Engineering and Technology Journal e-ISSN: 2456-3358
Volume 10 Issue 12 December-2025, Page No.-8300-8305
DOI: 10.47191/etj/v10i12.31, I.F. – 8.482


# The Influence of Robotic Automation on Production Processes in the Manufacturing Industry Including Cost, Time, and Quality Efficiency Using Statistical Data Analysis Methods

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**ABSTRACT**: This study analyzes the effect of robotic automation implementation on the production process of car AC pipe tube connectors at PT. CKU with a focus on time efficiency, cost efficiency, and product quality.The research background is based on the company's need to increase productivity and quality consistency amidst the increasing demands of the automotive manufacturing industry market.The methods used include literature studies, field case studies, production process observations, and quantitative data analysis using the Paired Sample T-Test to compare the performance of manual and automatic processes.The results of the study showed that robotic automation was able to reduce production cycle time from 218 seconds to 185 seconds per unit, increase output per shift, and significantly reduce the defect rate from 2.30% to 0.30%.In addition, the need for manpower has decreased from 3 operators to 1 operator per shift, so the company's salary costs have also been significantly reduced.The statistical test results produced a significance value <0.05, which indicates that the difference in performance between the manual and robotic processes is statistically significant.Overall, this study proves that robotic automation is a viable and strategic investment for companies, as it can improve productivity, cost efficiency, process stability, and overall product quality.These findings can serve as a reference for the manufacturing industry in adopting robotic technology to increase competitiveness.

**KEYWORDS**: Robotic automation; CNC machine; production efficiency; product quality; operational costs; Paired Sample T-Test; manufacturing industry; Tube Connector.

## 1. INTRODUCTION

The development of robotics technology has changed the way various industrial sectors operate, especially the manufacturing industry[13]. According to the *International Society of Automation* (ISA), automation is the creation and application of technology to monitor and control the production and delivery of products and services.

According to a report from the Boston Consulting Group, companies that adopt advanced automation experience an average productivity increase of 30%, a reduction in production costs of up to 25%, and a 20% improvement in product quality. To enhance consistency in maintaining product quality, robotic automation becomes the most effective and efficient strategy that companies can use. In addition to quality factors, robotic automation can also be used to optimize the COVI (cost out value in) system, shorten Cycle Time, and reduce downtime, which affects financing and production time.

A report from the *World Bank titled Jobs and Technology,* released on October 8, 2024, shows that the adoption of robots in the East Asia and Pacific region has continued to increase from 2000 to 2022. The indicator for robot adoption is measured by the number of robots per 1,000 manufacturing workers in a country.

