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A Concept of Sustainable Development of Ferry Services for Integrating the Inter-small Islands Connectivity: The case of the North Kalimantan Region-Indonesia

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Abstract

This study describes a concept of the sustainable development of the ferry services for integrating the inter-small islands connectivity addressed to the North Kalimantan. Several systematically stages that involve reviewing the transportation policy and spatial plan, analysing the potential area, demand, and capacity of the ferry services, surveying the hydro-oceanography characteristics, determining the conceptual design of passenger ferry, and evaluating the waterfront facilities of port were carried out. The capacity of the ferry services was divided into three scenarios based on the development plan that are short, medium, and long terms. The capacity of the ferry services simultaneously with the deck plan for the short term of the development plan was analysing to obtain the conceptual ferry design in each route of the ferry services. The quay length of the existing ports of Juata Laut, Ancam, Sei Jepun, and Liang Bunyu must be fulfilled the requirements to anticipate the implementation of the development plan.

Keywords: Conceptual ferry design; Ferry services; Inter-small islands connectivity; Sustainable development

1. Introduction

For the smoothness of economic cycle in a territory which consists of parts of islands, Government devotes some attentions to provide a safe transport service and infrastructure. As known, the regular passenger ferry services are the essential transport services in connecting between the outlying islands. Also, this services also is expected to promote a high potential small islands and tourisms. Therefore, the development of waterborne transport service for a territory which consists of parts of islands should be conducted proper and feasible.

The studies of the development of the ferry services have been conducted. In the following studies, some aspects have been considered in order to formulate the development plan. A demand model of the ferry services was developed and then a range of service development options including new services and service extensions, rationalization of the existing services, and improvements to wharf and vessel quality was evaluated [1]. The impacts and links between ferry fares, service, and economic development on the economy of a remote island, the Western Isles in Scotland as a case study, was analysed where the ferry services between islands and with mainland Scotland are vital to the continued economic and social well-being of the Western Isles [2]. The tender route map, the different stages and key issues concerning the public procurement of ferry services, was developed by analysing the ferry service procurement involves a continuous evolutionary process of specifying, offering, selecting, monitoring and reviewing services supplied [3] [4] analysed the passenger ferry routes by using the connectivity measures and proposed the new potential routes. [5] highlighted the problems ailing the water transportation sector in Kocby by conducting the observations on the ferry system. The relationship between the ocean wave climate and the economy of the Western Isles of Scotland was studied where the ferry services provide vital links between communities in this region [6]. The extent of mutual substitutability and complementarity of passenger transport services provided by ferry in the Baltic Sea Region was analysed and evaluated to obtain a concept of development of passenger ferry services [7]. The socio-economic impact of ferry provision on remote and rural islands' sustainability for the Zadar island archipelago was studied and then the political actors also must align with their needs in order to provide a long-term sustainable [8]. The changes in demand due to the diversity of travel motives was studied by identifying the distinct segments of travellers due to their motives of ferry travel and also three other segments with a mixture of these motives where each of these segments has a different profile in terms of their behavioural and socio-demographic characteristics [9] [10] studied the ferry system afloat regarding the funding, economic development, integration with other modes of transportation, environmental considerations, and services related to water transportation. [11] developed the holistic ship design for the future waterborne transport by optimizing the RoPAX.

Correspondingly, the government plays an important role in the development of the ferry services to serve in crossing the movement of people and goods to all region. By the government policy, a development of the ferry services can be realized and accomplished. Development [12] conducted a preliminary desktop research on the provision of domestic ferry services in a number of the overseas cities such as Europe, North America, Australia and South-East Asia. The ferry service with the unique opportunity for connecting and activating the communities across over 500 miles of shoreline in New York City was studied [13]. Europe's geography features many rivers, waterways, estuaries, long coastlines and islands, and therefore offers extraordinary opportunities for waterborne transport [14]. The ferry systems had been implemented for a number of reasons further to people moving, including economic development, tourism and city branding where the role of both private and government policy entrepreneurs was critical in explaining how the transport innovation occurred in each city [15]. [16] suggested the Government to explore the provision of the ferry routes and other service models.

The one of territory consisting of the parts of islands in Indonesia is the North Kalimantan (North Borneo) Province. As a Province surrounded by land, river and sea, North Kalimantan has five rivers including Sebuku, Sembakung, Sesayap, Kayan, and Bahau and seven small islands namely Derawan Island, Bunyu Island, Ligitan Island, Nunukan Island, Gosong Makassar Island, Tarakan Island, and Sebatik Island. Bulungan Regency, Nunukan Regency, Malinau Regency, Tana Tidung Regency, and Tarakan City. The primary waterborne transport service to connect inter-small islands and inlands that are accessed by river is high speed passenger ferry. However, a number of islands and inlands are still rarely connected whereas these have high potential economic cycle and further need regular public waterborne transport.

