Synchronization Model of Sea Transport Scheduling of Pioneer Ship and Sea Toll: Case Study at Maluku

Dika Virginia Devintasari1,2 Irwan Tri Yunianto1,3 Eka Wahyu Ardhi1,4 and Ilham Muliana Rahman1,5

1Department of Marine Transportation Engineering, Institut Teknologi Sepuluh Nopember Surabaya, Indonesia, 60111 Keputih, Surabaya, Indonesia
2 dika.virginia@its.ac.id
3 irwan@seatrans.its.ac.id
4 ekawahyu@seatrans.its.ac.id
5 ilhamrmt15@gmail.com

Abstract. Sea transportation is the only vessels connected to islands in Indonesia, especially Pioneer Shipping that has an important role to connect the smaller and isolated islands to reduce price disparity. Pioneer shipping becomes a Feeder Vessel from Sea Toll and Pelni Passenger Ship that must be maintained reliability of scheduling accuracy in accordance with ministerial regulation number 37 of 2015. The aim of this research is to create a model of synchronization ship scheduling that considers to the arrival of the main ship (sea toll and pelni passenger ship) with feeder vessel (pioneer shipping) that can determine the impact financially for users (passengers and shipper) and ship operators. Agent-based simulation methods are used in this research to obtain scheduled arrivals and departures of ships using AnyLogic Software 8.7.4 (Personal Learning Edition). Therefore, schedule is considering the synchronization between the departure and arrival of the main ship (sea toll transportation and passenger transport) with the feeder (pioneering transport) ship.

Indonesia is the largest island in the world with a total of 17,504 island. Therefore, Sea transportation has a significant role for Indonesia to improve people's welfare and connect the islands so that the economy growth significantly. Several programs have been run by the government to achieve the goal such as pendulum Nusantara in 2012, Sea Toll Program in 2015 as well as the provision of subsidies for pioneer shipping and economy class PT. PELNI’s passenger ships.

The Tol Laut (sea toll) has been applied and currently consists of 13 routes in which containerized goods are shipped to remote areas. On these routes, the Tol Laut is accelerating the containerization process in underserved regions (3TP, Lagging, Outermost, Remote and Border) to enhance linkages into domestic trade networks. Pioneers shipping is a feeder vessel for sea toll and passenger ship that serves as a means and infrastructure for community mobility and goods in the islands. One of them is Maluku province that consist of 696 islands and 55 ports. Ports in Maluku have the most connectivity between sea toll routes and pioneer shipping routes.
Table 1. Number of connectivity between Pioneer Shipping and Sea Toll

| No | Port     | Province       | Number of Routes |
|----|----------|----------------|------------------|
| 1  | Saumlaki | Maluku         | 18               |
| 2  | Tual     | Maluku         | 16               |
| 3  | Bitung   | Sulawesi Utara | 14               |
| 4  | Makassar | Sulawesi Selatan | 13               |
| 5  | Dobo     | Maluku         | 13               |
| 6  | Ambon    | Maluku         | 13               |
| 7  | Tanjung Perak | Jawa Timur | 12               |
| 8  | Tepa     | Maluku         | 12               |
| 9  | Sorong   | Papua Barat    | 12               |
| 10 | Kisor    | Maluku         | 11               |

Maluku province has greater connectivity than other provinces. It also has implemented in the connectivity of the Sea Toll route with the Pioneer shipping route, there are H-2, H-3, T-9 and T-12, since 2019 which have connected to 32 pioneer shipping routes that serving ports in the Maluku region and 6 PSO (Passenger Ships). Therefore, this connectivity must be maintained in which consist of determining the schedule to facilitate economic activities, improving the mobility of residents in the area and providing benefits for ship operators and service users.

