6-day stoppage savings on the return on investment is approximately 0.068 for an investment that is planned to return at the desired point in 3 years.

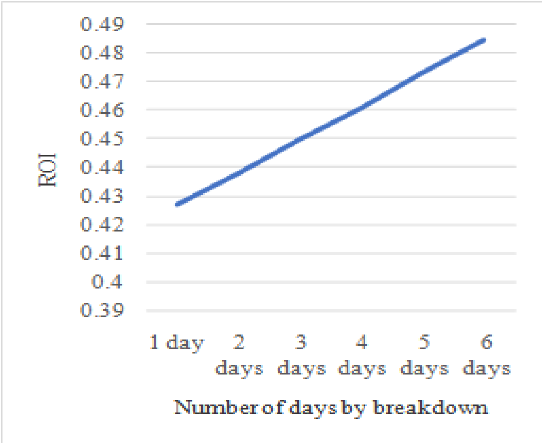

Figure 3 : The effect of decreasing downtime on the basis of days to return on investment

IV. RESULTS AND DISCUSSIONS

The analysis needed to be productive in the direction of investments depending on the rise of robots and automation systems used in the industry based on a study was conducted.

It is considered that production systems simulated with robotic simulation will be more accurate and realistic in terms of cost before the actual manufacturing cell is produced.

In this case, the pre-work of the system before making the robot program in the field commissioning, performing the necessary mechanical placement work, simulating accordingly, making the robot program into a ready package will reduce the installation stop in the field. In this way, the producer will avoid shortage of production due to downtime and will contribute greatly to the investment cost.

The increase in investment cost on a daily basis varies by 0.01% and it is observed that off-line simulation reduces installation costs considerably when people-oriented errors are omitted.

There are some flaws in this method of ROI calculation. Most of these figures are estimates unless a complex and time-consuming acquisition and production analysis is actually completed. Moreover, this does not take into account any problems that may occur, such as equipment failure or unplanned downtime. For a true reflection of the return on investment, manufacturers should conduct a detailed cost analysis based on the operations of their facility as well as a risk assessment.

However, there are also complementary benefits for robots that are not taken into account in this calculation. Robots are predictable and therefore offer peace of mind to improve productivity to improve a factory's profits. For example, eliminating the possibility of human error in manufacturing reduces scrap material, minimizes rework, and improves product consistency. Each of these factors represents a separate increase in the profit of a producer from the overall return on investment.

V. CONCLUSION

The effectiveness of offline simulation software for robot investment is investigated with the help of a model and the following inferences are obtained from this study.

1-Robotic investments have positively benefited the human factor and prevented it financially.

2-In ROI investments, the return on investment is negative in the first year and positive in the following years, depending on the size of the investment and the return on investment.

3-Offline robot simulation software can be used successfully for investment cost.

4- A sampling was made with the proposed modeling and it was shown that the reduction of the stop during installation with offline simulation software had a positive effect on 0.01% investment cost per day.

5-The production investment based on our study is a small scale investment and it is estimated that the productivity increase will be higher with the use of the model in larger scale investments.

6-Pre-installation with offline content before installation reduces the risks that may be encountered in the field

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