Refrigerated Container Handling Process Design Improvement in Container Terminal Through the Implementation of Internet of Things (IoT) Using Business Process Reengineering Approach

Nadiyah Nisa Azzahra, M. Dachyar
Industrial Engineering Department
Universitas Indonesia
Depok, Indonesia
nadiyahnisaazzahra04@gmail.com, mdachyar@yahoo.com

Abstract

Refrigerated containers are used to export perishable goods, such as fruit, dairy, vegetables, fish, and meat through the main port of Tanjung Priok in Jakarta. The handling of refrigerated containers has a bigger challenge because it requires special handling so that the quality of the cargo is maintained. The current manual monitoring handling of refrigerated containers creates a high risk of damage and deterioration of cargo quality. The aim of this research is to design an improved process for handling refrigerated containers through the use of the internet of things (IoT) technology with a business process re-engineering (BPR) approach to reduce the risk of cargo damage with a real-time monitoring system. This research provides three scenarios for process improvement in handling reefer containers and resulted in different handling processing times for each scenario.

Keywords
Refrigerated Container, Container Handling, Monitoring, Internet of Things (IoT), Business Process Reengineering (BPR)

1.Introduction
Since 2016, the non-oil and gas products export value has increased with an average growth value of 11% (Badan Pusat Statistik 2018). There are five sectors of non-oil and gas industry that are leading the export trade and are able to contribute 65% of the total national export value, which is the food and beverage sector, chemicals sector, textiles and clothing sector, automotive sector, and electronics sector. The sector which has the main role in export activities is the food and beverage sector, with 41% contribution or US $ 29.91 billion export value. This data shows that the food and beverage sector has enormous potential compared to other sectors and is expected to penetrate 2% of the world's export share by 2025, according to the Minister of Trade and Industry (Indonesia.go.id 2019). In the food and beverage sector, commodity products such as fruit, dairy products, vegetables, fish, and meat had positive export trend values over the past five years. Those commodity products are categorized as perishable goods with high sensitivity to temperature, humidity, and atmospheric composition (Filina-Dawidowicz and Gajewska 2018, Shen et al. 2019). Thus, the shipping process of perishable commodities requires special container by using a refrigerated container or commonly called reefer container to maintain the quality of the cargo being transported (Stander and Dyk 2017, Ludmiła Filina-Dawidowicz et al. 2015).

The reefer container handling process poses a more significant challenge because it requires efficiency in each port terminal service (Ludmila Filina-Dawidowicz and Gajewska 2018). Therefore, maintaining variations in temperature and humidity is the most critical factor to avoid effects on product quality (Tang et al. 2019, Stander and Dyk 2017). Action must be taken immediately if temperature abnormalities occur to maintain the cargo's quality. These standard temperature abnormalities can occur due to human error with a frequency of 60-70%, technical problems (25-35%), or extreme environments (5-15%) (Ludmiła Filina-Dawidowicz et al. 2015). However, current container manual monitoring results in an inability of the authorities to respond immediately when a temperature failure is detected (Złoczowska 2018, Ludmila Filina-Dawidowicz and Gajewska 2018). Thus, it can cause cargo damage and ultimately cause losses to both the cargo owner and the port terminal (Ludmiła Filina-Dawidowicz et al. 2015).

The purpose of this study is to design improvement of the refrigerated container handling process through the implementation of the internet of things (IoT) technology with a business process re-engineering (BPR) approach to keep cargo from damage and increase the processing time efficiency at container terminals. This study was conducted using an in-depth interview method with experts in container terminal services to obtain current process flow and processing time of each particular process.

This paper proposes the improvement model by implementing information technology in monitoring process to obtain real-time information on parameters in containers, such as temperature, humidity, shock, and others, to determine the cargo condition from time to time. So that, they can take the necessary actions as quickly as possible to avoid cargo damage and cargo quality deterioration (Tang et al. 2019, Moon et al. 2015).