In the present study, the waterborne transport service in North Kalimantan has been developed to sustain its smoothness of economic cycle, increase of passenger demand, and integration of inter-small island connectivity. This study highlights the development addressed to network plan of waterborne service, port capacity and facility, and conceptual ferry ship design.

2. Methods

The North Kalimantan Province consist of small islands and it is become as a case study for gaining a concept of sustainable development for the waterborne transport service in the inter-small island's connectivity. To gain a concept of the sustainable development of the ferry services, the following is several stages that are discussed and the flowchart of the stages is shown in Figure 1.

(1) Reviewing the transportation policy and spatial plan. This stage involves reviewing the national spatial plan (Rencana Tata Ruang Wilayah Nasional/RTRWN), provincial spatial plans (RTRWP) and district spatial plans (RTRWK). Also, this stage involves reviewing the regional transportation level (Tatrawil) and local transportation level (Tatralok). The purposes of this stage are to determine the potential area regarding the sustainable development of the ferry services. Besides the information of the potential area were obtained referring to RTRWN, RTRWP, RTRWK, Tatrawil, and Tatralok, the data of passengers and cars were collected in the ports and other related institutions by conducting observation and interview.

(2) Analysing the potential area as the development plan. This stage involves identifying the existing routes and new routes for the ferry services associated with geographic aspect and influence.

(3) Analysing the demand and capacity of the ferry services addressed to the development plan. This stage involves analysing the growth of passengers and cars by using the statical analysis of mean growth model and multiple linear regression. The multiple linear regression uses two variables namely the population and gross regional domestic product (GRDP).

(4) Surveying the hydro-oceanography characteristics in the port location. This stage involves measuring the waterfront facilities of the water depth of quay, berthing area (length, width, and depth), turning basin (diameter and depth), waterway (width and depth), and anchorage area (radius and depth).

(5) Determining the conceptual design of passenger ferry. This stage involves analysing the design requirement, ship capacity, main dimensions, and deck plan. The main dimensions of ferry are determined as the consideration of the ship capacity (passengers and cars) and hydro-oceanography characteristics.

(6) Evaluating the waterfront facilities of the existing port in accordance with the main dimensions of the conceptual ferry design. This stage provides the development plan of the waterfront facilities for the existing port and port of the new route of the ferry services.

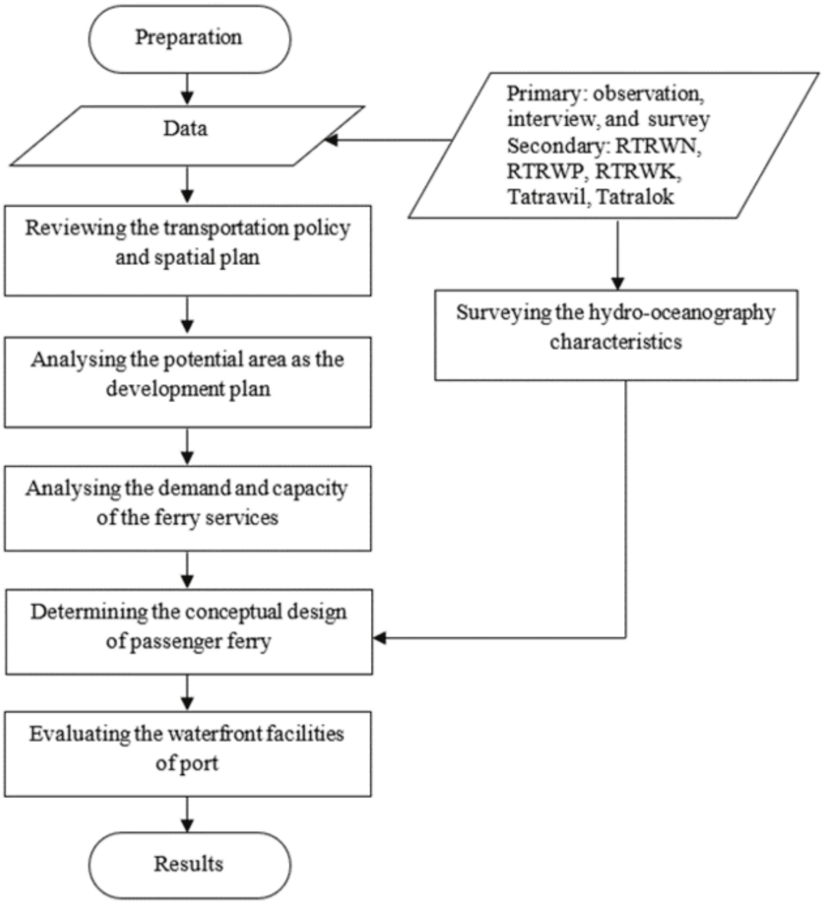

Figure 1. Flowchart of the study.

