Equipment Replacement Analysis from Manual Line to Automatic Line in Palletizing Activities: A Case Study

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Abstract.
A decision situation often encountered by a company is whether an existing asset should be retired from use, continued in service, or replaced with new technology to improve productivity and competitiveness. The purpose of this paper is to present an equipment replacement analysis, an electronic components company. This study aims to analyze three proposed robots to automate the production line as a challenger versus an old manual production line as a defender in palletizing activities. We offered both Market and Technical analysis as well as investment analysis for evaluating an automatic line. Data are analyzed, and four methods are considered for determining project feasibility, namely NPV, IRR, Payback Period, and CBA. According to the data analysis, it is found that Borunte's robot is the best alternative compared with the others. The proposed framework of equipment analysis seems to be helpful to the company to solve equipment replacement studies.

1. Introduction
Global business competition and customer demand with high product variations create a higher level of individualization, so competition between producers increases, supporting new developments such as mass customization [1]. Global business competition pressures continue to increase, requiring higher quality goods and services, shorter response times, and other changes. A decision situation often encountered a company is whether an existing asset should be retired from use, continued in service, or replaced with new technology to improve productivity and competitiveness [2]. There are three reasons for technology replacement: physical impairment, changing requirements, and technology [3]. The technology replacement problem requires careful engineering economy analysis to provide the information needed to improve productivity, efficiency, and the competitive position of an enterprise [4-6]. An equipment replacement from manual to automate is one way to improve productivity and efficiency [7].

Automation is one of the most effective methodologies for cost-cutting. It eliminates waste as scrap, reduces the workforce, reduces time, controls quality, and improves the overall performance of
any machine, system, or process in any industry with the complete assurance of large annual profit margins [2, 5, 7, 8]. The feasibility study is needed to decide the investment of new technology of equipment. The fixed assets, such as machinery, are important decisions for a company's success because they absorb a portion of the invested capital and involve significant funds and long-term impacts. There are two factors involved in investing in equipment, namely time and risk. Before conducting a feasibility study, the aspects to be examined must first be determined. These aspects will determine whether the investment project is feasible or not to be carried out. Some previous studies related to investment feasibility analysis and technology replacement are in the references of [9-13, 21]. One feasibility study that must be done to determine whether this investment is feasible or not is a feasibility study from the financial aspect [14]. Traditionally, the ideal level of automation is determined based on monetary comparison calculations [8, 16]. The costs for automation are compared with potential financial savings [15, 16]. In some types of investment, time plays an important role, whereas risk factors are more dominant in other types of investment [17]. Research on market and marketing aspects is needed to evaluate several things to consider: demand, supply, demand and supply projections, sales projections, products, market segmentation, marketing strategies, and implementation [16, 21].

This paper presents an equipment replacement analysis for an electronic components company. PT XYZ is one of a company that produces electronic components with various types of products in Malaysia. Hard drive companies and laptop companies usually use the parts. As an impact of global business competition, there is a very tight competition in the electronic components industry. In addition, labor costs will continue to increase following the development of the country's economy, while at the same time customers do not want an increase in product prices. It is very important for companies to be able to present competitive prices to customers by not ignoring the aspect of quality. If the company cannot compete in terms of the selling price, it is possible for the customer to switch to another company. This situation encourages the company to improve productivity, efficiency, and the competitive position of an enterprise. The company considers studying an equipment replacement policy from manual to automate the production line. By using the automation system, production costs can be suppressed due to the direct labor cost that is influenced by the country's economy has been eliminated, and this is evidenced in the techno-economic analysis through NPV, IRR, Payback and CBA. The company needs to explore the manual path that uses human power in carrying out its activities into an automation path that uses robots as perpetrators of its operations. The robot that will be used has three choices: ABB's robot, Borunte's robot, and Fanuc's robot. This study aims to analyze three proposed robots to automate the production line as a challenger versus an old manual production line as a defender in palletizing activities.

2. Approaches for analysis equipment replacement
The approaches for analysis equipment replacement consist of four stages, i.e., problem identification and collecting data, development a framework of equipment analysis, feasibility and sensitivity analysis, and simulation for migration. Figure 1 shows the flowchart of the analysis equipment replacement to solve the problem.

