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RESEARCH ARTICLE

ANALYSIS OF PLC-BASED AUTOMATED DOCK DOOR APPLICATION IN VEHICLE QUEUING SYSTEM OF COLD CHAIN

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ABSTRACT

Cold chain is a temperature management process to maintain the quality and safety of perishable products from the point of origin through the distribution chain to the end consumer. In 2020, almost all businesses got paralyzed because of Covid-19 pandemic, but not logistics. Due to the increasing needs of frozen food, medicine, ice cream, and other perishable products, the cold chain logistics activities are still running as usual, with several Covid-19 prevention guidelines to follow. Sadly, not all cold warehouses are equipped with the automation technology that can run automatically and obey the Covid-19 prevention guidelines. One approach that can minimize the number of employees working at the same time is a Programmable Logic Controller (PLC)-based automated dock door. This research analyzed the design of automated dock door as well as the distribution vehicle queuing system to ensure the effective distribution process with aims to determine the number of automated dock door design that should be built in the distribution process. Simulation is the approach applied in this research. The tools are CX-Programmer and CX-Designers software to analyze the design of automated dock door system and ProModel software to analyze the queuing problem of vehicles in the shipping area. Based on simulation, the number of automated dock door that should be built is 2 with the results showing that vehicles can run the distribution process according to warehouse operational time. The automated dock doors are improved by additional dock shelter as the sterilization area from Covid-19 and seal to ensure stable temperature that is set from -12°C until -15°C. This research used secondary and self-generated data to be applied to an ice cream products distribution warehouse. There is no automated dock door system in the warehouse at the initial condition of this research. The output of this research is to balance the application of automated dock door with a queuing system at a cold chain distribution warehouse so that stakeholders can decide how many automated dock doors to build. In the other hand, this application of automation technology also considers minimizing contact among employees to prevent the spread of Covid-19.

KEYWORDS

Cold Chain, Simulation, Dock Door, Programmable Logic Controllers (PLC), Queuing System.

1. INTRODUCTION

Cold chain is the process of managing the temperature of a perishable product to maintain quality and safety from the point of origin through the distribution chain to the end consumer. (GCCA, 2020). In Europe and North America in particular, the cold chain system itself is growing and developing rapidly, and it is even predicted that it will become an excellent market until 2025. With a Compound *Annual Growth Rate (CAGR) of 12.5%, it will increase market size of the cold chain from USD4.6 billion in 2020 to USD8.2 billion in 2025* (MarketsAndMarkets.com, 2020).

The main factors driving the growth of cold chains include the increasing demand for temperature-sensitive pharmaceuticals, the increasing demand for better quality food and beverages, the intensive need to reduce the waste of food and beverage consumption, the increasing demand for generic drugs due to high accessibility, and the government's focus on improving supply chain efficiency in the pharmaceutical sector, especially in Europe and North America. Cold chain is necessary for the survival of humanity because this system is involved in the distribution of food, drink, and medicine. Research on cold chain currently varies greatly; some of the examples are the development of the system, the impact it produces, the usefulness of the cold chain, and also the technology used.

In cold chain activities, there is also a distribution process, so there is a huge potential for various problems to emerge, which can unconsciously impact other aspects of the distribution process. One example is the use of technology in the loading dock area which can have an impact on queuing operational activities of transport vehicles. In this research, a system simulation will be carried out for automated dock door design and the impact for the queuing system. The results of the automated dock door design simulation will be used as the initial simulation data on the queuing system for reefer pickup. So that authors can provide appropriate

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recommendations to stakeholders in the distribution warehouse about the optimal number of automated dock doors to be built so that the queuing problem of transport vehicles in the distribution warehouse can be minimized.

2. Literature Review

2.1 Cold Storage and Loading Dock

In the activity of the ice cream product manufacturing industry, cold storage has an important role to maintain the temperature quality of the ice cream product (Lestari, 2020). As a liaison with distribution activities, a cold storage must also have a dock door that can be connected directly to the vehicle. Dock door or in other terms called loading/unloading dock/adjustable ramp is an area where the material handling process for loading and unloading products. This area is crucial in a company or even a distribution warehouse because the acceleration of product movement will be determined in the loading dock area design used. One of the most critical concerns is the dock door design. In the modern logistics concept (or the modern warehouse concept), of course, it must be able to adjust to the variations in the types of vehicles used, the conditions that occur, the company's targets, and the technology used (Andrew Garnett, 2014; Jonar, 2016).

2.2 Programmable Logic Controllers (PLC)

At the beginning of the industrial world, industrial equipment moved with an electric motor controlled by an operator. As technology developed, this system control process began to be replaced by equipment with the application of electromagnetic switches, known as conventional control systems (Omron Industrial Automation, 2020). However, this control system still has many shortcomings. This situation led to the development of Programmable Logic Controllers (PLC), a tool invented for the first time by engineers from General Motor in 1968. In the early days of its discovery, PLC was complicated to use and used a complicated language. However, PLC has experienced significant developments, and it becomes one of the most widely used tools in the industry. It is happening because PLC can work in harsh conditions with temperature fluctuations. PLC which was the first mass-produced was MODICON 084 by a company in the United States (Jonathan, 2010).

2.3 Human Machine Interface

Human Machine Interface (HMI) is a system that can be used to connect humans with a machine for monitoring and manipulating data (Omron Industrial Automation, 2020). This research uses CX-Designer software to simulate the interface system. This software offers interface system design, and that is integrated with the CX-ONE. The simulation of this software can be integrated with PLC.

2.4 Queuing System

Queuing is a common occurrence in everyday life. Some examples are the process of queuing for train ticket purchases at counters, queuing at toll road gates, queuing at bank tellers, and queuing in other situations. It should be noted that the study of queues is not a new thing; many studies, especially in industrial operations and management, examine the optimization of queues in order to achieve future improvement objectives. In fact, in the real world, most people do not like to wait even long enough, so it is no wonder that there is an opinion that waiting is the most annoying and tedious job (Rozha, 2020).