3. Results and Discussion

3.1. Spatial plan and transportation infrastructure

The Spatial Planning Law 24/1992 stipulates the hierarchical spatial planning in Indonesia consisting of national spatial plan (RTRWN), provincial spatial plans (RTRWP) and district spatial plans (RTRWK), [17]. The Spatial Planning Law 24/1992 is the policy subjected to plan-making process, plan implementation, and development control.

Meanwhile, the Ministry of Transportation of Indonesia Republic issued the Regulation No. KM 49 regarding the National Transportation System [18] where this regulation is a basis for planning, developing, and organizing the transportation in order to realize the effective and efficient transportation services, transportation safety and security, transportation business development, quality of human resources as well as science and technology, quality of the environment, saving energy, etc. Then, the national transportation system is arranged integrally and is manifested hierarchically in the national transportation level (Tatranas), regional transportation level (Tatrawil), and local transportation level (Tatralok).

3.1.1 Spatial plan of North Kalimantan

The provincial spatial plan (RTRWP) of North Kalimantan for years 2015-2035 has been determined and emphasized on the operational policy derived from the national spatial plan [19]. The operational policy consists of the development strategy through the optimization of resource utilization, synchronization of sectoral development, coordination across districts and sector, and division of roles and functions of districts.

The national spatial plan includes the city system plan and infrastructure network. The city system plan consists of the national activity center (pusat kegiatan nasional/PKN), provincial activity center (pusat kegiatan wilayah/PKW), and local activity center (pusat kegiatan lokal/PKL). In addition, the national activity center (PKN) has been developed to be the national strategy activity center (pusat kegiatan strategis nasional/PKSN) wherein the purpose is to encourage the development of the state border area. Recently in North Kalimantan (Kalimantan Utara) Province, the city system plan has been determined that Tarakan city as the national activity center (PKN), Tanjung Selor district and Nunukan district as the provincial activity center (PKW), Long Midang Nunukan, and Sei Menggaris, Nunukan district as the national strategy activity center (PKSN). Then, the local activity center (PKL) is in the Bulungan District including Salim Batu, Bunyu, Long Bia, Karang Agung, Sekatak Buji, and Tana Kuning. In Nunukan District, it includes Long Bawan, Long Layu, Mensalong, and Pembeliangan.

The district spatial plan (RTRWK) is subjected to activity services consisting of the activity service center (pusat pelayanan kegiatan/PPK), sub PPK, and environment center. The activity services include the function of local government, trade and services, defense, tourism, and education, and local settlement. The district spatial plans of Tarakan City 2012-2032 [20], Bulungan 2012-2032 [21] and Nunukan 2013-2033 [22]have also been determined. In the district spatial plans of Tarakan City, the activity service center (PPK) is in sub-district of Karang Anyar that serves Tarakan Barat, Tarakan Tengah, and Tarakan Timur, and in sub-district of Juata Permai that serves Tarakan Utara. The sub-PKK and environment center are located in Karang Anyar. In Bulungan District, the PKK is located in Salimbatu, Tanah Kuning, Bunyu Tengah, and Long Bia. In Bulungan District, the PKK is located in Binalawan, Binuang, Lembudud, Seipancang, and Tanjung Karang.

3.1.2 Transportation infrastructure system in North Kalimantan

The infrastructure system is addressed to support the economic activity and socio-cultural activity. Also, it integrates to integrate between surrounding area. The infrastructure system is developed based on area structure. Regarding waterborne transportation network, this is divided into the port and shipping route in river and the port and shipping route in sea.