In 2019, the realization of pioneering freight voyages and sea tolls were less than 70% of the targets set in the Pioneer Transportation and Sea Toll Transportation Decree. The inability is due to the waiting time for ships at the port to meet the amount of cargo that must be transported. As a result, the ship was experiencing delays to arrive at the next port which would also have an impact on the shipper. Such as condition certainly have a financial impact on service users or ship operators. Therefore, a ship scheduling study is required according to consider synchronization between the departure and arrival of the main ship (sea toll transportation and passenger transport) with the feeder (pioneering transport) ship.

1. Overview

In this study, the routes used in the analysis are ones that operated by PT. Pelni in 2019 include R-49, R-50, R-52, R-60, R-61 for pioneer shipping, H-3 and T-12 for sea toll and KM. Tidar and KM. Leuser routes for passenger ship with the following specifications.

1.1. Pioneer Ship Route R-49

Pioneer Ship Route R-49 serves several ports which are Ambon - Tual - Elat - Molu - Larat - Rumyaan - Tutukembong - Saumlaki - Adaut - Seira - Dawelor Dawera - Kroing - Masela - Saumlaki - Tutukembong - Sofyanin - Larat - Molu - Elat - Tual that served by KM Sabuk Nusantara 103 with route specifications below.

Table 2. R-49 Route Specification

| Item            | Value | Unit |
|-----------------|-------|------|
| Freq            | 22    | Times|
| Roundtrip days  | 14    | Days |
| Number of Segment | 20   | Unit |
| Port of Destination | 14  | Unit |
| Total Distance  | 1490  | Nm   |
| Number of Passenger / Year | 11,191 | Pax |
| Number of Goods / Year   | 5,596 | Ton  |
| Speed (Vs)       | 8.53  | Knot |
1.2. Pioneer Ship Route R-50
Pioneer Ship Route R-50 serves several ports which are Ambon - Amahai - Serui - Nila - Teon - Bebar - Wulur - Tepa - Lelang - Luang - Lakor - Moa - Leti - Kaisar - Ilwaki - Lirang - Kupang - Lirang - Ilwaki - Kaisar - Leti - Moa - Lakor - Luang - Mahuleta - Tepa - Wulur - Bebar - Teon - Nila - Serui – Amahai that served by KM Sabuk Nusantara 87 with route specifications below.

| Table 3. R-50 Route Specification |
|-----------------------------------|
| Item                              | Value  | Unit  |
| Freq                              | 22     | Times |
| Roundtrip days                    | 18     | Days  |
| Number of Segment                 | 32     | Unit  |
| Port of Destination               | 18     | Unit  |
| Total Distance                    | 1,918  | Nm    |
| Number of Passenger / Year        | 11,090 | Pax   |
| Number of Goods / Year            | 5,545  | Ton   |
| Speed (Vs)                        | 8.54   | Knot  |

1.3. Pioneer Ship Route R-52
Pioneer Ship Route R-52 serves several ports which are Ambon - Bebar - Wulur - Romang - Kisar - Leti - Moa - Lakor - Luang - Lelang - Tepa - Lewa - Dawelor Dawera - Kroing - Masela - Saumlaki – Tual that served by KM Sabuk Nusantara 71 with route specifications below.

| Table 4. R-52 Route Specification |
|-----------------------------------|
| Item                              | Value  | Unit  |
| Freq                              | 24     | Times |
| Roundtrip days                    | 14     | Days  |
| Number of Segment                 | 17     | Unit  |
| Port of Destination               | 17     | Unit  |
| Total Distance                    | 1,158  | Nm    |
| Number of Passenger / Year        | 16,930 | Pax   |
| Number of Goods / Year            | 8,465  | Ton   |
| Speed (Vs)                        | 8.89   | Knot  |

1.4. Pioneer Ship Route R-60
Pioneer Ship Route R-60 serves several ports which are Saumlaki - Larat - Molu - Ambon - Ambalau - Namrole - Lekula - Namrole - Ambalau - Ambon - Molu - Larat - Rumyaan – Tutukembong that served by KM Sabuk Nusantara 72 with route specifications below.