Queuing problems can be identified using ProModel software. This software is commonly used to simulate the processes regarding of system. ProModel software is a discrete event simulation technology that can be used to plan, design, and improve new or existing manufacturing systems, logistics activities, and other operational systems. It aims to describe accurately and even represent or reflect real-world processes, including inherent variability and interdependence in the entire system (ProModel Corporation, 2020). The entire system at the company will be represented in the ProModel software through defining the elements of a system model, and it is necessary to know if the following elements are a list of elements commonly used in the simulation, then there will be some adjustments later seeing the data on the existing system used (Harrell, et al., 2004). The model elements in the system include:

i. Entities

Objects that perform processes in the system and represent the inputs and outputs in the system.

ii. Location

A place visited by an entity to carry out a process, whether it is awaiting activity (queuing or doing other activities) or making decisions.

iii. Resources

Objects that help entities in carrying out processes in the system. Usually used in activities where the entity requires material handling to carry out movements and processes while in the system

iv. Arrival

Arrival is the process of the entity's arrival into the system. Usually defined by the time of arrival, the time between arrivals, and the number of entities arriving per unit time.

v. Processing

It is a stage of inputting the process of entities at each location. It is at this stage that the researcher must be meticulous in assembling the system algorithm so that the simulation can run according to the existing real system.

vi. Variable

Variable is a supporting factor that is declared to determine the existence of wasted value in the system. For example, some simulation studies are variables to determine lost customers, entities not included in the system, or defect items.

Simulation of vehicle queues for distribution activities has a similar process in each industry. The data of this research refers to a research by (Titarsole and Camerling, 2017) that aimed to maximize the utility of filling shed when servicing a gasoline tank trailer, focused on the alternative scenario of whether additional filling sheds are needed, and automation technology is not developed.

3. Research Methodology

This research is an applied research, and the output is not a new product but an application update from related research that has been done before. The stages carried out include: Studying the conditions of the existing system, looking for system or product weaknesses, modifying system or product weaknesses, and making adjustments for updating system or product applications (Zulvia, 2020). In this research, it was assumed that there is no specialized automated dock door to load the ice cream products of Company X's warehouse. This research targeted the application of a PLC-based automated dock door, complying the more effective and efficient temperature control as well as social distancing during the pandemic of Covid-19.

3.1 Dataset

The data used in simulation for this research is a secondary data from a research done in 2017 by (Titarsole & Camerling, 2017): The tank trailers queueing data at Pertamina Ambon Fuel Terminal. After adjusting, the data is used as the concept in the automated PLC-based dock door design as well as the queueing system modeling and simulation for an ice cream warehouse.

3.2 Methodology

Considering that the approach used is a simulation using ProModel software, the data processing technique involved the verification and validation steps as well as the manual computation. The first step was building a case study with 1 automated PLC-based dock door that was previously designed using CX-Programmer and CX-Designer. Then the number of provided dock-door was checked using the queuing data and the reefer pickup queueing system in ProModel software until we found the number of efficient dock door to facilitate all demand of ice cream to be distributed.

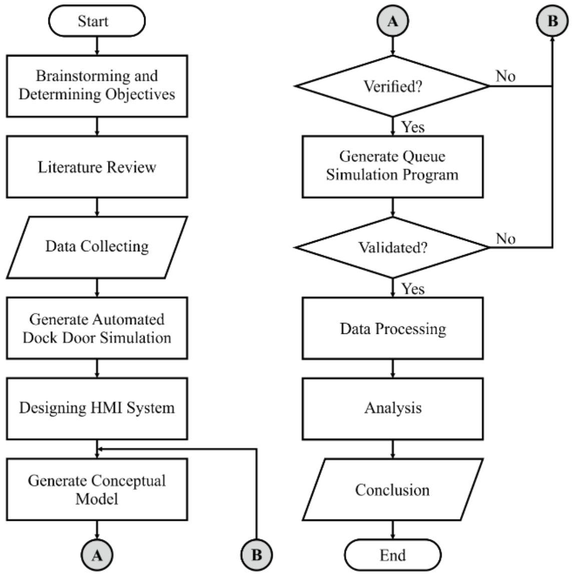

Figure 1: Research Methodology

4. Finding and Discussion

4.1 Case Study

In this research, the case study appointed is designing an automated dock door on the refrigerated supply chain in a company X, where the stages of the case study are as follows.

4.1.1 Distribution Warehouse

The real picture of the distribution warehouse area can be seen in Figure 2 below:

Figure 2: Parking Area to Loading Dock in Distribution Warehouse (Source: mmproperty.com, 2018)

The distribution warehouse specifications include:

Parking Area	: Can accommodate up to 104 vehicles
Shift	: 1 Shift (08.00 - 17.00 WIB.)
Effective Working Days	: Monday until Friday
Gate in and Gate out	: 2 slots

The operational process flow that occurs in the Distribution Warehouse is:

1) Reefer Pickup Enter

   At this initial stage, reefer pickup enters the parking area through the gate after completing the distribution process to several areas.

2) Reefer Pickup Queuing

   At this stage, reefer pickup will queue first until the loading dock is available based on the information listed on the LED Monitor board in the parking area.

3) Reefer pickup Doing Product Loading

   At this stage, reefer pickup has entered the loading dock area and carries out loading the product into the container.

4) Reefer Pickup Exit the Distribution Warehouse Area

   At this final stage, reefer pickup has finished loading the product, and it is time to distribute the product to several companies operating areas.

The distribution warehouse plans to build cold storage to distribute ice cream products in the West Java area. With a market share of 76.9% at the national level (Husaini, et al., 2019). The percentage of market share for West Java Province is:

$$\text{West Java Market Share} = \frac{\textit{Total Population of West Java (2020)}}{\textit{Projection of National Population (2020)}} \times 76.9\%$$

$$= \frac{9{,}316{,}712\ \text{(BPS Jabar,2020)}}{269{,}600{,}000\ \text{(Kusnandar, 2020)}} \times 76.9\% = 14{,}06\%$$

4.1.2 Competitor Distribution Warehouse

Based on the competitors' ice cream warehouses, it can be seen that the loading dock area of the warehouse still uses a conventional system and involves many workers in the shipping area, as shown in the following figure (DIAMONDfairIndonesia, 2016).

Figure 3: Competitors' Loading Dock (Source: (DIAMONDfairIndonesia, 2016)

Figure 4: Competitors' Shipping Area Cold Storage (Source: (DIAMONDfairIndonesia, 2016)

4.2 Collecting Data

The data collected is secondary data obtained based on literature studies and is referenced from several previous studies with similar concepts.

4.2.1 Data of Dock Door Design

In this research, the dock-door specifications refer to the dock door datasheets from the OSA Door Parts company (Part, 2020).