![Figure 1. Flowchart of analysis equipment replacement](image-url)
The company currently uses direct labor in the running of palletizing activities. This allows increased production costs because labor costs are directly impacted by the country's economy. To anticipate this issue, the company plans to change the system manually for automation. System automation through robots is chosen because robots can be used for a wide range of applications and workloads, and it works continuously relentlessly, this helps companies increase operational cost efficiency and reduce downtime that positively impacts the long-term cost savings. There are 3 alternative robots to consider, such as ABB, Borunte, and FANUC robot. The problem of this is how to analyze the feasibility of 3 proposed robots for automating the production line as a challenger versus an old manual production line as a defender in palletizing activities. The variables involved can be identified by conducting in-depth interviews and study the literature. We proposed both market and technical analysis as well as investment analysis for evaluating the investment of new technology to automate the production line. There are four methods considered for determining project feasibility, namely NPV, IRR, Payback period, and CBA.

a. NPV (net present value)
The Present Net Value (NPV) method takes into account the effect of time on the value of money already entered into the calculation. NPV was chosen because this method is used as a decision making for the selection of existing alternatives. The company’s management has decided to switch direct worker into robots due to various considerations such as aspects of cost, efficiency, optimization and safety. Therefore the company wants to know which alternative is the greatest.

\[ NPV = \sum_{i=1}^{n} \frac{Cash\ Flow_i}{(1+r)^i} - Initial\ Investment \]  

b. Internal rate of return (IRR)
The Internal rate of return method is defined as the interest rate that will make the total present value and expected proceeds to be received equal to the total present value of capital expenditure.

\[ IRR = r_1 + \frac{NPV_1}{NPV_1-NPV_2} (r_2 - r_1) \]  

c. Payback period
The Payback Period (PBP) method can be interpreted as the period for the return of investments that have been issued through the profits derived from a planned project.

\[ Payback\ Period = \frac{Initial\ Investment}{Yearly\ Cash\ Flow} \]  

d. Cost Benefit Analysis
The value of the benefit-cost ratio (BCR) for the respective alternative is shown in Table 6. According to Table 6, it can be seen that all alternatives possess a BCR of more than 1, which means that investment for all three alternatives can be feasibly implemented, respectively.

\[ BC\ Ratio = \frac{total\ benefit}{total\ cost} \]  

BC Ratio ≥ 1 → investment is accepted; BC Ratio < 1 → investment is rejected.

A typical automation migration strategy is shown in Figure 2. Phase 1: manual production with single independent workstations. Phase 2: automated production stations with manual handling between stations. Phase 3: automated, integrated production with automatic handling between stations. There are three alternative automation migration strategies, namely

- A big bang is a strategy with significant risk because the replacement of manual lines to automation lines is done at one time, but the time required is short.
- A phased introduction is a balanced migration strategy because the manual line's conversion to the automation line is done in stages so that the time required is quite long, but the risk is not much.
A parallel system is the strategy with the least risk but requires a high cost because it is used to integrate various lines.

Figure 2. A typical automation migration strategy.
(Source: https://electrical-engineering-portal.com)

3. A Case Study and Discussion

3.1 Production Capacity
This section contains the calculation of production capacity in pre-cut activities for base products using cycle time data and work hours. Production activity data can be seen in Table 1 below. It is assumed there are no obstacles when the process starts running. The Production capacity can be seen in Table 2 below. Based on Table 1 and Table 2, the difference in capacity between the manual and the automation line is recognized at 150,104 units/month.

Table 1. Production activity data

| Note                        | Total (Manual) | Total (Automation) | Unit  |
|-----------------------------|----------------|--------------------|-------|
| Cycle Time                  | 92             | 90                 | Second|
| Process                     | 84             | 84                 | Second|
| Loading-Unloading           | 8              | 6                  | Second|
| 1 hour                      | 3,600          | 3,600              | Second|
| Working Hour                | 10.5           | 10.5               | Hour/shift|
| Shift/day                   | 2              | 2                  | Shift/day|
| Working Day                 | 30             | 30                 | Days   |
| Total Machine               | 274            | 274                | Machine|
Table 2. Production capacity

|                    | Manual Line  | Automation Line |
|--------------------|--------------|-----------------|
| Capacity each Hour | 39 units/hour| 40 units/hour   |
| Capacity each Shift| 411 units    | 420 units       |
| Capacity each Day  | 822 units    | 840 units       |
| Capacity each Month| 24,652 units | 25,200 units    |
| Total Capacity     | 6,754,696 units | 6,904,800 units |

3.2 Robot Specification

We proposed three (3) robots to automate the production line as a challenger versus an old manual production line as a defender in palletizing activities. There are BB's robot, Borunte's robot, and Fanuc’s robot. The specification of the robots can be seen in Table 3.