| Table 5. R-60 Route Specification |
|-----------------------------------|
| Item                              | Value  | Unit  |
| Freq                              | 19     | Times |
| Roundtrip days                    | 14     | Days  |
| Number of Segment                 | 14     | Unit  |
| Port of Destination               | 9      | Unit  |
| Total Distance                    | 1,276  | Nm    |
| Number of Passenger / Year        | 17,073 | Pax   |
| Number of Goods / Year            | 8,537  | Ton   |
| Speed (Vs)                        | 9.24   | Knot  |

1.5. Pioneer Ship Route R-61
Pioneer Ship Route R-61 serves several ports which are Saumlaki - Dawelor Dawera - Tepa - Bebar - Lelang - Moa - Leti - Kisar - Romang - Sitularang - Lerokis - Upisera - Irwati - Kupang - Irwati - Upisera - Darokis - Arwala - Romang - Kisar - Leti - Moa - Lelang - Ulur - Tepa - Dawelor Dawera that served by KM Sabuk Nusantara 104 with route specifications below.
Table 6. R-61 Route Specification

| Item                  | Value | Unit |
|-----------------------|-------|------|
| Freq                  | 21    | Times|
| Roundtrip days        | 13    | Days |
| Number of Segment     | 26    | Unit |
| Port of Destination   | 17    | Unit |
| Total Distance        | 1,676 | Nm   |
| Number of Passenger / Year | 10,381 | Pax |
| Number of Goods / Year| 5,191 | Ton  |
| Speed (Vs)            | 8.04  | Knot |

1.6. Sea Toll Route H-3

Sea Toll Route H-3 serves several ports which are Tanjung Perak – Tenau/Kupang - Saumlaki - Dobo that served by KM Logistik Nusantara 6 with route specifications below.

Table 7. H-3 Route Specification

| Item                  | Value | Unit |
|-----------------------|-------|------|
| Freq                  | 19    | Times|
| Roundtrip days        | 19    | Days |
| Number of Segment     | 4     | Unit |
| Port of Destination   | 4     | Unit |
| Total Distance        | 3,094 | Nm   |
| Number of TEUs / Voyage | 99 | TEUs |
| Speed (Vs)            | 7.49  | Knot |

1.7. Sea Toll Route T-12

Sea Toll Route T-12 serves several ports which are Tanjung Perak – Kalabahi - Kisar – Moa – Tepa – Larat that served by KM Kendhaga Nusantara 5 with route specifications below.

Table 8. T-12 Route Specification

| Item                  | Value | Unit |
|-----------------------|-------|------|
| Freq                  | 19    | Times|
| Roundtrip days        | 19    | Days |
| Number of Segment     | 6     | Unit |
| Port of Destination   | 6     | Unit |
| Total Distance        | 2,422 | Nm   |
| Number of TEUs / Voyage | 63 | TEUs |
| Speed (Vs)            | 6.73  | Knot |

1.8. Passenger Ship Route KM. Tidar

Passenger Ship Route KM. Tidar serves several ports which are Makassar - Bau-Bau - Namlea - Ambon - Tual - Dobo - Kaimana - Fak-Fak - Sorong - Manokwari - Nabire - Manokwari - Sorong - Fak-Fak - Kaimana - Dobo - Tual - Ambon - Namlea - Bau-Bau with route specifications below.

Table 9. KM. Tidar Route Spesification

| Item                  | Value | Unit |
|-----------------------|-------|------|
| Freq                  | 20    | Times|
| Roundtrip days        | 17    | Days |
| Number of Segment     | 20    | Unit |
| Port of Destination   | 11    | Unit |
| Total Distance        | 4,198 | Nm   |
| Number of Passenger / Voyage | 13,659 | Pax |
| Speed (Vs)            | 20    | Knot |
1.9. Passenger Ship Route KM. Leuser