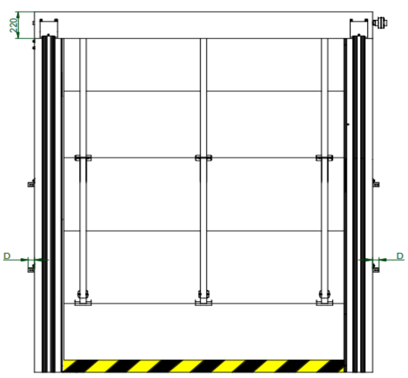

Figure 5: Front View Dock Door (Source: (Part, 2020)

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Figure 6: Top View Dock Door (Source: (Part, 2020)

4.2.2 Conceptual Model

If the entire system (operational activities) in the distribution warehouse is transformed into a conceptual model, the reefer pickup system's flow when it is operating will be illustrated, as shown in Figure 7 below.

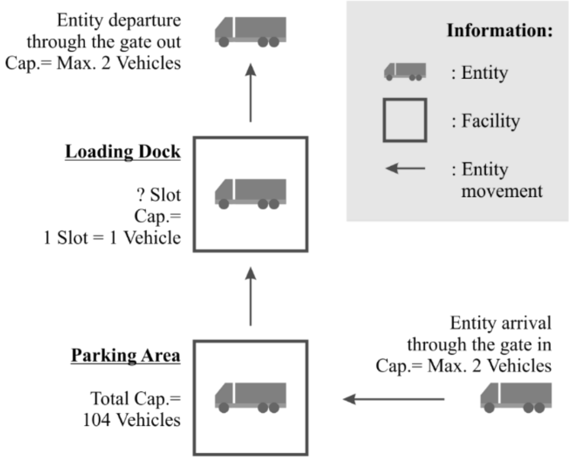

Figure 7: Conceptual Model

A literature study found that the flow pattern of entities in the system from the entrance to the exit (mmproperty.com, 2018). Entities start coming into the parking area through the entrances. Once in the parking area, entities will queue up. Then the entity moves to the loading dock when the capacity is available. In the last section, the entity will move towards the exit.

4.2.3 The Number of Reefer Pickup

Based on data from 14.06% market-share products ice cream of West Java Province and the average consumption of ice cream in Indonesia amounted to 0.8 liters per capita per year, it can be taken into account the number of vehicles needed for the activity distribution is as follows (Husaini, et al., 2019).

1) Calculation of the Total National Ice Cream Consumption (liter)

Ice Cream Consumption $= 0.8\ liter/year \times 269{,}600{,}000\ persons$

$= 215{,}680{,}000\ liter/year$

2) Calculation of Ice Cream Consumption in West Java Province (liter)

Ice Cream Consumption $= 14.06\% \times 215{,}680{,}000\ liter/year$

$= 30{,}324{,}608\ liter/year$

3) It is assumed that ice cream products will be produced every day so that the distribution warehouse will distribute ice cream products as many as

Ice Cream Distribution $= \frac{30{,}324{,}608\ liter/tahun}{240\ hari\ kerja\ efektif}$

$= 126{,}352.53\ liter/day$

4) Calculation of the Required Reefer Pickup Number

It is assumed that the reefer pickup used for distribution activities of ice cream products has the following specifications.

Reefer pickup Type = *Reefer pickup*, 3SZ VE, DOHC VVTi Liquid Cooler

Cabin Dimensions	= 237 × 155 × 129 cm
Transport Capacity	= 4000 liter
Total Dimensions	= 428 × 167 × 207 cm
Lowest Temperature	= −20°C

Figure 8: Reefer Pickup 4000 Liters (Source: (Kargo, 2020)

Number of Reefer Pickup $= \frac{126{,}352.53\ liter/day}{4000\ liter}$

$= 31.58 \approx 32$ Reefer Pickup/Day

The following is a recap of data on the number of transport vehicles taken based on the market share calculation above.

Table 1: Number of Reefer Pickup in The System

Day	Number of Reefer Pickup Arrivals	Number of Reefer Pickup in The System
Monday	32	32
Tuesday	32	32
Wednesday	32	32
Thursday	32	32
Friday	32	32
Average	**32**	**32**

The data is divided into two types: the data on the number of reefer pickup arrivals and the data on the number of reefer pickup in the system, taken from Monday to Friday. The product loading process is only carried out in 1 shift ≈ of 8 hours, from 08.00 s.d. 17.00 WIB. with rest hours starting from 12.00 s.d. 13.00 WIB. (for 1 hour).

4.2.4 Adjustment for Automated Dock Door Run Time

The automated dock door system installed on the loading dock will cause the original operating time data (based on the time of other vehicles) to change. This is because the system has a new procedure for handling reefer pickup when entering the loading dock. The reefer pickup procedure sequence when entering the loading dock to the dock door is: The reefer pickup enters the loading dock → the reefer pickup will be verified by the vehicle ID code by the proximity sensor → When the reefer pickup cabin position is stable on the dock shelter, the seal will expand → The dock shelter will sterilize the room as well as the reefer pickup cabin → after completion, the dock door will open automatically → the product can be loaded safely → the dock door will close again. Based on references from the YouTube documentary video (references are listed in the table), the run time of a dock door to operate is shown in Table 4.2 as follows.

Table 2: Automated Dock Door Run Time

Num.	Information	Run Time (Minute)
1	The time for the sensor verifying reefer pickup code. ***Invalid source specified.***	0.083
2	The time for the dock shelter deflating the seal ***Invalid source specified.***	0.3
3	The time for the dock shelter doing sterilization **Invalid source specified.**	0.3
4	The time for the automated dock door opens and closes **Invalid source specified.**	1
Total		**1.683**

4.2.5 Data of Reefer Pickup Operation Time

The following is a table of data on the operating time of the reefer pickup in the system. This data is time data obtained from literature studies with data generation and has been adjusted to automated dock door run time-based in Table 4.2.

Table 3: Reefer pickup Run Time in System

Reefer pickup -n	Reefer pickup Arrival Time (Minute)	Service Time/Reefer Pickup Loading (Minute)
1	2.86	17.22
2	2.78	16.11
3	4.02	19.7
4	2.79	16.14
5	3.14	15.9
6	2.12	17.28
7	3.23	16.12
8	3.56	21.15
9	2.12	17.35
10	1.18	18.8
11	2.37	15.51
12	1.52	17.11
13	3.87	19.31
14	3.27	20.29
15	2.36	16.23
16	3.45	20.43
17	2.49	16.19
18	3.97	18.23
19	1.67	15.36
20	2.39	19.45
21	2.47	18.31
22	1.89	17.21
23	2.77	18.26
24	1.44	15.11
25	3.94	19.14
26	3.05	19.65
27	2.85	18.33
28	2.27	20.12
29	2.81	17.28
30	3.36	16.11
31	2.12	17.21
32	3.23	18.26
Average	**2.73**	**17.78**

The time data is the initial data for this study. In another sense, the operating time data listed in the table are assumed to be the average operating time when the reefer pickup carries out distribution activities using a conventional system at the distribution warehouse. However, this data has not been added to the run time data from the application of the designed automated dock door so that adjustments need to be made to be used in data processing, both manual calculations and simulation software.