2. Literature Review

2.1 Container Terminal

Based on the Regulation of the Minister of Transportation of the Republic of Indonesia Number 51 of 2015, it states that the terminal is a port facility consisting of a berth and a berth or berth, a place for stacking, a place to wait and board passengers, and/or a place for loading and unloading goods (Kementerian Perhubungan Republik Indonesia 2015). Each container terminal performs four essential functions: receiving, storing, staging, and loading, either imports or exports (Cimino et al. 2017). The container terminal is referred to as an open material flow system with two external interfaces. Those interfaces are a dock for loading and unloading ships and on the land side as a place for loading and unloading trucks (Steenken et al. 2004). Terminals are considered as the most critical node in the container cargo supply chain (Azab et al. 2019).

2.2 IoT-Based Reefer Container Monitoring System

Internet of Things (IoT) was first introduced in 1999 by Kevin Ashton, which defined as a smart network infrastructure that allows many individually identifiable objects (sensors, actuators, wireless devices, etc.) to connect one another to perform tasks (Gao 2019). Another definition says that IoT refers to a network of interconnected things that have a unique identity and communicate via standard protocols (Muhammad Dachyar et al. 2019).

IoT devices in port terminal send data and receive commands from a remote-controlled device, allowing direct integration into the field through the system for improvement (Al Kaderi et al. 2019). The key IoT technology for ports has several requirements, such as high security, high reliability, high recognition rate, and high stability (Dong et al. 2013).

Currently, IoT has been applied in several world port terminals. The Nhava Sheva Gateway Terminal (NSIGT) in India used an automatic gate system supported by optical character recognition (OCR) technology to increase container handling by up to 500 trucks per hour through a single gate (JOC 2017). The Port of Rotterdam in Netherland used IoT technology in the form of sensors to collect air and weather data to determine tides and currents, temperature, wind speed and direction, air level, dock height, and visibility. Adopting this technology could save up to an hour to dock, which could save about US$ 80,000 (Port of Rotterdam 2018). The Hamburg Port Authority used smart lighting sensors that only illuminate the required area based on motion detection, which can collect and control energy consumption by adjusting factors, such as temperature, pressure, electric drive, etc. An energy efficiency system allows it to save by 12 thousand tons of CO_2 per year (Sia Partners 2016).

Several papers have also researched the application of IoT in monitoring refrigerated containers. Environmental variations that are unfavorable to the quality of goods being transported make monitoring the status of containers important (Kshirsagar 2020). The method widely used for monitoring reefer containers is by collecting information data via wireless communication technology. The wireless sensor network is considered as a reliable solution. The wireless sensor node can continuously measure the reefer container's temperature and humidity as a localized container. Data is sent by wireless sensor network (WSN) nodes and stored using remote databases and is part of a cloud service or remote server. Then, the data analysis results are presented to the user through a real-time interface

(Moon et al. 2015). Kshirsagar (2020) uses a system consisting of temperature, humidity, and gas leak sensors that can be seen respectively through an LCD screen. If there are parameters that do not match the set values, personnel will be given a warning signal. This system also has a WiFi module for sending the latest data to IoT applications. So, stakeholders can see from various places. Amrutha V. A (2015) also uses a cargo monitoring system based on the WSN. This system depicts storage data, cargo tracking systems, and temperature and humidity sensors to improve the delivery of goods without damage. The temperature of the cargo container is monitored. If the temperature exceeds the threshold value, a signal is generated automatically and data is stored. Container location and temperature details will be sent at each interval.

2.3 Business Process Re-engineering (BPR)

According to Hammer & Champy (1993), BPR is a fundamental rethink and a radical redesign of business processes to achieve increased performance and new critical measures, such as cost, quality, service, and speed. Business Process Re-engineering is also defined as a business management strategy that focuses on analyzing and designing material and information workflows and processes within an organization. This technique recommends that the old process system should be removed and replaced with a new system that is more innovative and effective (M. Dachyar and Christy 2014). BPR aims to achieve dramatic increases in company performance measures using the latest information technology (IT) to fundamentally and radically redesign business processes (M. Dachyar and Pertiwi 2020).