Passenger Ship Route KM. Leuser serves several ports which are Surabaya - Benoa - Bima - Labuan Bajo - Makassar - Bau-Bau - Wanci - Namrole - Ambon - Saumlaki - Tual - Dobo - Timika - Agats - Merauke - Agats - Timika - Dobo - Tual - Saumlaki - Ambon - Namrole - Wanci - Bau-Bau - Makassar - Labuan Bajo - Bima – Benoa – Surabaya with route specifications below.

| Item                      | Value | Unit |
|---------------------------|-------|------|
| Freq                      | 12    | Times|
| Roundtrip days            | 28    | Days |
| Number of Segment         | 28    | Unit |
| Port of Destination       | 15    | Unit |
| Total Distance            | 5,722 | Nm   |
| Number of Passenger / Voyage | 9,009 | Pax  |
| Speed (Vs)                | 14    | Knot |

2. Simulation Model

2.1. Base Model Design

According to the aim of this study, which is to obtain a synchronous scheduling model between pioneer shipping with sea tolls and passenger ships, the basic model has been structured to meet all of the study's criteria. The basic model is built on agent-based modeling, starting from business processes or activities that exist in the system as well as the processes of each agent. The components of creating this scheduling synchronization model are as follows:

- The time of the sailing ship is affected by the speed of the ship from each port visited (Sea time).
- The time of the ship at each port (Port Time).

![Figure 1. Illustration of scheduling synchronization model environment](image-url)
departure of the origin port will be recorded as the time of estimated arrival and departure time, respectively.

2.2. Agent Behavior and Interaction
Agent behavior and agent interaction is a group of data that become the basic setting on the model. This data contains the regulation of ship behavior and speed as the main behavior of the ship that will affect of the ship sailing time and the waiting time at the port for port agents. The inputs of the speed data distribution are written as follows.

Table 11. Speed Data Distribution

| Routes | Distribution       | Routes | Distribution       |
|--------|--------------------|--------|--------------------|
| H-3    | Uniform (6.45 , 9.45 ) | R-49   | Normal ( 3.56 , 7.46 ) |
| T-12   | Uniform (5 , 9.49 )   | R-50   | Normal ( 0.767 , 8.45 ) |
| P-5    | Normal (2.11 , 16.3 ) | R-52   | Normal ( 1.15 , 8.89 ) |
| P-17   | Normal (0.65 , 9.97 ) | R-60   | Normal ( 0.549 , 9.24 ) |
|        |                    | R-61   | Normal ( 1.69 , 8.04 ) |

2.3. Ship Agent Algorithm

The ship will start moving when there is a "Start" message from the main agent on the simulation, then the ship will choose the initial location of the port and the next destination port using a certain predetermined speed and then the ship will provide arrival information to the port agent to dock. When completed, the ship will receive a "Service Finished" message to proceed to the next port.

2.4. Port Agent Algorithm

The port will receive a arrival message from the ship, then the port will serve the ship in accordance with the berth time that has been set to the main agent, if it has finished the port will send a message "service Finished" to the ship.

2.5. Simulation Model
The initial interpretation of the model is described in the Action Chart and Agent Component diagrams in the main page that will govern how the simulation process works which can be seen in the following image.
2.6. Verification and Validation
In the verification stage of the simulation model, there are 2 stages, namely no errors in the model that has been made and successfully run the model and visualize the process of movement of the model correctly. To make sure there are no errors in the model that has been created can use the Build Problem feature in the view menu. If there is no problem then the model will display the following image.

![Figure 5. Debugging Simulation in Anylogic](image)

Validation tests are conducted with Welch's T-test or t-test unequal variance. T-test validation is used to compare two groups that are unpaired or do not affect one and the other, provided that the values of different data variants, the number of samples are the same, normal distribution. Replication of the model to validate obtained the following data.

| Route | Voyage Existing | Replication |
|-------|-----------------|-------------|
| H-3   | 3               | 3 4 3 3 3 3 3 3 4 3 |
| T-12  | 3               | 2 3 3 3 3 3 3 3 2 3 |
| P-5   | 20              | 18 18 20 19 21 19 19 19 19 21 |
| P-17  | 12              | 10 12 11 13 12 12 12 12 13 11 |
After obtaining replication of the results of the model, then the next is to get the average value, variation, and standard deviation obtained the following values.