4.3 Data Processing

In this process, the data that has been obtained will be processed using several data testing and simulation software so that the final results of the research conducted can be obtained.

4.3.1 Automated Dock Door System Simulation

The results of the implementation of alternative practical work solutions to cross-study programs are in the form of a simulation design of the effectiveness of using automatic dock doors using Programmable Logic Controllers (PLC) in the perishable product industry. The automated dock door design is simulated using the CX-Programmer software.

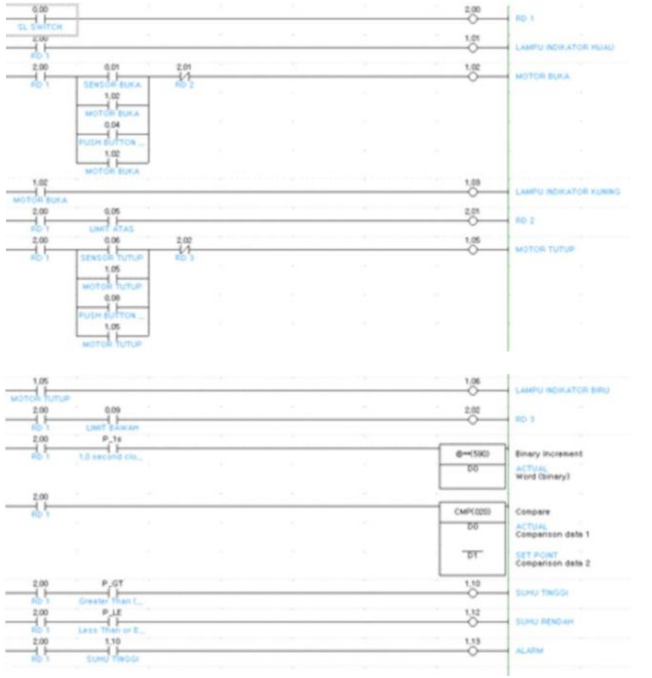

Figure 9: The Circuit System on the CX-Programmer Software

The figure above is a series of ladder diagrams of the system. The system designed consists of room temperature control and dock door control. The system intended can be simulated with two types of power: automatic mode and manual mode. When the switch selector is ON, the system will be active, indicated by a green indicator light. When the system is active, the temperature sensor will display the current temperature conditions and activate the automated dock door control system. The temperature value read by the sensor (actual condition) will be compared with the system setpoint condition (-15 °C). When the temperature is below -15 °C, this condition is called a normal condition indicated by a green temperature indicator light. When the displayed temperature exceeds (above) -15 °C, the system will turn on the purple temperature indicator light, and an alarm will sound.

When the open sensor detects a recognized reefer pickup in the dock door system, the motor will be active with a yellow indicator light on. The dock door will open upward until the upper limit sensor is HIGH. When the upper limit sensor is HIGH, the motor will stop, which is indicated by the yellow indicator light goes out. When the close sensor detects the reefer pickup engine's condition, the motor will actively move to close down, which is indicated by a blue indicator light. The dock door will continue moving downwards until the lower limit sensor is HIGH. When the lower limit sensor is HIGH, the motor will stop, which is indicated by the blue indicator light goes out. The process of controlling the dock door can be done manually by pressing the START / STOP pushbutton. Pushbutton START functions to open the dock door manually. While the STOP pushbutton functions to close the dock door manually. From a series of ladder diagrams, the system is integrated into the CX-Designer to display the HMI system on PLC. The display interface of the system that has been designed can be seen in Figure 10 below.

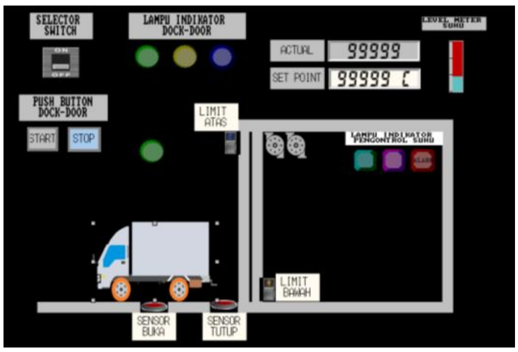

Figure 10: System View in CX-Designer Software

The system simulation in CX-Designer is used to show how the system works when applied. After the simulation process, the system is displayed in miniature through mockup design. The controller used in the mockup uses Arduino Uno, while the vehicle parking method's design uses the simulation in ProModel software.

4.3.2 Data Normality Test Using the Kolmogorov-Smirnov Method

In this initial stage, the researcher will first test the normality level of the operating time data used in the simulation. The data on the length of service time for the vehicles used are referenced based on literature studies and data generation. This test is carried out on time between arrival and service time data of the vehicle using the IBM SPSS software.

Table 4: Normality Test of Time Between Reefer Pickup Arrivals

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Time Between Arrivals	,084	32	,200*	,976	32	,683
*. This is a lower bound of the true significance.						
a. Lilliefors Significance Correction						

The following is a histogram display of the time data normality test between the reefer pickups' arrival when entering the system.

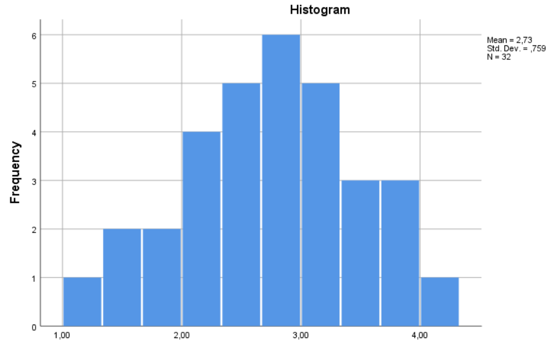

Figure 11: Time Between Arrival of Reefer Pickup Data Histogram

Based on calculations using SPSS software, it was found that the significance value using the Kolmogorov-Smirnov method was 0.200. This value has already passed the limit of 0.05, which states that H_0 is accepted or, in another sense, the data to be used is correctly distributed. Even in the histogram graph, the data also shows that the resulting curve shape is close to the normal distribution.

Table 5: Normality Test of Reefer Pickup Service Time (Loading)

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Service Time	,136	32	,142	,954	32	,189
a. Lilliefors Significance Correction						

The following is a histogram display of the normality test of the reefer pickup service time data in the loading dock area.

