Analysis of Automation Implementation in Indonesia Container Terminal

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Abstract. Indonesia container terminals have several prospect factors in implementing automation. Consider that condition, this paper provides automation parameters the are used to measure the container terminal readiness to implement automation. Those parameters also sorted out using Best-Worst Method and assisted by the experts in weighting the parameters. The four parameters in sequence order are container throughput, yard capacity, investment cost, and environment management. Besides, Indonesia container terminals must handle several constraint factors in implementing automation such as automation requires high investment, low return investment, labor conflict, incapability of Indonesia electric provider, and Human resource in Indonesia still abundant.

1. Introduction

The international maritime trade using container continue to increase over time. Based on [19], the containerization has reached 152 million TEUs. The increase of containerization also in line with the growth of container ship size. In 1968, a container ship could only accommodate 1,530 TEUs. However, as the increasing demand for containerization, the total capacity that one container ship could accommodate in 2019 reach 24,000 TEUs [5].

The containerization and ship size growth affect the container terminal to adapt to the issue by increasing its operation and service. According to this literature [2], automation could increase productivity, increase safety, reduce noise and pollution, and reduce operational expenses. From those benefits, automation could be one of the efforts that can be pursued by the container terminal.

The trend of automation in the container terminal continues to rise as it shown in Figure 1. Since 1993, automation is widely applied in many container terminals throughout the world. In 2019, there are 66 container terminals have implemented automation. According to [18], a survey result conducted by industry reveals nearly 75\% of terminal operators consider automation is necessary to remain competitive in the next three of five years. With the benefits gain from automation, it certainly could increase competitiveness between container terminals.
With the trend of automation in the container terminal as shown in Figure 1, it is very possible numerous container terminal throughout the world or in Indonesia will implement automation with different prospects and constraint. Therefore, analysis regarding Indonesia container terminal prospect factors in implementing automation and constraint factors of automation implementation conducted in this paper by asking practitioners perspectives through questionnaires. At the same time, the container terminal should know their readiness in implementing automation. Analysis regarding automation parameters carried out to measure the container terminal readiness. The container terminal is advisable to achieve the parameters step-by-step before implementing automation. Best-Worst Method applied to sort out the parameters to make the terminal easier in achieving the parameters. Experts are taking a role in weighting the parameters. This study can be used for Indonesia container terminal as a basis before implementing automation.

2. Method

The first step in this paper is to do literature studies regarding automated container terminal. The next step is to find the prospect factors and the constraint factors Indonesia container terminal to implement automation. While in this step, practitioner’s perspectives are needed to know the real condition regarding the prospect and the constraint factors of automaton implementation in Indonesia container terminal. Subsequently, this paper provides an analysis regarding automation parameters. The Best-Worst Method (BWM) applied to know the sequence order of the automation parameters. Several experts taking a role in weighting the parameters.

2.1. Automated Container Terminal

The automated container terminal was first implemented at ECT Delta, Port of Rotterdam in 1993. The container terminal was equipped with Automated Guided Vehicle (AGV) and Automated Rail Mounted Gantry (ARMG) crane [15]. Since then, many container terminals follow to embrace automation, and now automation becomes a trend in the container terminal.

Automated Container Terminal (ACT) differentiate by the level of automation. There are two levels of automation in ACT, they are semi-automated and fully-automated. According to [18] in semi-automated container terminals, the automation implemented to either Yard Crane (YC) or Horizontal Transport (HT). While in fully-automated container terminal, both YC dan HT is implemented to automation. However, as technology continues to develop, Quay Crane (QC) is lately being applied to automation. Thus, it makes QC as one of the equipment that has to be automated in fully-automated container
terminal. Both semi-automated or fully-automated container terminal gives different impacts to the container terminal. Table 1 shows the difference between semi or fully automated container terminal.