Table 13. Validation Item Recapitulation

| Route | Voyage Existing | Mean (s) | (s²) | n   | n-1 |
|-------|-----------------|----------|------|-----|-----|
| H-3   | 3               | 3.2      | 0.42 | 10  | 9   |
| T-12  | 3               | 2.8      | 0.42 | 10  | 9   |
| P-5   | 20              | 19.3     | 1.06 | 10  | 9   |
| P-17  | 12              | 11.8     | 0.92 | 10  | 9   |
| R-49  | 20              | 20.1     | 0.88 | 10  | 9   |
| R-50  | 10              | 9.6      | 0.52 | 10  | 9   |
| R-52  | 19              | 18.6     | 0.52 | 10  | 9   |
| R-60  | 19              | 19       | 0.67 | 10  | 9   |
| R-61  | 18              | 18.6     | 0.97 | 10  | 9   |

Then continued with the calculation of the degree of freedom (df) with the following equation.

\[
df = \frac{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)^2}{\frac{\left(\frac{s_1^2}{n_1}\right)^2}{n_1-1} + \frac{\left(\frac{s_2^2}{n_2}\right)^2}{n_2-1}}
\]

(1)

From the results of the equation above, processing is carried out to get \(t (df, \alpha/2)\) with a value of \(df = 9\) and \(\alpha = 0.05\), so that it is obtained \(t_9 (0.025)\) of 2.6850. Then the next step is to find the t-test value using the following equation.

\[
t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}
\]

(2)

After getting the t-test value then check the t-critical value with the following equation.

\[t_{\text{critical bawah}} \leq t_{\text{test}} \leq t_{\text{critical atas}}\]

Table 14. Comparison of t-test values with Welch’s t test

| Route | Voyage Existing | df  | Bottom t-critical | t-test | Top t-critical |
|-------|-----------------|-----|-------------------|--------|---------------|
| H-3   | 3               | 9   | -2.685            | -1.5   | 2.685         |
| T-12  | 3               | 9   | -2.685            | 1.5    | 2.685         |
| P-5   | 20              | 9   | -2.685            | 2.0896 | 2.685         |
| P-17  | 12              | 9   | -2.685            | 0.6882 | 2.685         |
| R-49  | 20              | 9   | -2.685            | -0.3612| 2.685         |
| R-50  | 10              | 9   | -2.685            | 2.4495 | 2.685         |
| R-52  | 19              | 9   | -2.685            | 2.4495 | 2.685         |
| R-60  | 19              | 9   | -2.685            | 0      | 2.685         |
| R-61  | 18              | 9   | -2.685            | -1.964 | 2.685         |
Therefore, it can be inferred from the results of the comparison of the value of t-test each tray with the value of t-critical that $H_0$ is accepted because the value of t-test $\mu_1 = \mu_2$ has a value as in Table 14 which is between the bottom t-critical and the top t-critical. The simulation model is valid.

3. Scenario Test

The scenario analysis in this study was divided into 3 (three) scenarios, which are simulations according to existing conditions, changes in the initial departure time of pioneer ships and adjustment RTD of pioneer ship from decree. This scenario will analyse the roundtrip days of each ship, the schedule of the resulting ship, the arrival time of the ship at the base port of Ambon and Saumlaki as the port of analysis in this study, the waiting time of cargo and passengers at the base port which has an impact on the financial users and ship operator annually.