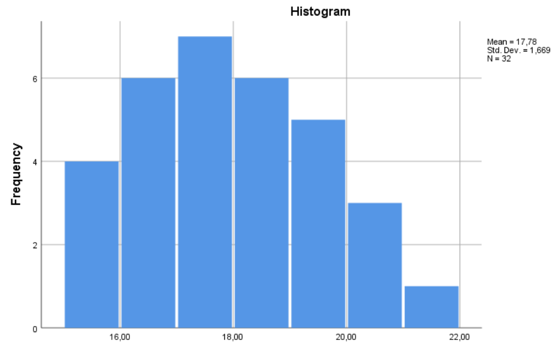

Figure 12: Data Histogram Reefer Pickup Service Time (Loading)

Based on calculations using SPSS software, it was found that the significance value using the Kolmogorov-Smirnov method was 0.142. This value has already passed the limit of 0.05, which states that H_0 is accepted or, in another sense, the data to be used is normally distributed. In the histogram graph, the data also shows a tendency to be normally distributed.

4.3.3 Manual Calculation (Before ProModel Software Simulation Test) (Scenario 1)

Average service time (Minutes)	= 17.78 ≈ **20**
Work Shift (Hours)	= 8
Operational Time	= 08.00 s.d. 17.00 WIB.
Time Off	= 12.00 s.d. 13.00 WIB.

1) The number of Automated Dock Doors is 1

- The number of Reefer Pickup served in 1 hour

$$= \frac{60\ Minutes}{Average\ service\ time\ (Minutes/Reefer\ Pickup)} \quad (1)$$

$$= \frac{60\ Minutes}{20\ Minutes}$$

= 3 Reefer Pickup

- 1 Shift

$= 8\ Hours\ \times\ 3\ Reefer\ Pickup/Hours$

= 24 Reefer Pickup/Shift/Day

2) The number of Automated Dock Doors is 2

- The number of Reefer Pickup served in 1 hour

$$= \frac{60\ Minutes}{Average\ service\ time\ (Minutes/Reefer\ Pickup)} \quad (2)$$

$$= \frac{60\ Minutes}{20\ Minutes}$$

= 3 Reefer Pickup

- The number of Reefer Pickup served by 2 automated dock doors.

$= 2\ Automatic\ Dock\ Door\ \times\ 3\ Reefer\ Pickup/Hours$

= 6 *Reefer Pickup*/Hours

- 1 Shift

$= 8\ Hours\ \times\ 6\ Pickup\ Reefer/Hours$

= 48 Reefer Pickup/Shift/Day

4.3.4 Simulation Model (Scenario 1)

This simulation model will describe the first scenario designed (loading dock area conditions with 1 automatic dock door). The first scenario system will be represented in the ProModel software by defining elements based on the conceptual model. Based on the first scenario built, the simulation model layout used in this simulation can be seen in Figure 10. In the layout drawing, a detailed description of the ice cream distribution activity at the Distribution Warehouse, where the initial process starts from the reefer pickup entering the system through the entrance (gate in), then experiencing queues the parking area. After that, the reefer pickup will enter the loading dock area to load the ice cream product to the reefer pickup cabin. Then the reefer pickup that has been filled with the product can be dispatched and exited through the gate out.

Figure 13: The layout of the Simulation Model of Ice Cream Warehouse

4.3.4.1 Entities

Entities in this system are defined as Pickup_Reefer. Pickup_Reefer is a vehicle that operates from the parking area to the loading dock. Based on the speed unit conversion, 1 km / h is equivalent to 54,680 fpm. Meanwhile, the Pickup_Reefer speed standard for operating in the distribution warehouse area no more than 30 km/hour. This speed limit is adjusted to the speed limit of vehicles in residential areas based on information from the website (Biro Komunikasi dan Informasi Publik, 2015). So that the speed of the Pickup_Reefer entity used in this simulation is 1640 fpm, as shown in the following figure.

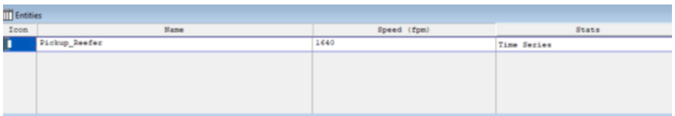

Figure 14: Entities in the Ice Cream Warehouse Simulation

4.3.4.2 Location

The location defined in this simulation consists of Pintu_Masuk, Area_Parkir, Dock_Door, and Pintu_Keluar. Pintu_Masuk and Pintu_Keluar have a capacity of 2 slots (2 Pickup_Reefer can be passed at once). Next is Area_Parkir, this location is the gathering place for Pickup_Reefer before entering the Dock_Door area, this parking area has the discipline of First in First Out (FIFO) queuing, which is the entity that comes first, then the entity will be served earlier. Then the last location is the Dock_Door area, which is the location where the Ice Cream Walls products will be loaded into the Pickup_Reefer cabin.

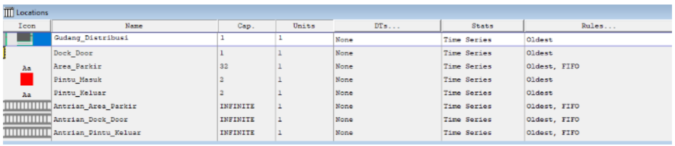

Figure 15: Location in the Ice Cream Warehouse Simulation

4.3.4.3 Arrival

Arrival in this simulation is the entity's mechanism when it enters the system. In this simulation, the defined entity is Pickup_Reefer when entering through Pintu_Masuk location. The arrival of Pickup_Reefer is defined as a Quantity Each of 1 because Pickup_Reefer enters the system one by one (discrete), the First Time component is of the Time Only type (it is simulated that the entity arrives for one day = 1 work shift = 8 hours, the running time setting is done in the simulation section. option), the Occurrences component has a value of 32, because the Pickup_Reefer that will enter the Area_P Parkir location is 32 vehicles. The Frequency component usually is distributed N (2.73, 0.747) Minutes based on time data between entity arrivals.

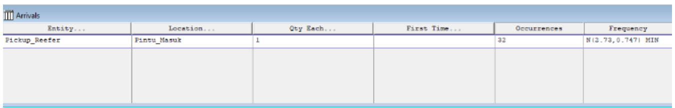

Figure 16: Entity Arrivals in the Ice Cream Warehouse Simulation

4.3.4.4 Processing

Processing is a description of the activities carried out by entities in the system, both from entering to leaving the system. In this simulation, the processes that Pickup_Reefer go through are sorted from their respective Process and Routing, where entities are processed from the location of Pintu_Masuk to exit at Exit operation.