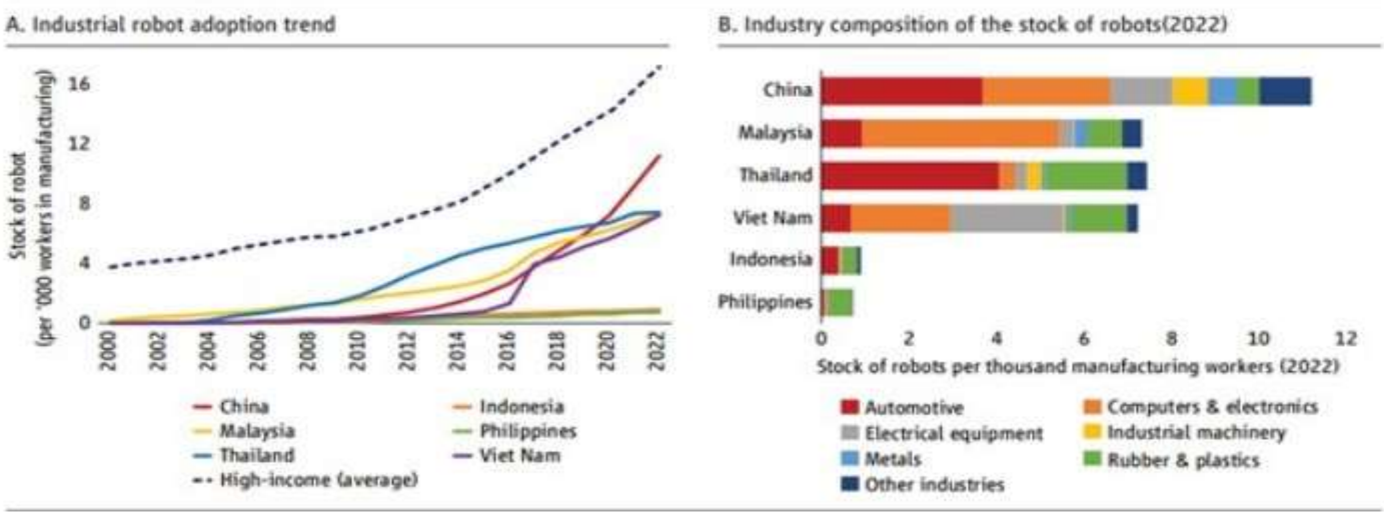


**Figure 1. Robot adoption rate in East Asian manufacturing industry**
**Source:** International Federation of Robotics (IFR)

1 of the aspects that affects the efficiency of the production process is the installation of raw materials into CNC machines. At PT. CKU, the process of installing raw materials is still done manually. These various reasons prompted the researchers to implement robotic automation in the process of loading materials into CNC machines. This decision aims to improve time efficiency, reduce costs, and enhance production quality.

## 2. LITERATURE REVIEW

The development of industrial robots began in the early 20th century, when the concept of automation first emerged. 1 key moment was Charles Babbage's invention of the automatic cutting machine, which laid the foundation for the development of robotics technology. However, the term "robot" itself is derived from the Czech word "robota,"

meaning forced labor, and was introduced by playwright Karel Čapek in his play "R.U.R." in 1920. This moment opened the human mind to the possibility of creating machines that could perform human tasks.

Industrial robots refer to the use of automated systems and machines in manufacturing processes to perform tasks typically performed by human operators. Sustainable production in the manufacturing sector emphasizes reducing environmental impacts, conserving resources, and promoting social responsibility while maintaining economic viability [14].

Robots are designed to handle repetitive, high-precision and physically demanding tasks so that they can increase productivity, reduce errors, and improve overall efficiency [1].

Industrial robots are equipped with various sensors, actuators, and control systems to interact with their environment and carry out predetermined tasks [3].

Adaptive design in industrial robotics involves the ability of a robot to autonomously adjust its behavior and operations in response to changes in the production environment or task requirements [9]. This allows the robot to handle variations in product design, process parameters, and environmental conditions [2].

By incorporating adaptive design principles, industrial robots can optimize their performance, adapt to new situations, and achieve higher levels of efficiency and productivity. Flexible design in industrial robotics focuses on the robot's ability to handle diverse tasks and quickly switch between different production processes [15].

Flexible robots are designed to be reprogrammable, reconfigurable, and capable of performing multiple tasks with minimal downtime [8].

Efficiency in manufacturing refers to the ability to achieve production goals with minimal input of resources, time, and cost. Industrial robots with adaptive and flexible design principles contribute to efficiency by streamlining production processes, reducing human error, and maximizing operational productivity.

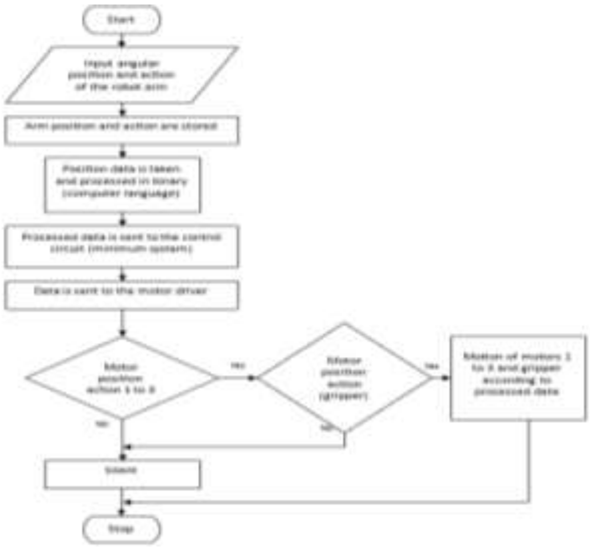

**Figure 2. Robot system flow chart**
**Source:** [4]

## 3. RESEARCH METODOLOGY

This research is a quantitative study that will examine the factors that will determine the success of implementation.