3.1. Roundtrip Days and Ship Frequency

Roundtrip days (RTD) is the time the ship travels from the origin port to the destination port then return to the origin port while the frequency is the total trip of the ship in one year on each route. Here is an equation for calculating the RTD and frequency of each ship.

$$\text{Roundtrip Days} = \sum_{i=1}^{n} \sum_{j=1}^{m} ST_{ij} + \sum_{i=1}^{n} \sum_{j=1}^{m} PT_{ij}$$

(3)

$ST_{ij}$ : Sea Time (Days) spent from port of the origin $i$ to the port of destination $j$

$PT_{ij}$ : Port Time (Days) spent from port of the origin $i$ to the port of destination $j$

$i$ : Port of Origin

$j$ : Port of Destination

$n$ : Number of Port Origin

$m$ : Number of Port Destination

$$Frequency = \frac{365 - z}{RTD}$$

(4)

$Frequency$ : Number of Trip (Times)

$Z$ : Not operating time of ship (Days)

$RTD$ : Roundtrip Days (RTD)

3.2. Ship Schedule

Analysis of ship schedules is an analysis to find out the arrival and departure scheme of each ship formulated with the following equation.

$$ETA_{Pel} = Starting Time$$

(5)

$$ETA_{Pel_{x+1}} = ETA_{Pel_x} + PT_{ij} + ST_{ij}$$

(6)

$$ETD_{Pel_x} = ETA_{Pel_x} + PT_{ij}$$

(7)

$ETA$ : Estimation Time of Arrival

$ETD$ : Estimation Time of Departure

$Pel_x$ : Port of Review
3.3. Arrival time of the ship at Port
In this study, the model created can find the arrival and departure times of ships at each port, which related to the analysis in this study, the time of arrival and departure of ships at the base ports of Ambon and Saumlaki, using the following equations:

\[
ETA(R_n,Pel_x) \approx ETA(TL_n)Pel_x \approx ETA(P_n,Pel_x)
\] (8)

- \( R_n \): Pioneer Ship Route n
- \( TL_n \): Sea Toll Route n
- \( P_n \): Passenger Ship Route n
- \( Pel_x \): Port of Review
- \( \approx \): On the same day

3.4. Waiting Time
From the time of arrival of each ship at the port, it can be known the waiting time for the ship to wait for the next ship's arrival either when the pioneer ship waits for the arrival of the main ship or the main ship waiting for the pioneer ship, which will have an impact on the financial users of the service by using the following equation.

\[
WT \text{ Arrival of the main ship} = ETA(P_n,TL_n)Pel_x - ETA R_n Pel_x
\] (9)

\[
WT \text{ Arrival of the pioneer ship} = ETA(R_n,Pel_x) - ETA(P_n,TL_n)Pel_x
\] (10)

To calculate the cost due to waiting for the arrival time of the ship used the following equation.

\[
\text{Cost of Waiting} = \sum_{i=1}^{n} Q_{Rn,TL_n,P_n} \times Wt_{Rn} TL_n, P_n \times C_{wt}
\] (11)

\[
\text{Lost Income} = \sum_{i=1}^{n} Q_{Rn,TL_n,P_n} \times Wt_{Rn} TL_n, P_n \times Pnd_{wt}
\] (12)

- \( Q \): Number of Cargo or Passanger (Ton, Pax)
- \( Wt \): Average Waiting Time for Ship Arrival (Hour)
- \( CWt \): Cost per day (Rp/Day)
- \( Pnd_{wt} \): Lost income per day (Rp/Day)

3.5. Financial Impact on Ship Operator
The financial impact provided to the ship operator consists of the operational costs and ship revenue. The operational cost of the ship is a cost that must be incurred by each ship for 1 year consisting of fixed costs and variable costs. The fixed cost component consists of crew salary, crew supplies, fresh water, ship maintenance, ship insurance, ship fumigation while variable costs are costs that must be incurred by the ship when the ship makes a voyage such as fuel costs, lubricant costs, freshwater passengers,
safety of goods, marketing, port services, overhead. Ship revenue is derived from the large number of cargo or passengers transported each year at a predetermined rate.

4. Scenario Test Result

Based on the results of the running model test with 3 scenarios, a comparison of results between the three scenarios for RTD and frequency, synchronization, or arrival time of the ship on the same day, costs due to waiting time for the ship to arrive and ship revenue and cost are as follows.