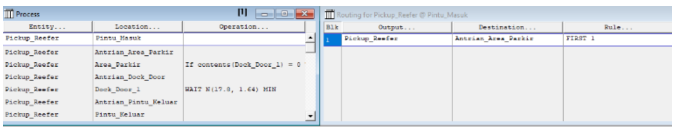

Figure 17: Process and Routing in Ice Cream Warehouse Simulation

The following is an explanation of each Pickup_Reefer operation at each location in this Ice Cream warehouse simulation model.

1) Pickup_Reefer at Pintu_Masuk

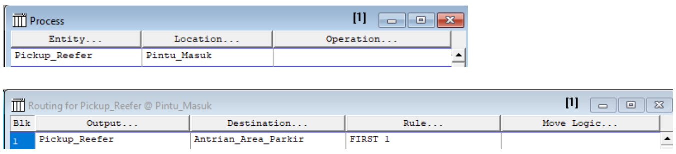

Figure 18: Process and Routing: Pintu_Masuk → Antrian_Area_Parkir

In this process, Pickup_Reefer will enter through Pintu_Masuk then through Antrian_Area_Parkir without any simultaneous operations. The location of Antrian_Area_Parkir in this simulation is to illustrate the movement of Pickup_Reefer when the simulation is run.

2) Pickup_Reefer at Antrian_Area_Parkir

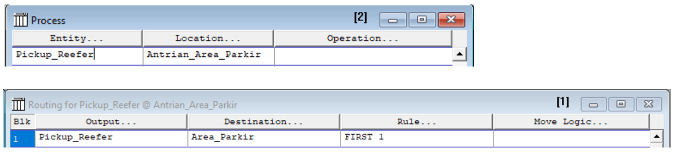

Figure 19: Process and Routing: Antrian_Area_Parkir → Area_Parkir

In this process, Pickup_Reefer will go through Antrian_Area_Parkir without any simultaneous operations. Then Pickup_Reefer arrives at the Area_Parkir location to queue or wait until the capacity on Dock_Door is available again.

3) Pickup_Reefer at Area_Parkir

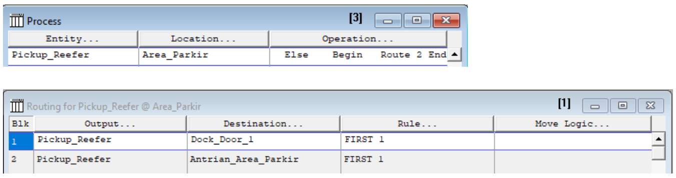

Figure 20: Process and Routing: Area_Parkir → Antrian_Dock_Door

In this process, Pickup_Reefer will queue at Area_Parkir with the simultaneous operation is the statement and function "if ... then ... else". Logically, when Pickup_Reefer enters Area_Parkir, Pickup_Reefer will first confirm the availability of vehicle capacity at Dock_Door. Suppose Dock_Door is 0 (available capacity). In that case, Pickup_Reefer can load the product on Dock_Door. However, on the other hand, if Dock_Door is other than 0 (capacity is not available), then Pickup_Reefer will queue first at Area_Parkir (In writing this operation logic, routing entities to queuing at Area_Parkir is represented by Pickup_Reefer which re-enters Antrian_Area_Parkir, this is done because the software cannot accommodate the routing processes at the same location, so it is necessary to make adjustments which are logically within the scope of a single system). Here is the operation statement.

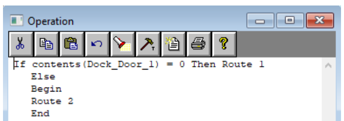

Figure 21: Operation Statement at Area_Parkir

4) Pickup_Reefer at Antrian_Dock_Door

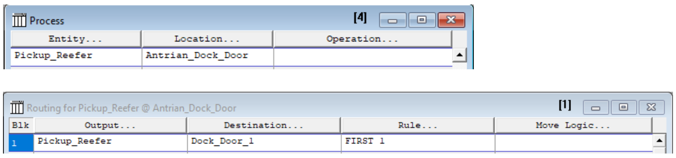

Figure 22: Process and Routing: Antrian_Dock_Door → Dock_Door

In this process, Pickup_Reefer will go through Antrian_Dock_Door without any accompanying operations until Pickup_Reefer arrives at the Dock_Door location.

5) Pickup_Reefer at Dock_Door

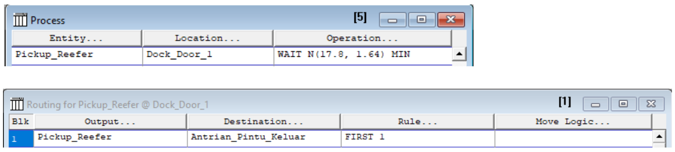

Figure 23: Process and Routing: Dock_Door → Antrian_Pintu_Keluar

In this process, Pickup_Reefer will be processed in the Dock_Door area with the simultaneous operation which is Wait N(17.8, 1.44) Minutes, which means that every Pickup_Reefer on Dock_Door will be served based on the normally distributed time. If the service (loading) process has been completed, then Pickup_Reefer will go through the Antrian_Pintu_Keluar for the departure process and will go through the Pintu_Keluar location first so that Pickup_Reefer is ready to distribute Ice Cream products.

6) Pickup_Reefer at Antrian_Pintu_Keluar

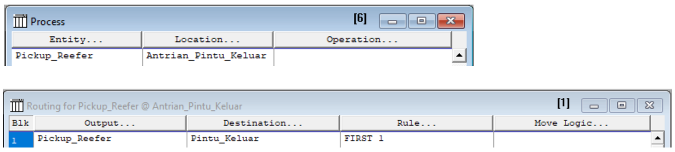

Figure 24: Process and Routing: Antrian_Pintu_Keluar → Pintu_Keluar

In this process, Pickup_Reefer will go through Antrian_Pintu_Keluar without any accompanying operations until Pickup_Reefer arrives at Pintu_Keluar location.

7) Pickup_Reefer at Pintu_Keluar

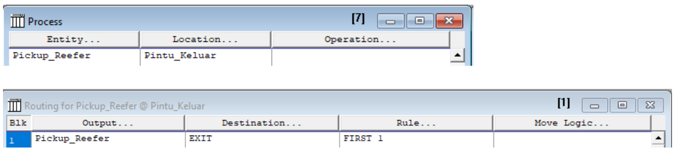

Figure 25: Process and Routing: Pintu_Keluar → Exit

In this process, Pickup_Reefer will be in Pintu_Keluar without any accompanying operations until Pickup_Reefer is dispatched via the Exit command (exit the system). When Pickup_Reefer exits the system, it means that the simulation model has finished running.