Table 3. Robot specification

| Specification | ABB | Borunte | Fanuc |
|---------------|-----|---------|-------|
| Axis          | 6   | 6       | 5     |
| Max Load Capacity (kg) | 10  | 5      | 50    |
| Reach (mm)    | 1550| 940     | 2003  |
| Power Consumption (kWh) | 0.67 | 0.75   | 2.5   |
| Price (RM)    | 81705 | 48185  | 125700 |

Source: Ref. [18-20]

3.3 Total Cost Ownership (TCO)

This section explains the total cost ownership of each alternative robot by using the data that has been collected. In this calculation, one robot used can carry out four palletizing activities, so that the total robot used is 68 robots. We assumed 15 years of a lifetime to calculate the total cost of ownership (TCO). TCO contains some data including expected life cycle, the interest rate which adjusts to the actual interest rate in Malaysia, investment cost for 68 robots, average energy consumption/year, average maintenance cost/year, and average engineer cost/year for 15 years. The TCO for each Robot is 16,221,072.82 MYR for ABB’s robot; 14,014,097.6 MYR for Borunte’s robot and 20,868,535 MYR for Fanuc’s robot.

3.4 Financial Analysis

There are four methods considered for determining project feasibility, namely net present value (NPV), internal rate of return (IRR), payback period (PP), and benefit-cost analysis (BCA). The NPV calculation uses a discount factor (or minimum attracted rate of return-MARR) of 3%, while the internal rate of return calculation uses a discount rate of 14% and 15%. The calculation of financial analysis can be seen in Table 4 and Figure 3.

Table 4. NVP robot

| Robot | NPV DF 3% | IRR (%) | PP              | BCA  |
|-------|-----------|--------|-----------------|------|
| ABB   | 7,856,828 | 14.82  | 5 Years 10 Months | 2.022 |
| Borunte | 8,272,967 | 19.67  | 4 Years 9 Months | 2.516 |
| Fanuc | 6,143,439 | 9.47   | 7 Years 10 Months | 1.521 |
3.5 Sensitivity Analysis
We also conducted a sensitivity analysis to find out how much inaccuracy the use of an assumption can be tolerated without the invalidation of the decision. The managers must determine the sensitivity of their choice to the underlying assumptions. The sensitivity analysis results of NPV, IRR, PBP, and BCR, it can be seen in Figure 4 until Figure 7. There are five scenarios; namely, income rises 25%, income rises 15%, average income, income falls 15%, and income falls 25%. From the five scenarios and the four analysis methods, it is found that the three robots are worth investing in. However, the payback period method shows that if there is a 15% decrease in income, the payback period is more than five years for the three robots. At the same time, the company only allocates a five year payback period. Therefore Borunte’s robot is the best choice for investment because when there is a 15% decline in income, the payback period for Borunte robots is still between 5-6 years. While the ABB robot and Fanuc robot under normal conditions, the payback period has exceeded five years.

Figure 4. Sensitivity analysis of NPV

Figure 5. Sensitivity analysis of IRR
3.6 Market Analysis
Over time, the trend of HDD products has decreased due to the development of storage device technology switching to SSD and Cloud technology. SSD is a storage device that uses flash memory, also known as NAND, to store data. In contrast to HDDs, which contain spinning disks, SSDs have no moving mechanical parts, and thus are more resistant to physical shock, run silently, and offer faster processing speed and response rates.

The use of robots as a substitute for operators can be an alternative because the use of company operators must pay salaries, which over time, will continue to increase following the applicable bank interest. The use of operators also has several other limitations, such as working time and national holidays. This is different from the use of robots because robots can work without any restrictions on working hours. In addition, the use of robots also has the advantage of being more flexible in various activities because they can be arranged with programming. When looking at HDD market conditions, robot investment is not feasible to apply because HDD market conditions continue to decline. However, this can change when the company also expands to the production of SSD parts that have an increasing market tendency.

3.7 Technical Analysis
In the technical aspect, there are several parameters, namely the identification of tool requirements and tool specifications. For the specification of the number of axes, the ABB robot and the Borunte robot have the same amount of axes, which is 6, while the Fanuc robot has only five axes. In palletizing activities allocated for 4 CNC machines, a robot that is flexible in various movements is needed, therefore robots with six axes are recommended compared to robots with five axes. For maximum load capacity specifications, ABB robot has a capacity of 10 kg, Borunte robot has a capacity of 5 kg, and Fanuc robot has a capacity of 50 kg. The three robots have met the specifications needed to carry out palletizing activities because of the weight of ± 300 grams. In this case, the needs of the company include covering 4 CNC machines with a range of 500 mm. All three robots have specifications that are worth investing because they can reach more than 500 mm, ABB robot has a range of 1550 mm, Borunte robot has a range of 940 mm and Fanuc robot has a range of 2008 mm. In the electricity consumption specification, ABB robot is 0.67 kWh, Borunte robot is 0.75 kWh, and Fanuc robot is 2.5 kWh. Of the three robots by considering electricity consumption, the ABB robot is recommended to be chosen because it will affect the factory overhead during the production process.