According to Bhaskar (2018), the BPR framework has six phases. In the first stage, top management must recognize and understand what they want and why they want it. In the second stage, a vision is needed to get the business going in the right direction. The third stage relates to benchmarking, where current processes and activities are evaluated to identify areas of focus of attention. The fourth stage is related to the transformation in which a feasibility study is carried out. The work is assessed to measure the resources needed and the changing scope from the transformation carried out. The fifth stage concerns the implementation of the BPR project. The final step is about monitoring and evaluating the whole project, where the progress of performance is monitored and the identification of areas that need modification.

There are some best practices in conducting BPR, such as task elimination, task composition, integral technology, empowerment, order assignment, reordering, specialist-generalism, integration, parallelism, and numerical involvement (Ferretti and Schiavone 2016).

3. Methods

In conducting this study, there are four major stages. In the first stage, the study of literature was carried out to formulate the background, problems, and objectives of this research. In the second stage, an in-depth interview with experts was conducted to collect and understand the current process of manual reefer container monitoring in the container terminal. Then, the current process is modeled and simulated with iGrafx software. Next stage, the result was analyzed to find the problems and weaknesses from the current model, and an interview was conducted to obtain the voice of customer (VOC). In the last stage, the existing problems are combined with the VOC to produce solution recommendations. The solutions were classified and designed in three scenarios, then modeled and simulated in iGrafx software. Finally, each scenario's result was compared with the result of the as-is process to obtain the best scenario to be implemented.

4. Data Collection

The data collection is carried out by conducting interviews to get the overall process, which will be mapped into a flow process chart (FPC) as the basis for making business process modeling. FPC is used to show step by step of the whole process using symbols that indicate the type of activity. From the FPC, the overall processes can be categorized into 22 operating processes, 2 movement processes, 4 inspection processes, and 7 delay processes. The time of each process is known by conducting interviews with stakeholders and processed statistically to determine the form of distribution and will be the input for the simulation of the As-Is process in the iGrafx software. The time of each process can be seen in Table 1 below.

Table 1. Reefer Container Monitoring Process Time

No.	Process	Time (Minutes)	No.	Process	Time (Minutes)
1	Input data of container identity	Normal (2,45;0,56)	18	Waiting for the initial readiness of the reefer unit	Uniform (0,75-1)
2	Container physical inspection	Uniform (7-8)	19	Record the setpoint temperature of the reefer unit	Uniform (0,16-0,33)
3	Container damage confirmation to container's owner	Triangular (2,3;2,8)	20	Record reefer unit plug in temperature	Uniform (0,33-0,5)
4	Provide container damage information to ship planner	Uniform (1-2)	21	Waiting for the monitoring schedule	Constant (120)
5	Input data of container condition	Normal (1,54;0,28)	22	Records reefer container monitoring time	Uniform (0,16-0,25)
6	Waiting for the result of the container's weight	Uniform (2-3)	23	Check reefer container's condition	Triangular (5;7;6,5)
7	Waiting for the results of the Truck Identification (TID) and e-Ticket inspection	Triangular (2;3;2,3)	24	Record reefer container monitoring temperature	Uniform (0,33-0,5)
8	Waiting for Container Movement Slip (CMS) allocation	Uniform (2-3)	25	Provides the abnormal temperature of the container to the control tower	Uniform (2-3)
9	Transfer container to stacking yard	Normal (6,34;1,42)	26	Contact shipping company regarding container temperature abnormalities	Weibull (7,4;8,5)
10	Check suitability of container location	Uniform (0,3-0,5)	27	Waiting for reefer container repairation	Normal (47,4;8,02)
11	Contact the control tower officer regarding the location of the container	Triangular (4;5;4,6)	28	Disconnecting the reefer connecting cable with switch (plug out)	Uniform (5-7)
12	Record the data of reefer container identity	Uniform (0,5-1)	29	Records reefer unit plug out temperature	Uniform (0,33-0,3)
13	Record container entry time	Weibull (9,39;0,22)	30	Recording reefer container exit time	Normal (0,2;0,02)
14	Check the condition of the reefer unit connecting cable	Uniform (4-5)	31	Record the final status of the reefer unit	Uniform (0,5-1)
15	Perform reefer damage reparation	Triangular (20;30;22)	32	Transfer container to quay	Normal (6,4;0,7)
16	Connect the reefer unit cable to the switch (plugin)	Uniform (5-7)	33	Identify the type of container	Uniform (1-2)
17	Turn on the reefer unit	Uniform (0,16;0,25)	34	Loading containers onto ship	Uniform (5-10)