4.3.5 Determination of the Number of Replications

In a simulation study, so that there are not many data deviations, this simulation needs to be done n replications first. So, to get the value of n, it is necessary to do an initial replication of n_0, which is 10 replications, based on research conducted by (Sugiarto & Buliali, 2012). The parameter tested in this simulation model is the number of Pickup_Reefer departing from the Distribution Warehouse. In determining the number of replications, the simulation model will run as many as 10 replications with a 95% confidence level used. Information relating to replication calculations can be seen in the following table.

Table 6: The Information of Replication Calculation

Num.	Information	Value
1	*Confidence Level*	0.95
2	*Significance Level*	0.05
3	*Sample Size* (n)	10
4	n-1	9
5	$\frac{\alpha}{2}$	0.025
6	t_9, 0.025	2.26
7	$Z_{0.025}$	1.96

In Table 7 below, 10 initial replication trials were carried out by calculating the average and standard deviation of the number of Pickup_Reefer departures from the Ice Cream Warehouse.

Table 7: Data of 10 Initial Replication Calculations

Replication	Location	Number of Arrivals
1	Gate out	32
2	Gate out	32
3	Gate out	32
4	Gate out	32
5	Gate out	32
6	Gate out	32
7	Gate out	32
8	Gate out	32
9	Gate out	32
10	Gate out	32
Average		**32**
Standard Deviation		**0**

Calculation of confidence intervals:

$$hW = \frac{t_{n-1,\frac{\alpha}{2}} \times s}{\sqrt{n}} = \frac{2.26 \times 0}{\sqrt{10}} = 0 \approx e \quad (3)$$

Next, the number of estimation will be calculated, which will be used in the simulation as the replication value.

$$n` = \left(\frac{Z_{\frac{\alpha}{2}} \times s}{e}\right)^2 = \left(\frac{1.96 \times 0}{0}\right)^2 = 0 \quad (4)$$

Based on the calculation results, the replication result is 0. It can be concluded that the replication value that will be input in the simulation model of the Ice Cream Warehouse is 1 replication.

4.3.6 Verification

Verification that is carried out in the simulation process aims to determine whether the simulation model that has been designed in the ProModel software is following the conceptual model (Harrell, et al., 2004). The verification process carried out in this simulation is to ensure the flow of the system and errors in each simulation process, starting from the Pintu_Masuk location to the Pintu_Keluar location using the trace and debug features. Figure 7 is the result of checking the model using the trace feature when the simulation is run.

Figure 6: Tracing Process of Ice Cream Warehouse Model Simulation

These results indicate that there are no errors in the ProModel element when the simulation is run. For example, at 00:01:668, it is shown that Dock_Door capacity is available so that Pickup_Reefer can enter the Dock_Door area according to the set operating time, which is distributed N(17.8, 1.64) Minutes and at that simulation time the running operating time is 15.945 Minute. Besides, if Dock_Door capacity is not available, according to the logic of the operation, Pickup_Reefer will return to Antrian_Area_Parkir (where this process is considered the same as Pickup_Reefer when queuing at Area_Parkir) until the capacity of Dock_Door is available again. Besides, a debugging process is carried out to ensure there are no errors in the simulation model that has been created. The debugging process in this simulation can be seen in Figure 7 below.

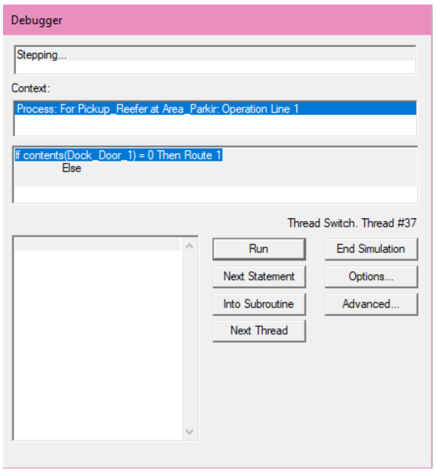

Figure 7: Debugging Process of Ice Cream Warehouse Model Simulation

Through the debugging process, it can be concluded that in the Context bar which states that there is a process when Pickup_Reefer is in the Area_Parkir location, the process of determining Pickup_Reefer to enter Dock_Door is being carried out based on the available capacity. This corresponds to the operation statement that has been entered in processing.

4.3.7 Validation

Validation in the simulation process aims to determine whether the simulation model that has been designed truly reflects the real system (existing) (Harrell, et al., 2004). The validation process in this simulation model is carried out by comparing the behaviour of the entities in the simulation model with the real conditions (existing) in the Distribution Warehouse, Mega Distribution Center based on the documentary video (mmproperty.com, 2018). Besides, the validation process can also be carried out by conducting interviews with experts who have more knowledge about operational activities at the Distribution Warehouse, Mega Distribution Center, but this was not done considering the time and research situation that was not possible at this time.

4.4 Analysis

Based on the processed data, the results obtained will be analyzed to determine the conclusions of this research.

4.4.1 Analysis of Automated Dock Door Design

Based on the simulation of the dock door system that has been designed in the CX-Designer software, the dock door will work if there is a registered reefer pickup approaching the dock shelter (the dock door system identifies the arrival of the reefer pickup via a proximity sensor embedded around the dock shelter). A registered reefer pickup is a vehicle that is indeed recognized by the automatic dock door system, which is a vehicle that has a unique identification or ID from the Distribution Warehouse. The ID will be verified in advance by the reader sensor embedded together with the proximity sensor. Once verified, the dock door system will activate chamber sterilization mode (as an effort to prevent the spread of Covid-19 by spraying disinfectant on the reefer pickup that enters the dock shelter) together with the seal on the lip of the shelter will actively expand (this expanding seal serves to compress the air so that the temperature between the cold storage and the outside storage area can be maintained during the loading process of the Ice Cream product into the reefer pickup cabin). Besides, this automatic dock door system also has a temperature sensor that functions to detect changes in temperature extremes, so that the dock door system can provide a marker when the temperature is unstable through the LED monitor information display and an alarm (buzzer) that will light up during the product loading process. Take place. So if the temperature in the dock door area and the dock shelter (actual) experiences a difference from the set temperature setpoint (for example: -15 °C), the dock door will close for a while until the actual temperature returns to the set point. The automated dock door system design can be seen in Figure 4.27 below.