3.8 Investment Analysis
We considered four methods for determining project feasibility, namely net present value, internal rate of return, payback period, and benefit-cost ratio. Based on Table 4, it can be seen that all alternatives have the NPV value > 0. Borunte’s robot has the highest NPV value, and the lowest is Fanuc’s robot. Based on the IRR analysis, it can be seen that all alternatives have the IRR value more significant than MARR. In this case, the MARR is 3%, so all investment is feasible due to have IRR more than 3%
Both ABB’s robot, Borunte’s robot, and Fanuc’s robot are suitable for investment. Based on the payback period analysis, it can be seen that no alternatives have PBP for more than ten years. The most extended payback period of the investment of the three robots is the Fanuc robot. The fastest is the Borunte robot (Table 4). In BCR analysis, it is known that the ABB robot has a BRC value of 2,022, the BCR value for the Borunte’s robot is 2,516, and the BRC value for the Fanuc robot is 1,521. The highest BCR value is Borunte’s robot, while the lowest is the Fanuc robot. We assumed that the same amount budgets the maintenance cost of the robot. Table 7 shows that the Borunte’s robot is ranked first for investment, while the ABB robot is ranked second, and the Fanuc robot is ranked third.

### Table 5. Recapitulation of investment feasibility analysis

| Robot  | NPV   | IRR   | PP    | BCR    | Ranking |
|--------|-------|-------|-------|--------|---------|
| ABB    | second| feasible | second | second | 2       |
| Borunte| the best | feasible | the best | the best | 1       |
| Fanuc  | third | feasible | third | third | 3       |

#### 3.9 Suggestion for Migration Strategy
In this case study, the automation is carried out at the machine level because the automation is carried out in the form of installation of industrial robots for palletizing activities. The automated migration strategy that can be analyzed is the big bang strategy or phased introduction strategy due to only one activity and is not integrated with other processes. In the big bang strategy, the process of changing the manual line to the automation line is done at one time, which means the manual line will be dismissed to be replaced into the automation line. It is required seven days to replace the manual line into an automation line. It means within seven days. The production activity will be stopped in the process of installing the robot. Table 5 and Table 6 show the calculation of factory productivity during the robot installation process.

### Table 6. Simulation installing robots using the big bang strategy

| Day | Machine | Activity | Production |
|-----|---------|----------|------------|
| 1   | 120     | OFF      | 0          |
| 2   | 120     | Manual   | 129,360    |
| 3   | 120     | OFF      | 0          |
| 4   | 120     | Manual   | 129,360    |
| 5   | 120     | OFF      | 0          |
| 6   | 120     | Automation | 98,640   |
| 7   | 120     | OFF      | 0          |
| Total |         |          | 782,640    |

### Table 7. The Simulation installing robots using the phased introduction strategy

| Day | Machine | Activity | Production |
|-----|---------|----------|------------|
| 1   | 120     | OFF      | 0          |
| 2   | 120     | Manual   | 129,360    |
| 3   | 120     | OFF      | 0          |
| 4   | 120     | Automation | 98,640   |
| 5   | 120     | Automation | 98,640   |
| 6   | 120     | OFF      | 0          |
| 7   | 120     | Automation | 98,640   |
| Total |         |          | 782,640    |
The manual line will be partially terminated to be replaced into an automation line, and the other part will continue the production process, so that production does not stop. It can be seen that in the process of installing a robot using the phased introduction strategy with a duration of 7 days, a production of 782,640 is produced through a combination of manual-automation in 7 days. The time given for the robot installation process is seven days for 274 machines. By using the big-bang method in 7 days, all devices stop doing production activities. There is no product produced during the installation of the robot. Whereas with the phased introduction method, the installation of robots is divided into two stages: 120 CNC machines are stopped for the installation of 30 robots in 3 days, and 154 other CNC machines continue to run production so that within three days 388,080 products are produced. The second phase of 154 CNC machines was stopped for the installation of 34 robots in 4 days, and 120 CNC machines that had been integrated with the robot continued to carry out the production process so that in 4 days for 394,560 products were produced. It is obtained that the use of the phased introduction method is better compared to the big-bang method because there are still machines running the operation process during the installation process. This takes into consideration the large number of parts that must be produced and the cost efficiency because using parallel systems requires quite a lot of cost.

4. Conclusion
This paper presents a case study for equipment replacement analysis for improving the productivity and competitiveness of an electronic components company. This article proposed a framework of equipment analysis including market and technical analysis as well as investment analysis and considered four methods for determining project feasibility, namely net present value, internal rate of return, payback period, and benefit-cost ratio. According to the data analysis, it is found that Borunte's robot is the best alternative compare with ABB's robot and Fanuc's robot as well as with the old manual production line. For implementing the result, an automation migration strategy is needed for moving the manual line to the automation line. The use of the phased introduction method is better compared to the big-bang way. Therefore, future research is needed to consider after-tax replacement analyses, to improve the calculating of the economic life of a new asset, and to develop a model for economical replacement time.

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