5. Results And Discussion

5.1 Current Reefer Container Monitoring Process (As-Is)

The reefer container handling process was created using Business Process Model Notation (BPMN) to represent the overall business process. The As-Is model consists of three lanes: gate in, stacking yard, and quay. The overall process consists of 30 processes that can be seen in Figure 1 and the sub-process of monitoring activity consists of 6 processes and it will starts when entering the monitoring schedule (see Figure 2). The simulation is also validated with the face and event validity methods to see whether the model has been made appropriate and describes the actual process.

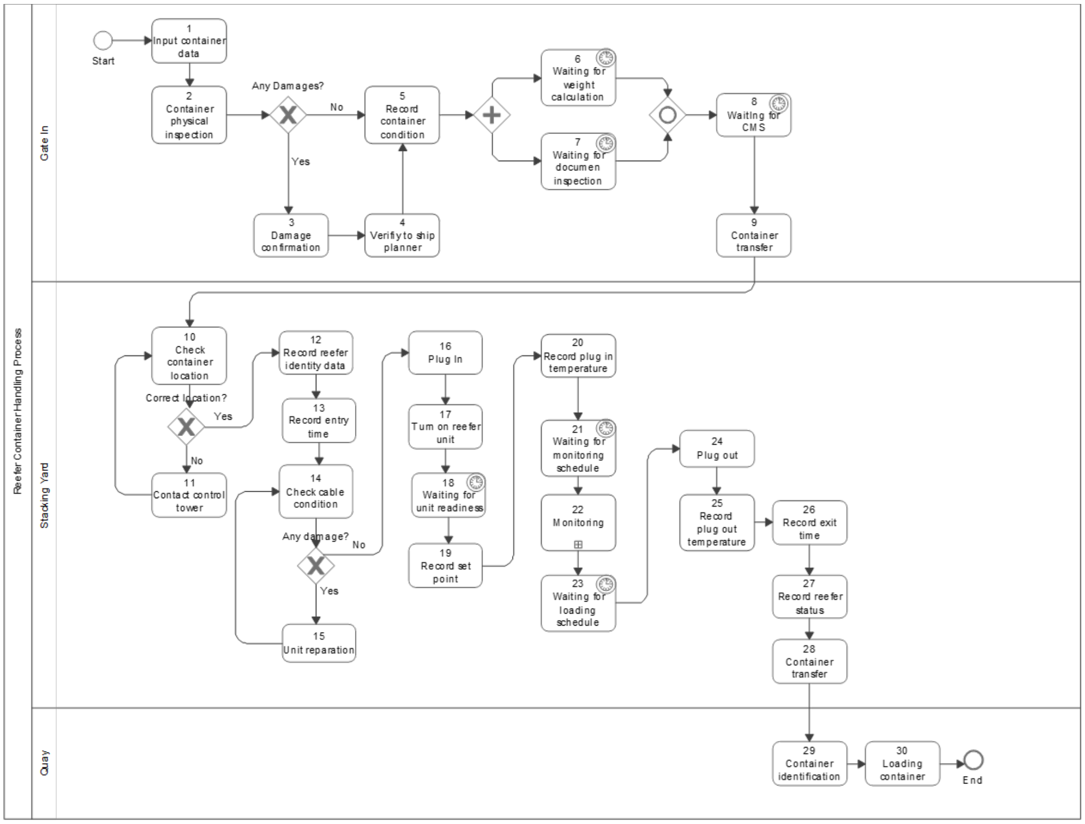

Figure 1. Current Overall Reefer Container Monitoring Process (As-Is)