| Table 1. Comparisons Fully and Semi Automated Container Terminal |
|---------------------------------------------------------------|
| Factors                              | Fully-automated Container Terminal | Semi-automated Container Terminal |
|--------------------------------------|-----------------------------------|----------------------------------|
| Productivity                        | ++                                | +                                |
| Electricity Needs                   | -                                 | 0                                |
| Environment Protection              | ++                                | +                                |
| Initial Costs                       | -                                 | 0                                |
| Operational Cost Reduction          | ++                                | +                                |
| System Complexity                   | -                                 | 0                                |

++ = very good; + = good; 0 = moderate; - = not good

In implementing automation, the equipment will have an electric system and added with some features so it could be supervised and remotely operated from the control room, this certainly would reduce human intervention. The equipment does not require with the electric system. By all means, this will cut off operational expenses for fuel and reduce air pollution. Another operational cut off is union wages as automation reduces human intervention. However, automation will require a very high initial cost [2]. According to [9], automation could increase productivity by eliminating loss time at shift changes, meal break, and in-accurate stacking. Yet, automation has a complex system to integrate with.

2.2. Obstacle in Implementing Automation in Container Terminal

Automation implementation is challenging for the container terminal, there are several obstacles that the container has to consider before doing the implementation. According to [2] automation requires large initial costs and may generate labor conflict. The container terminal must provide investment for purchasing the equipment, training the operator, and build infrastructure to support automation. The container terminal must handle a traditional way of thought of management that reluctant to risk when facing investments in innovation. The process of implementation will take time and it may disrupt the operation of the container terminal [14] [15]. With automation, the system of the equipment will be modified to electric. Consider this issue, the container terminal has to make sure of the existence of the electric provider that could accommodate the electricity of the equipment [14].

2.3. Best-Worst Method (BWM)

Best-Worst Method (BWM) is one of Multi-Criteria Decision-Making techniques to solve a problem in several alternatives and criteria evaluated [4]. This BWM technique was created by Rezaei in 2015. The name Best-Worst Method named after the solving steps of BWM which compare the best and the worst criteria to other criteria. The experts choose the best, and the worst criteria could lead to more consistent comparisons and also mitigate the anchoring bias [12]. Expert's judgment is needed to assists in weighting parameters in BWM to sort out the parameters of automation.

3. Results and Discussion

The results and discussion of this paper divided into three subsections, the first analysis is regarding the prospect factors of automation implementation in Indonesia, then the analysis of automation parameters, and the last analysis is regarding the constraint factors that the Indonesia container terminal must handle. Those analyses explained in the next following sub-sections.

3.1. Prospects of Automation Implementation in Indonesia Container Terminal

There are several prospects Indonesia container terminal to implement automation. This paper conducts a survey to gather valid information regarding prospects of automation implementation in Indonesia that distributed to four practitioners. The result of the survey obtained five prospect factors of automation.
implementation in Indonesia container terminal. The first prospect factor is many large ships began entering Indonesia, from the literature [13] it stated that there more than 5,000 ships that have gross tonnage more than 10,000 have entered Indonesia. The second factor is Indonesia fully supports green port implementation. The green port implementation refers to Ministry of Transportation Regulation No.51/1999 Article 6 verse 2.e. The next factor is Indonesia container throughput is increasing over time, according to [20] Indonesia container throughput continues to rise, and in 2018, the container throughput reaches 12,853,000 TEUs. The last two factors are Indonesia union trade wage increase, and the number of accidents occurs in container terminal also increases. Automation will start to gain attention from many Indonesia container terminals to adapt to conditions of the increasing Indonesia container throughput, and many large ships began to enter Indonesia. Consider the benefit of automation which reduce pollution and noise, reduce operational cost and reduce accident, automation seems able to handle all the conditions and problems that is started to occur in Indonesia.