Based on the RTRWN, RTRWP and RTRWK, the inland ports for high-speed passenger ferry cover in Bulungan District including Tanjung Selor port, Ancam port, Sekatak port, and Bunyu port, in Tarakan City including Tengkayu I port, in Nunukan District including Nunukan port, Sebuku port, Sei Menggaris port, Sembakung port, Mensalong port, Binter port, Tau Lumbis port, and Sungai Ular port. The shipping route that is serviced those ports from Bulungan District to other areas is Sekatak to Tarakan, Tanjung Selor to Tarakan, Tanjung Selor to Bunyu, Bunyu to Tarakan, Ancam to Tarakan, Long Bia to Long Tungu, and Long Beluah to Tanjung Selor. The shipping routes from Nunukan District to other areas, these include Nunukan to Sebatik, Nunukan to Bambangan, Sedadap to Mantikas, Nunukan to Sungai Nyamuk, Nunukan to Simanngaris, Nunukan to Sungai Ular, Mensalong to Binter and Tau Lumbis, Mensalong to Tarakan, Nunukan to Pembeliangan, and Nunukan to Atap.

Meanwhile, the ports for ferry in Bulungan District include Kayan II port, Bunyu port, and Ancam port. The Juata port and Nunukan port are in Tarakan City and Nunukan District, respectively. The route for ferry is divided into three clusters that are crossings between countries, crossings between provinces, crossings between regencies. For crossings between countries Indonesia-Malaysia, the area is connected by the shipping route including Nunukan (Indonesia)-Tawau, Sabah (Malaysia), and Tarakan (Indonesia)-Tawau, Sabah (Malaysia). For crossings between provinces, the area is connected by the shipping route including Tarakan (North Kalimantan)-Toli Toli (Central Sulawesi). In addition, for provinces, crossings between regencies, the area is connected by the shipping route including Tarakan-Sebatik, Tarakan-Pulau Bunyu, Tarakan-Nunukan-Ancam, Tanjung Selor-Tarakan, Malinau-Tarakan, and Tana Tidung-Tarakan.

3.1.3 Development plan of waterborne transportation infrastructure in North Kalimantan

The development plan of the waterborne transportation infrastructure in North Kalimantan Province has been determined and addressed to sea transportation and river-lake-ferry transportation. For infrastructure of the river-lake-ferry transportation, the development plans will be focused on the maintenance and facility improvement ferry ports in Tarakan, Bulungan, and Nunukan. Also, the inland ports in Bulungan and Nunukan will be constructed.

Based on the regional transportation level (Tatrawil), the program of the ferry service for the three districts of Bulungan, Tarakan, and Nunukan is focused as follows:

(1) Optimizing the ferri services for the routes of Tarakan-Toli Toli, Tarakan-Nunukan, and Tarakan-Ancam.
(2) Optimizing the ferri port services of Juata Port (Tarakan), Ancam Port (Bulungan), and Nunukan Port.
(3) Developing the cross-country transportation services for Tarakan (Indonesia)-Tawau (Malaysia) and Nunukan (Indonesia)-Tawau (Malaysia).
(4) Developing the cross-district transportation services Tarakan-Sebatik and Tarakan-Bunyu Island.
(5) Developing the river transportation services in Bulungan Regency including Sekatak-Tarakan, Tanjung Selor-Bunyu, and Long Bia-Long Tungu-Long Beluah-Tanjung Selor.
(6) Developing the river transportation services in Nunukan Regency including Nunukan-Simanggaris, Nunukan-Sungai Ular, Mensalong-Binter-Tau Lumbis, Mensalong-Tarakan, Nunukan-Beliangan, and Nunukan-Atap.

Meanwhile, based on the local transportation level (Tatralok), the development plan of the transportation networks for ferry transportation in Nunukan District will be divided into two main routes as follows:

(1) Northen Belt (Sabuk Utara) with the crossing routes including Nunukan–Sebatik, Nunukan–Bambangan, Sedadap–Mantikas, Nunukan–Sungai Nyamuk, Nunukan–Sei Menggaris, and Nunukan–Sungai Ular.
(2) Southern Belt (Sabuk Selatan) with the crossing routes including Mensalong–Binter–Tau Lumbis, Nunukan–Pembeliangan, and Nunukan–Atap.

3.2 Development plan of the ferry services in North Kalimantan

The implementation of the ferry transportation becomes more important in archipelagic provinces including in North Kalimantan. This is expected to support the economic activity and socio-cultural activity, to serve the potential areas, to reduce the transportation cost, and to realize the effective and efficient transportation services.

Figure 2. The existing and new route of ferry services in North Kalimantan based on the reviewed results.

Based on the reviewed results, several areas are not potential to be connected by ferry services. The potential area depends on the movement of goods and people, population density, and agricultural product and mining product. Also, the hinterland connectivity of those areas due to the movement of goods and people, regional commodities, transportation infrastructure remains low magnitude.