4.1. RTD and Ship Frequency

The average frequency of SK in scenario 1 is obtained a value of 73%, in scenario 2 obtained a value of 80% and in scenario 3 obtained a value of 91%. Therefore, it can be said that scenarios 2 and 3 are better than scenario 1. As for the average employee frequency in scenario 1 obtained a value of 100%, in scenario 2 obtained a value of 107%, and in scenario 3 obtained a value of 127%, so it can be said that scenario 2 is better than scenario 3 because it is close to the value obtained close to scenario 1.
4.2. The Arrival of The Ship on the same day

Figure 8. Comparison the number of synchronization or ship arrivals on the same day at at Saumlaki Port

At the port of Saumlaki obtained the number of ships come at the same time which is 5 times in scenario 1 and then increased in scenarios 2 and 3 with the largest frequency in scenario 3 as much as 9 times while in scenario 2 occurred 8 times.

Figure 9. Comparison the number of synchronization or ship arrivals on the same day at Ambon Port

At the port of Saumlaki obtained the number of ships come at the same time which is 15 times in scenario 1 and then increased in scenarios 2 and 3 with the largest frequency in scenario 3 as much as 27 times while in scenario 2 occurred 17 times.

4.3. Matrix of Financial Impact for Service Users and Ship Operator

Based on the results of the third test the scenario obtained costs and benefits when using alternative scenarios namely scenario 2 and scenario 3 compared to existing scenarios or scenario 1 are as follows.

Table 15. Matrix of financial impact for service users

| Scenario   | Passenger (Mil IDR) | Cargo (Mil IDR) | Cost of Waiting (Mil IDR) | Lost Income (Mil IDR) |
|------------|---------------------|-----------------|---------------------------|-----------------------|
| Scenario 1 | 139.85              | 73.61           | 364.19                    | 774.85                |
| Scenario 2 | 157.48              | 80.48           | 410.1                     | 847.11                |
| Scenario 3 | 185.03              | 52.76           | 481.98                    | 555.37                |
From the table above, alternatives to scenario 2 and scenario 3 are obtained the impact of the increase of existing conditions on the costs that must be incurred and lost revenue to wait for the arrival of the ship is as follows.

### Table 16. Benefits of using alternative scenarios of service users

| Scenario   | Service Users (Mil-IDR) | Cost of Waiting | Lost Income  |
|------------|-------------------------|-----------------|--------------|
| Scenario 2 | -24.49                  | -               | -118.17      |
| Scenario 3 | -24.33                  | -               | 101.7        |

Based on Table 16 it is known that scenario 3 is better than scenario 2 because it has a greater difference value compared to scenario 2. While the financial impact matrix for ship operators is as follows.

### Table 17. Matrix of financial impact for ship operator

| Scenario   | Ship Operator (Mil-IDR) | Revenue     | Cost          | Profit        |
|------------|-------------------------|-------------|---------------|---------------|
| Scenario 1 |                         | 23,042.06   | -182,795.72   | -159,753.66   |
| Scenario 2 |                         | 23,623.41   | -188,938.94   | -165,315.52   |
| Scenario 3 |                         | 25,361.89   | -191,894.85   | -166,532.96   |

the benefits obtained by the ship operator for scenario 2 amounted to -5,562 Mil-IDR and scenario 3 amounted to -6,779 Mil-IDR so that scenario 2 is better than scenario 3 because it has a greater profit value difference than scenario 3.