3.2. Automation Parameters
There are several parameters that are used for measuring the container terminal readiness in implementing automation. Through literature studies, there are four parameters obtained. The parameters are:

a) Container Throughput
Literature [17] stated that the number of throughput that the container terminal has to reach is 500,000 TEUs. But this only for high wage rates area. On the other side, on Port Performance Conference that was held in December 2019, Felix Kasiske said 1,000,000 TEUs/year should be the benchmark that the container terminal has to reach. An argument regarding container throughput as parameters added by Moody’s Investor Service on its report said container terminal with 1,000,000 TEUs/year or less, implementing fully-automated container terminal is not for them. It can be concluded that the amount of container throughput that the container terminal has to reach for implementing semi-automated container terminal is 1,000,000 TEUs/year, and for implementing fully-automated container terminal is 2,000,000 TEUs/year.

b) Investment Cost
Investment cost becomes one of the parameters to measure the financial readiness of the container terminal in implementing automation. Automation requires a large initial cost for purchase the automated equipment, operator training costs, and infrastructure to support automation [2]. The amount of cost that needs to be provided by the container terminal depends on the level of automation. As the level of automation getting higher, the costs need to be provided increase as well.

c) Environmental Management
In conventional container terminals, the use of loading and unloading equipment such as cranes or trucks mostly still used diesel fuel. Based on the literature [1], the emission source at the container terminal is 38% from the ship, 25% from the crane, and 26% from the truck. In addition to contributing pollution to the air, manual loading and loading equipment also causes noise from the surroundings. The container terminal shall refer to Government Regulation No.41/1999 to know the emission standard and Ministry of Environment and Forestry Decree No.28/1996 to know the noise standard.

d) Yard Capacity
One of the advantages of implementing automation at container terminals is to provide more capacity in the same space [2]. In addition to the features added, the structure also upgraded. The container terminal shall calculate the Yard Occupancy Ratio (YOR) to find out whether the container terminal has exceeded this parameter or not. The maximum value of YOR written on Directorate General of Sea Transportation Decree No.UM.002/38/18/DJPL-11.

BWM technique applied as a method in this paper to sort out the parameters that have been collected. The parameters as the criteria be weighted based on four expert judgment. The weighting result shown
the priority rank of parameters that the container terminal has to look up before implementing automation. The aggregated results are shown in Table 2.

| $j$ | Criterion                        | Preference of The Best Criterion | Preference of The Worst Criterion |
|-----|----------------------------------|----------------------------------|----------------------------------|
| $j_1$ | Container Throughput             | 1                                 | 6                                |
| $j_2$ | Investment Cost                  | 6                                 | 4                                |
| $j_3$ | Environmental Management         | 5                                 | 1                                |
| $j_4$ | Yard Capacity                    | 6                                 | 6                                |

The best and the worst criterion is compared through a pairwise comparisons with a scale 1 - 9. The result of the pairwise comparisons shown in Table 2 are used to find the optimal weight. The process using linear programming formula, consider non-negativity, and sum of the results is one. The equation is written below:

$$\text{Min } \xi$$

Subject to:

$$\left| \frac{w_B - a_{Bj}}{w_j} \right| \leq \xi , \text{ for all } j$$
$$\left| \frac{w_w - a_{wj}}{w_w} \right| \leq \xi , \text{ for all } j$$

$$\sum w_j = 1$$
$$w_j \geq 0 , \text{ for all } j$$

(1)

$\xi$ : consistency indicator

$a_{Bj}$ : the preference of the best criterion over criterion

$a_{wj}$ : the preference of the criterion over the worst criterion

$j$ : criterion

$W_j$ : weight of criterion

$W_B$ : weight of the best criterion

$W_w$ : weight of the worst criterion

The results of Eq. (1) is solved using SOLVER on Microsoft Excel. The optimal weight of the parameters shown in Table 3.