Correspondingly, the compliance of regulation is together considered with the potential areas to the development plan of the ferry routes. Therefore, the route of the ferry services based on the reviewed results is obtained where there are nine new routes and five existing routes as shown in Figure 2. The existing routes of the ferry services are Tarakan-Nunukan, Nunukan-Seimanggaris, Nunukan-Pulau Sebatik, Tarakan-Ancam, and Tarakan-Toli Toli (Central Sulawesi). Then, nine new routes of the ferry service are Tarakan-Pulau Bunyu, Tarakan-Pulau Sebatik, Tarakan-Tidung Pala, Tarakan-Sekatak, Pulau Sebatik-Sei Menggaris, Nunukan-Atap, Nunukan-Ancap, Tarakan-Malinau, and Tarakan-Derawan (East Kalimantan).

On the other hand, based on Figure 2, several new routes for only serving inter islands in North Kalimantan can be considered to be eliminated geographically as the development plan of the ferry services. The geographic aspect can affect ship frequency number, time and cost, and main dimensions of a ferry. The new routes of Tarakan-Tidung Pala, Tarakan-Malinau, and Tarakan-Sekatak can be eliminated because this area of these routes such as Tidung Pala, Malinau, Sekatak can be reached efficiently using land vehicles from Ancam area that is served by the existing ferry with the route of Tarakan-Ancam. The new routes of Tarakan-Pulau Sebatik, Pulau Sebatik-Sei Menggaris, Nunukan-Atap, Nunukan-Ancam can be eliminated because Nunukan area can be a center for the movement to handle the route of Tarakan-Pulau Sebatik through the route of Nunukan-Pulau Sebatik, and Nunukan-Atap through the route of Nunukan Sei Menggaris. The Atap area can be reached efficiently using land vehicles from Sei Menggaris.By the considerations discussed above, the elimination of several new routes has an impact on increasing the capacity of the existing routes. Therefore, the development plan of the ferry services is addressed to new route, port infrastructure, and ship capacity of ferry. The development plan of the ferry services is subjected to the routes of Ancam (Bulungan)-Juata Laut (Tarakan), Juata Laut (Tarakan)-Pulau Bunyu (Bulungan), Juata Laut (Tarakan)-Sei Jepun (Nunukan), Sei Jepun (Nunukan)- Liang Bunyu (Sebatik), and Sei Jepun-Sei Menggaris (Nunukan).

3.3 The demand and capacity of the ferry services

Here, the demand of the ferry services is predicted by using the data within years 2012-2016 wherein the data includes the number of passengers and cars provided by the fast passenger ferry port and ferry port, and the socio and economic hinterland areas including population and gross regional domestic product (GRDP).

Based on the data of passengers within years 2012-2016, the growth of the departure and arrival of passengers in Malianu port for the fast passenger ferry was 16.15% and 5.20%, respectively. In Tideng Pala port for the fast passenger ferry, the growth of the departure and arrival of passengers was 16.15% and 5.42%, respectively. In Tengkayu I port for the fast passenger ferry, the growth of the departure and arrival of passengers was 2.4% and 5.42%, respectively. In Juata Laut port for the ferry, the growth of the departure and arrival was 35.97% and 36.52%, respectively. In Sei Jepun port for ferry and fast passenger ferry, the growth of the departure and arrival was 65.46% and 49.85%, respectively.

In this present study, there were two statical analysis that were used to determine the demand of ferry services subjected to passengers and cars. Two statical analysis are the mean growth model and multiple linear regression. The multiple linear regression was used with two variables namely the population and gross regional domestic product (GRDP). The use of each statical model depends on the reasonable or logical results.

By the forecast of the demand of ferry services subjected to passengers and cars within years 2018-2041, in the route of Sei Jepun-Liang Bunyu, the forecast of the passengers using the mean growth is 4.9%, and the forecast of the cars is 4.92%. In the route of Sei Jepun-Sei Menggaris, the forecast of the passengers using the mean growth is 4.92%, and the forecast of the cars is 4.92%. Then, in the route of Juata Laut-Pulau Bunyu, the forecast of the passengers using the mean growth is 7.0%, and the forecast of the cars is 2.12%.