A. Literature Review
In this study, data and information were collected through a literature review, which includes scientific journals and online information sources related to the topic of improving production effectiveness with the help of robotic technology.

B. Case Study
The case study was conducted at an automotive manufacturing company that has implemented robotic automation for the production process. Through interviews with several related departments, this study will explore practical experiences and lessons learned from the implementation of robotic technology.

C. Data Analysis
The data obtained from case studies, literature studies, and surveys will be analyzed separately. Qualitative analysis will be used to identify patterns, themes, and trends in qualitative data, while quantitative data will be collected through field activities. This data is used to answer research questions or test research hypotheses.

D. Validation and Interpretation
To reduce the likelihood of systematic or random errors that could compromise the objectivity of research results, the author conducted discussions with industry experts and academics who are competent in the field of robotics technology integration. As a result, the findings obtained are more reliable and useful for decision-making, whether in the academic world, public policy, or the industrial sector.

## 4. RESULTS AND DISCUSSION

This research focuses on production processes in the automotive manufacturing industry. The aim of this study is to analyze the effectiveness of robotic automation compared to manual processes. In the industrial world, automated processes make it possible to produce large quantities while maintaining high quality. All obstacles must be addressed to achieve optimal results for the company.

A. INITIAL IDENTIFICATION

PT. CKU is a manufacturing company that produces automotive components. Its production process requires 9 operators on 1 production line, divided into 3 shifts. According to company data, the company has spent US$ 32.300 to provide basic salaries for the year 2024. This cost does not include transportation, insurance, and year-end bonuses. Therefore, the company invested US$ 15.320 in robots from China.

**Figure 3. Manual production process (personal documentation, 2024)**

Figure 3 shows the production process for car air conditioning pipe tube connectors. This process still requires human labor, with 1 operator for 2 machines. To meet customer demand, PT. CKU requires 6 machines, requiring 3 operators per shift. The processing time for this process is 218 seconds per unit.

**Tabel 1.** Output data of PT. CKU

| Indicator | Manual Process | Automatic Process |
|---|---|---|
| Company Outcomes | Operator Salary Per Month | Monthly Robot Maintenance |
| Production Time | 218 sec/pcs Formula: 218 sec x 7 working hours = 2076 pcs in 1 production line | 185 sec/pcs Formula: 185 sec x 8 working hours = 2790 pcs in 1 production line |
| Product Defect Rate | 2,30% | 0,30% |

Table 1 compares the results before and after implementing a robotic automation system. The data focuses on company outcomes, production times, and product defect rates.

To ensure changes in efficiency after robot automation, the author includes data from the results of the Paired Sample T-Test.

A. The basic concept of the Paired Sample T-Test is as follows:
   1. The independent sample t-test is used to determine whether there is a difference in the means of 2 paired samples;
   2. The data scale used in the Paired Sample T Test is Interval/Ratio Data and the data analyzed is Before-After or Pre-Post Data (before and after).

B. Criteria for testing normality using the 1-Sample Kolmogorov-Smirnov Test:
   1. If the significance value (P value) is <0.05, then the data is not normally distributed;
   2. If the sig. (P Value) > 0.05, then the data is normally distributed.

C. Paired Sample T-Test Test Criteria:
   1. If the sig. value (2-tailed) is <0.05, there is a significant difference between the manual and robotic process result.
   2. If the sig. value (2-tailed) > 0.05, then there is no significant difference between the results of the manual and robotic processes.

**One-Sample Kolmogorov-Smirnov Test**

| | | OUTCOME_BEFORE_AUTOMATION | OUTCOME_AFTER_AUTOMATION |
|---|---|---|---|
| N | | 12 | 12 |
| Normal Parameters[a,b] | Mean | 987,2500 | 302,6667 |
| | Std. Deviation | 101,35188 | 10,79843 |
| Most Extreme Differences | Absolute | ,182 | ,236 |
| | Positive | ,182 | ,228 |
| | Negative | -,151 | -,236 |
| Test Statistic | | ,182 | ,236 |
| Asymp. Sig. (2-tailed) | | ,200[c,d] | ,064[c] |

a. Test distribution is Normal.
b. Calculated from data.
c. Lilliefors Significance Correction.
d. This is a lower bound of the true significance.