| $j$ | Criterion                        | Weight     |
|-----|----------------------------------|------------|
| $j_1$ | Container Throughput             | 62.23%     |
| $j_2$ | Yard Capacity                    | 15.04%     |
| $j_3$ | Investment Cost                  | 15.04%     |
| $j_4$ | Environmental Management         | 7.08%      |

The table 3 shows that container throughput is the first parameter that has to achieve by the container terminal with total aggregate weight of 62.23%. According to the experts, container throughput is related to the container terminal revenue, so container throughput is the key of the container terminal movement. The more container throughput in the container terminal, the more profit will be obtained. There are two parameters have identical results with total aggregate weight of 15.04% as shown in table 3. Regarding this matter, experts said that yard capacity needs to be considered first because as the throughput increase, the container terminal has to make sure if the yard capacity could accommodate the amount of throughput by calculating the yard occupancy ratio. If the yard occupancy ratio has
exceeded the maximum value of YOR that is written on Directorate General of Sea Transportation Decree No.UM.002/38/18/DJPL-11, it means the container terminal has surpassed the parameter. The third parameter that has to achieve is investment cost. If the container terminal has exceeded the first two parameters, the container terminal has to consider the container terminal financial readiness. The higher level of automation to be implemented, the more cost has to be provided by the container terminal. The last parameter is environmental management with total aggregate weight of 7.08%. Although the expert said that managing the environment should be done by many parties not only by the container terminal itself, this parameter still has to be considered by the container terminal to reduce the air pollution and noise and support the green port implementation.

3.3. Constraint Factor of Automation Implementation in Indonesia Container Terminal

Although Indonesia container terminal has prospects in implementing automation, the container terminal still has to consider the constraint factor in implementing automation. A survey conducted through a questionnaire distributed to four practitioners in different backgrounds to know the constraint factor of automation implementation in Indonesia container terminal. The result shows in Figure 2.

![Five factors that constraints Indonesia container terminal in Implementing Automation](image)

**Figure 2.** The results of the survey

According to Figure 2, the result of the survey shows that 75% of practitioners agreed that the reason why many Indonesia container terminals have not yet implemented automation is that implementing automation requires high initial costs. According to [2], the cost used for acquiring the equipment, operator training, and build infrastructure to back up the automation. 50% of the practitioners agreed that automation has a low return on investment. In literature [8] stated that the return of investment is lower than the industry norm. Another result shows that 25% of the practitioners agreed that the electric provider in Indonesia could not handle the amount of electricity needed to operates the equipment. Without any sufficient electrical power, the operation of the container terminal is not working. According to [11], Implementing automation will reduce labor to operate the equipment. 25% of the practitioners agreed that implementing automation will generate labor conflicts. Union trade will fight for their positions in the workplace. The container terminal needs to propose an agreement with the union trade and involve them in the automation project. The last result of the survey shows that 25% of practitioners agreed that human resources in Indonesia are still abundant.

4. Conclusions

Indonesia container terminals have several prospect factors in implementing automation. Those prospect factors are many large ships began entering Indonesia, Indonesia fully supports green port
implementation, Indonesia container throughput is increasing over time, Indonesia union trade wage increases, and the number of accidents occurs in container terminal also increases. Consider the prospects, Indonesia container terminals have to measure their readiness before implementing automation by achieving the automation parameters. The method of Best-Worst method applied in this paper to sort the parameters in sequence order. Four experts taking a role in weighting parameters. The four automation parameters in sequence order are container throughput, yard capacity, Investment cost, and environment management. Besides, Indonesia container terminal has several constraint factors in implementing automation. There are five factors that constraints Indonesia container terminal in implementing automation. Those factors are automation requires high initial cost, low return of investment, incapability of Indonesia electric provider in accommodating electricity in the container terminal and automation could generate labor conflict.

5. Future Research
The existence of this paper is worthwhile as a guideline for the container terminal, especially in Indonesia, to implement automation. Developments can be done for the future researcher regarding this topic such adding more detail parameters consider the internal and external factors.

6. References

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