Meanwhile, two routes of the ferry services that used the multiple linear regression are Sei Jepun-Juata Laut and Juata Laut-Ancam wherein the multiple linear regression were used as follows:

for the route of Sei Jepun-Juata Laut

$$Y_{pi} = -2915{,}81 - 0{,}1156\, X_{1i} + 0{,}0022\, X_{2i} \tag{1}$$

$$Y_{ci} = -1612{,}47 – 0{,}0135\, X_{1i} + 0{,}00041\, X_{2i} \tag{2}$$

for the route of Juata Laut-Ancam,

$$Y_{pi} = -11842{,}74 + 0{,}088\, X_{1i} + 0{,}0001\, X_{2i} \tag{3}$$

$$Y_{ci} = 19011{,}37 – 0{,}3759\, X_{1i} + 0{,}003\, X_{2i} \tag{4}$$

where Y_{pi} is the number of passengers in *i*th observation, Y_{ci} is the number of cars in *i*th observation, X_{1i} is the number of populations *i*th observation, and X_{2i} is the number of GRDP in *i*th observation, *i* is the period (year = 2018, 2019, 2020........).

Based on the results of the forecast within year 2018-2041, the capacity of the verry services is determined by using the formula as follows:

$$Capacity\ (C) = \frac{number\ of\ demand\ per\ year}{ship\ frequency\ per\ year} \tag{5}$$

The capacity of the ferry services that was obtained is then divided into three scenarios of development plan that are short term 2018-2023, medium term 2024-2031, and long term 2031-204. Also, it was considered into several ship frequencies (ship trip per week). The number of passengers and cars per week in accordance with the development plan scenario for each route of the ferry services is shown in Table 1.

Table 1. The development plan of the ferry services capacity for each route.

Route of ferry service		Capacity per week		
		Short term	Medium term	Long term
Juata Laut-Ancam				
a.	Passengers	278	384	605
b.	Car Gol. IV	7	14	21
c.	Car Gol. V	7	11	16
d.	Car Gol. VI	2	4	7
Juata Laut-Pulau Bunyu				
a.	Passengers	98	155	287
b.	Car Gol. IV	2	4	7
c.	Car Gol. V	2	4	7
d.	Car Gol. VI	2	4	7
Juata Laut-Sei Jepun				
a.	Passengers	120	216	462
b.	Car Gol. IV	7	10	15
c.	Car Gol. V	5	7	9
d.	Car Gol. VI	3	5	7
Sei Jepun-Liang Bunyu				
a.	Passengers	216	317	521
b.	Car Gol. IV	5	8	13
c.	Car Gol. V	8	15	20
d.	Car Gol. VI	2	4	7
Sei Jepun-Sei Menggaris				
a.	Passengers	60	110	187
b.	Car Gol. IV	4	7	11
c.	Car Gol. V	3	5	7
d.	Car Gol. VI	-	1	1

3.4 Waterfront facility and hydro-oceanography characteristics in the port location

In this study, the waterfront facilities in each existing port including the quay length, berthing area, turning basin area, waterway area, water depth of quay, and anchorage area was measured. Also, the data that are provided by the related institution regarding the waterfront facilities in each existing port were collected. The depth of the berthing area, basin area, waterway, quay, and anchorage area were measured by doing the bathymetry survey as shown in Figures 3 to 6. Based on the bathymetry survey and the collected data, the size of the waterfront facilities in each existing port is shown in Table 2.

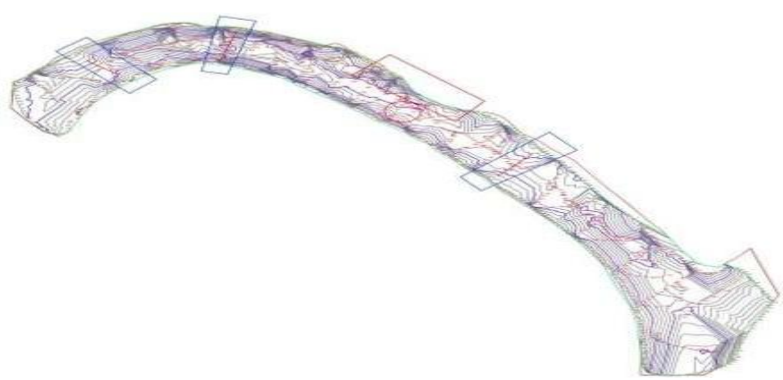

Figure 3. Bathymetry map around the Sei Menggaris port.