**Figure 4. Results of the normality test using the 1-Sample Kolmogorov-Smirnov Test**

**Paired Samples Statistics**

| | | Mean | N | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Pair 1 | OUTCOME_BEFORE_AUTOMATION | 987,2500 | 12 | 101,35188 | 29,25777 |
| | OUTCOME_AFTER_AUTOMATION | 302,6667 | 12 | 10,79843 | 3,11724 |

**Figure 5. Results of Paired Samples Statistics Test**

**Paired Samples Correlations**

| | | N | Correlation | Sig. |
|---|---|---|---|---|
| Pair 1 | OUTCOME_BEFORE_AUTOMATION & OUTCOME_AFTER_AUTOMATION | 12 | ,086 | ,790 |

**Figure 6. Results of Paired Samples Correlations Test**

**Paired Samples Test**

| | | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference Lower | Upper | | | |
| Pair 1 | OUTCOME_BEFORE_AUTOMATION - OUTCOME_AFTER_AUTOMATION | 684,58333 | [illegible] | 29,15514 | 620,41329 | 748,75336 | 23,481 | 11 | ,000 |

**Figure 7. Results of the Paired Samples Test**

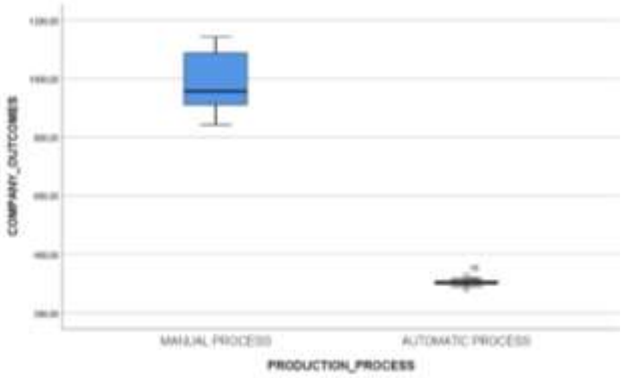


**Figure 8. Comparison of company outcomes between robot processes and manual processes**

Figure 8 shows a comparison of company outcomes during the manual process and the robotic process that the company has to bear. From the graph, it can be seen that the implementation of robotics can increase the cost efficiency of the production process. In the manual process, the company's average outcome is USD$ 985 whereas in the automated process, the company's average outcome is USD$ 308.

**Figure 9. Production process after automation process (personal documentation, 2025)**

Figure 9 shows the production process after robotic automation; the implementation of robotics has reduced the number of operators to 1 person per shift to operate 6 machines in 1 production line.

**B. ANALYSIS RESULTS**

The results of the Paired Samples Test above (Figure 5), the sig. (2-tailed) value <0.05 proves that the data from the comparison between the manual process and the robotic process is normally distributed. By looking at the salary comparison graph (Figure 6), the company's outcome burden decreased after robotic automation. The results of this study indicate a very significant difference between the manual process and the robotic process.

## 5. CONCLUSION

Based on the research conducted on the Tube Connector production process at PT. CKU, the researcher can conclude:

1. Robotic automation significantly improves production efficiency, as evidenced by the reduction in cycle time from 218 seconds to 185 seconds per unit.
2. Product quality improved significantly, as indicated by the decrease in defect rates from 2.30% to 0.30% after the use of robots.
3. Operational costs decrease because the need for operators is reduced from 3 people per shift to 1 person, thereby reducing the company's annual salary burden.
4. Production output increases because faster cycle times allow the company to produce more units in a single shift.
5. The results of the Paired Sample T-Test showed a significance value of < 0.05, proving that the performance difference between manual and automated processes is statistically significant and valid.
6. The implementation of robotics has a positive impact on process stability, with a reduction in operational variations and an improvement in product quality consistency.
7. A robotics investment of US$ 15.320 is proven to be feasible, as it provides long-term savings through reduced labor costs and increased output.
8. Overall, robotic automation is an effective strategy for enhancing productivity, cost efficiency, and production quality in the automotive manufacturing industry.

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