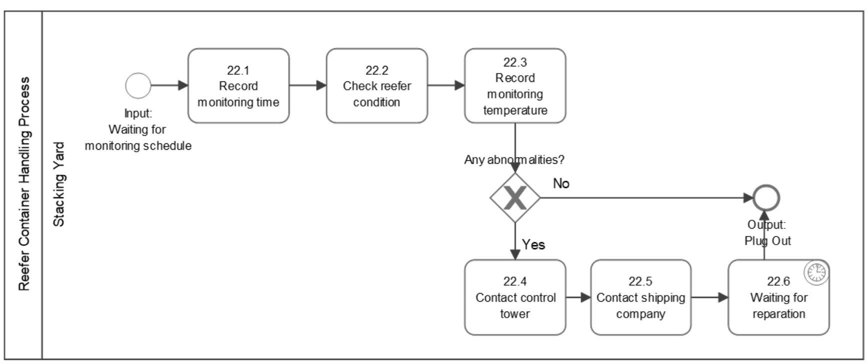

Figure 2. Current Container Reefer Monitoring Sub Process (As-Is)

The average cycle time for the overall process is 239.4 minutes and the service with the largest cycle time is the stacking yard service. There is a process of waiting for the monitoring schedule in the stacking yard as the process with the longest processing time. The detail of the As-Is simulation result can be seen in Table 2 below.

Table 2. Reefer Container Monitoring Process Simulation Result

Process	Avg. Cycle Time (minutes)
Overall Process	239.66
Gate In Service	24.72
Stacking Yard Service	204.25
Quay Service	10.69

5.2 Analysis of Current Process and Designing Solutions

Based on the current model's simulation results, improvements are made to the process by identifying processes that take a long time and also based on existing problems from interviews with experts. Several issues were encountered at the gate in service and the stacking yard, including:

- Physical inspection of containers process takes a longer time than other process in the gate service
- Recorded monitoring temperature on the report is different from the temperature shown on the screen of the reefer unit
- Manual monitoring causes the reefer man to take a long time to respond in case of container parameter abnormalities
- Error temperature setting and documents by external parties cannot be detected
- Information regarding cargo conditions must pass through several stakeholders before being received by the sender

Furthermore, the reefer handling process analysis is carried out using the voice of customers (VOC) method. VOC is divided into two types of drivers, data and information and processes. Data and information indicate reports regarding container monitoring, while the process indicates the stages or processes carried out on containers while at the container terminal. Then, solutions were made by looking at the relationship between problems and final outputs (goal) from VOC (See Table 3).

Table 3. Reefer Container Monitoring Goal-Problem-Solution

Goal	Problem	Solution
Process efficiency.	The manual inspection process at the gate in takes longer time than other processes.	Automate process using laser and OCR technology for automatic container inspection to reduce processing time.
Speed in responding to parameter changes of the reefer unit.	Manual monitoring process causes the reefer man to take a long time to respond.	Use a continuous monitoring system and present real-time reports so that corrective action can be taken immediately.
Availability of data and information in real-time to show conditions of reefer parameter.	Error temperature setting and documents by external parties cannot be detected.	Present real-time data on a web site that can be accessed by the terminal operator and senders.
Availability of accurate data and information according to actual conditions.	The recorded monitoring temperature on the report is different from the temperature on the display of the reefer unit.	Automate data input by the system for precise results.
Ease of accessing and sending data between parties and services.	Information regarding the condition and location of the cargo must pass through several parties before it is received by the party concerned.	Present information that is easily accessible and sent by various parties in an appropriate format.

5.3 Reefer Container Monitoring To-Be Process

The proposed improvement of the reefer container monitoring process is divided into three scenarios based on the classification of solutions made before. Scenario 1 and 2 have different system implementation strategies, while Scenario 3 is a combination of those systems. The detail of the scenario can be seen in Table 4.

Table 4. Reefer Container Monitoring Process Improvement Scenarios

Scenario	Container Damage Detection System	IoT-Based Monitoring System
1st Scenario	✓	
2nd Scenario		✓
3rd Scenario	✓	✓

In scenario 1 of process improvement, an automatic container damage detection system is implemented at the gate in service. At the gate in, the process that takes the longest time is the container's physical inspection because this process requires manual inspections. An automatic container damage detection system is used to speed up the inspection process. This damage detection system will scan the entire surface of the container and send data in the form of image that shows the damage's coordinates so that officers will easily know what kind of damage occurred and the damage's location accurately. In addition, this system will also automatically provide container data input, such as line number, axis number, container number, truck number, seal number, etc. So, officers do not need to enter these data manually. This system will speed up container processing at the gate in due to the reduction of manual and repetitive activity across multiple processes and reduces the risk of harm to the load due to undetected damage.