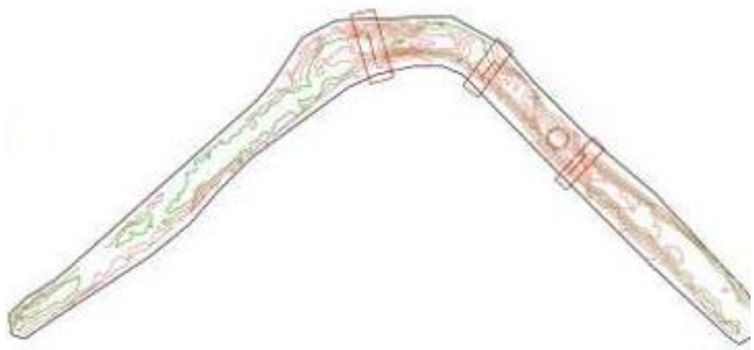

Figure 4. Bathymetry map around the Sei Jepun port.

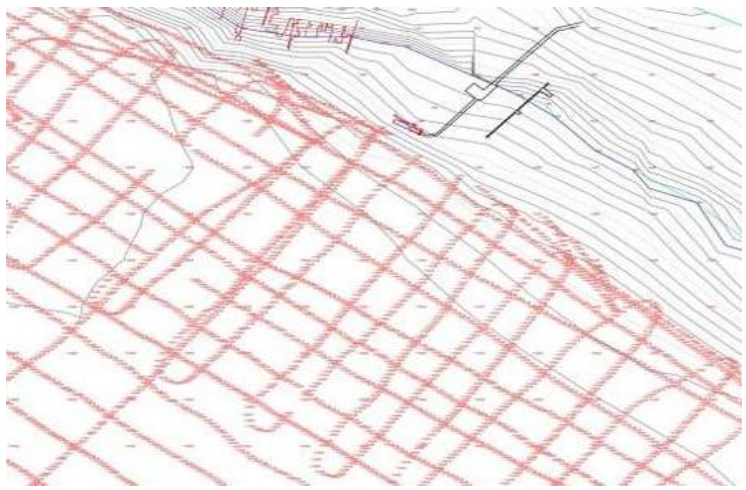

Figure 5. Bathymetry map around the Liang Bunyu port.

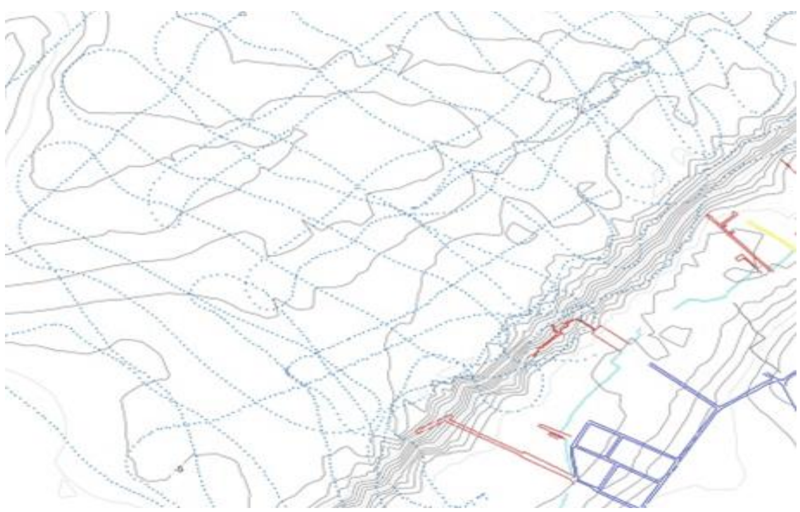

Figure 6. Bathymetry map around the Juata Laut port.

Table 2. The waterfront facilities in the existing port.

Description	Unit	Existing port					
		JL	SJ	LB	SM	A	PB
Quay length	m	46	25	30	68	47	-
Water depth of quay in LWS	m	5-20	3.5-10	4.5-12	3.5-10	3.5-10	15.0
Berthing area							
a. Length	m	63.65	52.0	52.0	60.0	50.0	60
b. Width	m	22.0	21.0	20.0	20.0	20.0	20.0
c. Depth in LWS	m	5-10	3.5-5.0	4.5-6	3.5-10	3.5-10	4-6
Turning basin							
a. Diameter	m	200	200	200	75	36	200
b. Depth in LWS	m	6-20	5-9	6-22	5-10	5-7.5	5-8
Waterway width	m	1000	1000	1000	78.53	38.0	193
Waterway depth in min. LWS	m	5.8	8.0	9.0	4.0	4.0	9.0
Anchorage area							
a. Radius	m	183.65	142.0	154.0	152.0	162.0	200
b. Depth	m	15.0	10.0	12.0	10.0	14.0	15.0

3.5 Conceptual design of ferry

In this study, the conceptual design of ferry in the routes of ferry services is subjected to the determination of the ferry main dimensions and deck plan. The determination of the ferry main dimensions and deck plan considers the ferry capacity based on the results of capacity analysis, and hydro-oceanography characteristics.