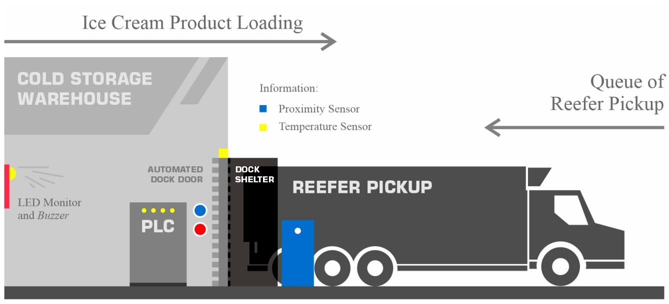

Figure 28: Automated Dock Door Schematic

The authors conclude that the system is very significant to apply not only to the distribution of ice cream products but also to other cold chains, such as fresh food and beverage products, medicinal products, and pharmaceuticals, or even meat and dairy products. Meanwhile, the use of a dock shelter, as well as a sterilization chamber, can also be applied to distribution cases in general, this is quite impactful and is one of the industry's efforts to prevent the spread of the Covid-19 considering the conditions in 2020 are currently happening in the Covid-19 pandemic.

4.4.2 Manual Calculation Analysis (Before ProModel Software Simulation Test)

Based on the results of manual calculations, the use of 1 automated dock door cannot have a significant effect on the queuing system at the Ice Cream Warehouse. By using the calculation of service time for 20 minutes/reefer pickup, then in 1 work shift (8 hours/day) of the warehouse, the automated dock door is only able to serve as many as 24 reefer pickups. This means that 8 reefer pickups cannot be served per day. In this case, the distribution warehouse can determine whether it is better to add additional automatic dock door facilities or implement other alternative solutions, such as adding work shifts, increasing vehicle capacity.

This research simulates the calculation by adding automatic dock doors, so that the number of automated dock doors is currently 2 and the result is that the two automatic dock doors can serve up to 48 reefer pickups/day. This indicates that the Ice Cream Warehouse is capable of handling 32 reefer pickup queues per day. However, it should be reconsidered that the distribution warehouse capability is 48 reefer pickups/day, while the market share of Ice Cream of West Java Province only requires 32 reefer pickups/day, of course, this will cause idle time for the distribution warehouse. This condition can be further research on cost efficiency.

4.4.3 Analysis of the Queuing System Simulation Model Scenario 1 (ProModel Software)

Based on the simulation of manual calculations that have been carried out with scenario 1, where the system being built is a new system (the simulation is tested using 1 dock door). So to get more accurate results, a simulation test was carried out using ProModel Software. The results are also shown in Entity Activity, where 26 reefer pickups were successfully served, while 6 reefer pickups were still in the system. Based on these results, it can be concluded that the use of 1 automatic dock door is not significant enough to provide good service for all existing reefer pickups so that all reefer pickups cannot be served optimally in the 8-hour simulation test (1 work shift/day). The results of the entity's activities can be seen in the following figure.

ENTITY ACTIVITY

Entity Name	Total Exits	Current Quantity In System	Average Minutes In System	Average Minutes In Move Logic	Average Minutes Wait For Res, etc.	Average Minutes In Operation	Average Minutes Blocked
Pickup Reefer	26	6	198.73	0.0	0.0	117.44	81.29

Figure 29: General Report-Entity Activity of 1 Dock Door Simulation Model

4.4.4 Analysis of the Queuing System Simulation Model Scenario 2 (ProModel Software)

Simulation with scenario 1 has shown less than optimal results for the queuing system at the Ice Cream Warehouse, so the author tries to develop a scenario by adding 2 automatic dock doors. Then the results obtained in the entity's activities, 32 reefer pickups were successfully served. Based on these results, it can be concluded that the use of 2 automatic dock doors is quite effective in providing good service for all existing reefer pickups because all reefer pickups can be served maximally in the 8-hour simulation test (1 work shift/day). The results of the entity's activities can be seen in the following figure.

ENTITY ACTIVITY

Entity Name	Total Exits	Current Quantity In System	Average Minutes In System	Average Minutes In Move Logic	Average Minutes Wait For Res, etc.	Average Minutes In Operation	Average Minutes Blocked
Pickup Reefer	32	0	108.90	0.0	0.0	82.22	26.68

Figure 30: General Report-Entity Activity of 2 Dock Door Simulation Model

However, with the addition of 2 automated dock doors, the total time used by the two automatic dock doors to serve all reefer pickups in 8 hours (1 work shift/day) is only around 4.76 hours. This means that the automatic dock door is idle for 3.24 hours/day. For this reason, the distribution warehouse needs to reconsider the selection of a more appropriate alternative solution to optimize the queuing system in the warehouse distribution operational activities.

LOCATION STATES BY PERCENTAGE (Single Capacity/Tanks)

Location Name	Scheduled Hours	% Operation	% Setup	% Idle	% Waiting	% Blocked	% Down
Gudang Distribusi	4.76	0.0	0.0	100.00	0.0	0.0	0.0
Dock Door 1	4.76	99.11	0.0	0.89	0.0	0.0	0.0
Dock Door 2	4.76	98.02	0.0	1.98	0.0	0.0	0.0

Figure 31: General Report-Location States by Percentages of 2 Dock Door Simulation Model

5. Conclusion

The simulation of an automated dock door system based on PLC is carried out by designing a system ladder diagram in the CX-Programmer software to describe the system control logic. Meanwhile, the HMI system display is simulated in the CX-Designer software. The impact generated by the use of an automated dock door system in the distribution warehouse is that it is an easy process compared to conventional systems. This is because workers do not need to exert excessive force to open and close the dock door manually. The entire automated dock door system has been arranged to run automatically with the following procedure:

1) Reefer pickup enters the loading dock;
2) Reefer pickup will be verified vehicle ID code by the proximity sensor;
3) when the reefer pickup cabin position is stable on the dock shelter, the seal will expand;
4) the dock shelter will sterilize the room as well as the reefer pickup cabin;
5) When finished, the dock door will open automatically;
6) Products can be loaded safely;
7) the dock door will close again;
8) Reefer pickup distributes Ice Cream products.

With this procedure, the reefer pickup queue can be minimized. Recommendations that can be given for the construction of loading docks are 2 dock doors, because based on the simulation scenario that has been carried out, with 2 dock doors all reefer pickups operating to distribute Ice Cream can be served according to the operational time set by the Distribution Warehouse.

For further research, this research can be developed by adding an analysis that can be approached on the factors of development costs, profits to be generated by the company, the ergonomics of workers, and the quality of the perishable products that are distributed through automated dock doors based-PLC.

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