The proposed scenario 2 model is designed using an IoT-based real-time monitoring system to monitor container parameters. The monitoring process is currently carried out manually by the reefer man in the stacking yard at intervals every two hours. Based on the interviews conducted, this process has the highest risk of load damage because the reefer man cannot respond directly to temperature changes between these time intervals. Thus, the use of this real-time monitoring system will increase time efficiency due to the elimination of manual processes in terms of direct inspection of each container and in terms of recording data because it has been carried out and recorded automatically by the system. This system also increases the cargo's safety because the parameters can be monitored by two parties (container terminal and sender), notification warning alarms can also be obtained directly by both of them without the need for intermediaries. Most importantly, the response can be made immediately and remotely. This scenario will also make the processes be more transparent and accurate and minimize human errors.

The process improvement proposed in scenario 3 implements an automatic container damage detection system and an IoT-based real-time monitoring system, a combination of scenario 1 and scenario 2. The scenario 3 model can be seen in Figure 3 and the sub-process of monitoring process activity in Figure 4. The process with double lines indicates that the process will change due to the implementation of new systems. This scenario is suitable for port terminals that want to get the most in-depth overall process efficiency and get the most benefits. This scenario is suitable for port terminals with mature readiness and focused on increasing automation throughout the process.

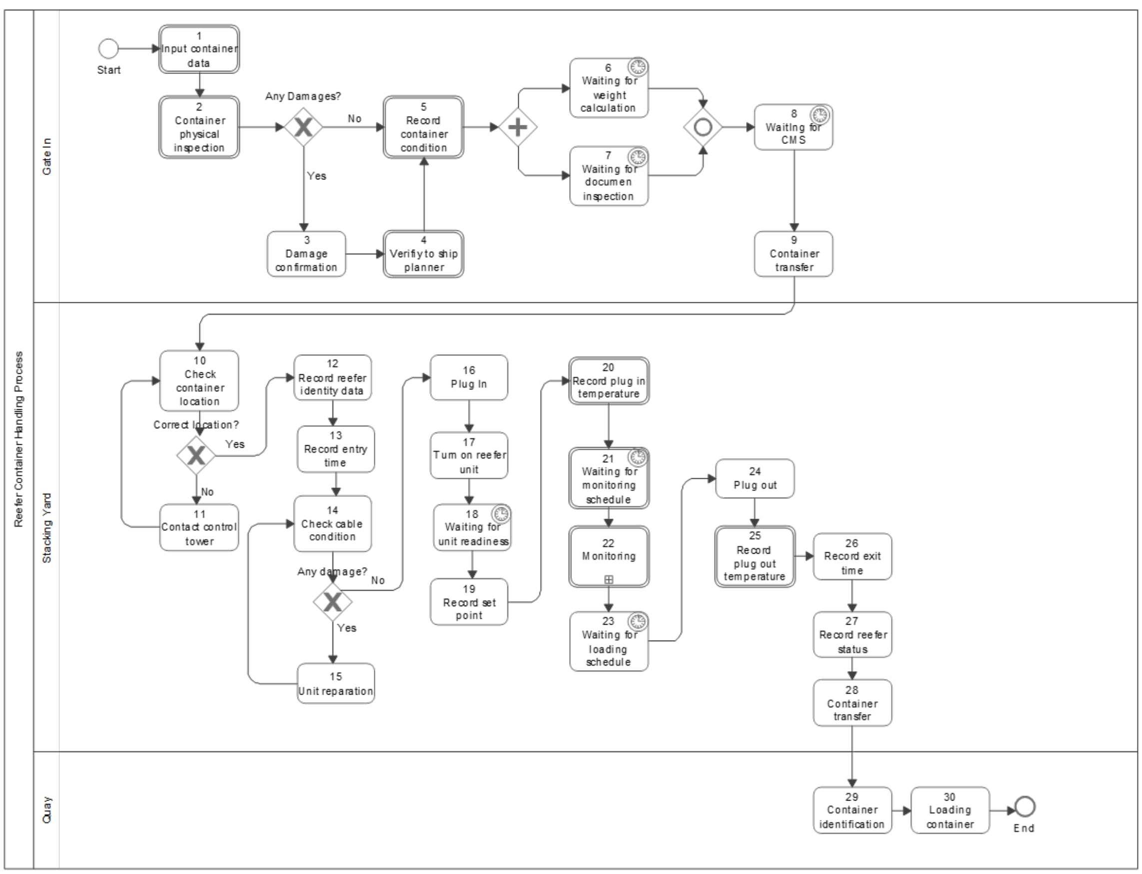

Figure 3. Scenario 3 To-Be Model Monitoring Process

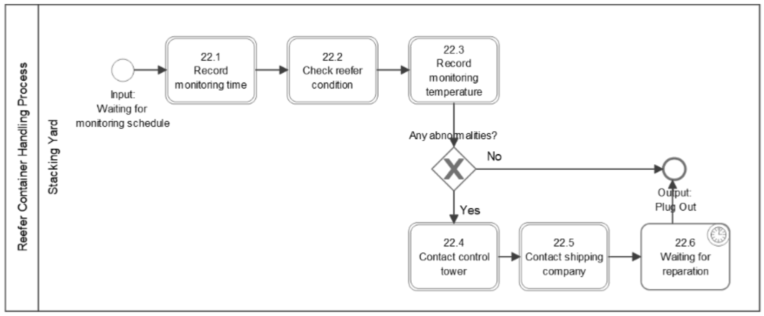

Figure 4. Scenario 3 To-Be Model Monitoring Sub Process

Table 5 below shows the result of the scenario 3 model simulation. The average cycle time for each service has been decreased because of the implementation of new systems mentioned before. The average cycle time for the overall process was reduced to 91.84 minutes.