5. Conclusion

- The condition of pioneer ships, sea toll and passenger ships that became the object in this research found that the achievement of Target Frequency on target SK by 73% and the use of RTD more than target SK which reached 129%, where at Aaumlaki port occurred as many as 5 ships in sync or coming on the same day with the average waiting time of the main ship for 34 hours and the waiting time of pioneer ships for 31 hours, While at ambon port there are 15 times coming on the same day with the average waiting time of the main ship and pioneer ship for 42 hours
- The scheduling synchronization model is influenced by the ship departure time and RTD used where, in the change of departure scheme in scenario 2 obtained an increase in the number of target SK frequency by 7% to 80% with the 128% RTD SK up to 128% and there was an increase in the frequency of ships in sync or coming on the same day at the Port of Saumlaki to 8 times with the average waiting time of the main ship for 35 hours and the average waiting time of the pioneer ship during the 34 hours, while at ambon port there was an increase in the frequency of ship arrivals on the same day to 17 times with an average waiting time of the main ship for 40 hours and an average waiting time of pioneer ships for 37 hours. In scenario 3 there was also a change in the availability of the frequency target to 91% with the 125% RTD SK reach and there was an increase in the frequency of synchronous ships compared to scenario 1 and scenario 2 which occurred 9 times at saumlaki port with an average waiting time of the main ship for 31 hours and 37 hours waiting time for pioneer ships, while in Ambon Port there was synchronization as much as 27 times with an average waiting time of the main ship of 42 hours and 49 hours. hours to board a pioneer ship.
- The best-case scenario option when viewed from the financial impact on service users is scenario 3 as evidenced by the difference in costs due to waiting time for the ship between scenario 3 with existing conditions of 24.33 Mil-IDR while the difference in costs due to waiting for the ship for scenario 2 amounted to 24.49 Mil-IDR and the difference in lost revenue scenario 2 amounted to 118.17 Mil-IDR and scenario 2 amounted to 101.70 Mil-IDR. When viewed from the revenue and operating costs of the ship the best option is scenario 2 which is
Evidenced by the difference in profit with existing conditions obtained a value of -5,562 Mil-IDR while in scenario 3 obtained the difference in profit value with existing conditions of -6,779 Mil-IDR.

References

[1] Borshchev, A., & Filippov, A. (2004). From System Dynamics and Discrete Event to Practical Agent Based Modelling: Reasons, Techniques, Tools. England: Oxford.

[2] Darmansyah, S. (2012). Analisis Desain Stasiun MRT Jakarta dengan Pemodelan Berbasis Agen. Depok: Universitas Indonesia.

[3] Devany, J. (2020). Model Simulasi Perencanaan Replanting Eucalyptus di PT. Toba Pulp Lestari, TBK. Medan: Universitas Sumatera Utara.

[4] Grigoryev, I. (2020). The Big Book of Simulation Modelling. Russia: Anylogic.

[5] Ibrahim Hasyim, T. A. (2005). Analisis Kinerja Armada dengan Kinerja Korporat pada Perusahaan Pelayaran Pengangkut Minyak. ITS.

[6] Koza, D. F. (2018). Liner Shipping Service Scheduling and Cargo Allocation. Elsevier.

[7] Law, A. M. (2014). Simulation Modelling and Analysis 5th Edition. Singapura: McGraw-Hill, Inc.

[8] Litman, T. (2020). Evaluating Accessibility for Transport Planning. Victoria: Victoria Transport Policy Institute.

[9] Niko Wijnoelst, T. W. (2009). Shipping Innovation. Amsterdarm, The Netherlands: Delft University Press.

[10] Pinedo, M. L. (2002). Scheduling: Theory, Algorithms, and Systems. New York: Springer.

[11] Remoundos, M. L. (2016). Developing Islands' Passenger Transport Connectivity Indices. Piraeus: University of the AEGEAN.

[12] Sel Ozcan, D. T. (2018). Cargo Allocation and Vessel Scheduling on Liner Shipping with Synchronization of Transhipments. Elsevier.

[13] Shuaian Wang, A. A. (2014). Liner Ship Route Schedule Design with Port Time Windows. Elsevier.

Acknowledgments

Authors would like to be obliged to Institut Teknologi Sepuluh Nopember for providing laboratory facilities and PT. Pelayaran Nasional Indonesia for their data and information.