Table 5. Scenario 3 Reefer Container Monitoring Process Simulation Result

Process	Avg. Cycle (minutes)
Overall Process	91.84
Gate In Service	13.55
Stacking Yard Service	67.60
Yard Service	10.69

After conducting the simulation, the result of each scenario proposed was compared with the As-Is model to calculate the efficiency process from the reduction of average cycle time from each scenario. The comparison of efficiency processes from scenario 1, 2, and 3 can be seen in Table 6 below.

Table 6. Time Comparison Between As-Is Model and To-Be Model Results

As-Is Process	To-Be Process		Efficiency (%)
Avg. Cycle Time (minutes)	Scenario	Avg. Cycle Time (minutes)	
	Scenario 1	3.81	4.5%
239.66	Scenario 2	1.72	56.9%
	Scenario 3	1.53	61.7%

6. Conclusion

This research proposes to improve the reefer container monitoring process, which consists of three scenarios consisting of technology integration and business process elimination. Scenario 1 uses a technology integration approach by implementing an automatic container damage detection system (ACDD). Scenario 2 uses a technology integration and process elimination approach by implementing an IoT-based reefer real-time monitoring system (RRMS). Scenario 3 is done by combining the system implementation in Scenario 1 and 2. Scenario 3 is the best scenario with a reduction in the whole process's average cycle time by 61.7% from 3.99 hours to 1.53 hours. However, the scenario that becomes the priority to be implemented in accordance with the objectives and main focus of the study, increase the ability to respond to the container’s parameters abnormality quickly, is scenario 2 with a reduction in the average cycle time of the whole process by 56.9% from 3,99 hours to 1.72 hours.

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Biographies

Nadiyah Nisa Azzahra is a research assistant at Laboratory of Management Information System and Decision Support (MISDS), Industrial Engineering Dept., Universitas Indonesia. Her research focused on Business Process Reengineering.

M. Dachyar is a Professor, and Head of Management Information System and Decision Support (MISDS) Laboratory, Industrial Engineering Dept., Universitas Indonesia. His research on management information system, decision support system, operations management, and business process reengineering.