3.5.1 The requirements of ferry design

Based on the development plan of the routes of ferry services, four existing ports and one new route of the ferry services are obtained including Ancam (Bulungan)-Juata Laut (Tarakan), Juata Laut-Pulau Bunyu (Bulungan), Juata Laut (Tarakan)-Sei Jepun (Nunukan), Sei Jepun (Nunukan)-Liang Bunyu (Sebatik), and Sei Jepun (Nunukan)-Sei Menggaris (Nunukan). By considering the load factor of 0.6, the demand of the ferry services per week in short term of the development plan is shown in Table 3.

Table 3. The demand of the ferry services per week in North Kalimantan Province.

Description	Unit	Route of Ferry Services				
		A-JL	JL-PB	JL-SJ	SJ-LB	SJ-SM
Distance	mil	38	22	101	3	38
Load Capacity						
a. Car						
1) Car Gol. IV	unit	7	2	7	5	4
2) Car Gol. V	unit	7	2	5	8	3
3) Car Gol. VI	unit	2	2	3	2	-
b. Passengers	person	278	98	120	216	60

A-JL, Ancam (Bulungan)-Juata Laut (Tarakan)
JL-PB, Juata Laut-Pulau Bunyu (Bulungan)
JL-SJ, Juata Laut (Tarakan)-Sei Jepun (Nunukan)
SJ-LB, Sei Jepun (Nunukan)-Liang Bunyu (Sebatik)
SJ-SM, Sei Jepun (Nunukan)-Sei Menggaris (Nunukan)

3.5.2 Main dimensions of ferry

To determine the main dimensions of ferry in the term of length between perpendiculars (Lbp) and breadth (B), the approach of ferry capacity is firstly used. The capacity approach is divided into the space requirement for the car in a main deck and the space requirement for passengers in an accommodation deck. Therefore, the Lbp and B of ferry are defined by the function [22] as follows:

$$L \times B = f(A_P, A_V) \tag{6}$$

$$A_P = f(N_P, A_S) \tag{7}$$

$$A_V = f(N_V) \tag{8}$$

where L is ship length in the term of the length between perpendiculars (m), B is the ship breadth (m), A_P is the passenger area (m^2), N_P is the number of passengers, A_S is the chair area for passengers (m^2), N_V is the number of cars, and A_V is the area for car.

The function of N_V and A_V to Lbp can be defined as the same formula [24] as follows:

$$L_{ak} = \Sigma(k_i L_{ki}) + J_{mb}(k - 1) \tag{9}$$

where L_{ak} is the length of car area in main deck (m), k_i is the number of columns for car, L_{ki} is the lenght of car (m), k is the number of columns for car, and J_{mb} is the distance between cars 0.3 m.

Then, the function of the function of N_V and A_V to B can be defined as the same formula (Asri S. et al., 2015) as follows:

$$B_{ak} = \Sigma(b_i B_{ki}) + J_s(b - 1) + 2\,J_{kd} \tag{10}$$

where B_{ak} is the width of the car area (m^2), b_i is the number of rows for car, B_{ki} is the width of car (m), J_s is the distance between car's sides (m) 0.6 m, b is the number of rows for car, and J_{kd} is the distance between car's sides in the last row and ship's sides 0,6 m.

Based on the regulation of the ship classification [25] the space in near ferry's ramp door cannot be used for car space, therefore, the border of the car must be in the same vertical line of the collision bulkhead. For this consideration, the Lbp and length waterline (Lwl) can be calculated by using the formula [24] as follows:

$$L_{bp} = L_{ak} / 0.9\,. \tag{11}$$

$$L_{wl} = 1{,}04\,L_{bp} \tag{12}$$

On the other hand, in the main deck, a space for the room of stair to the engine room and to the accommodation deck, and warehouse for mooring equipment are also considered in determining the breadth (B) of ferry. Therefore, the breadth of ferry can be determined by using the formula (Asri S. et al., 2015) as follows:

$$B = B_{ak} + 2\,J_{ds} \tag{13}$$

where B_{ak} is the width of car (m), and J_{ds} is the distance between ship's side and car's side. The width of car B_{ak} is measured in the midship or the middle of the length of car area in main deck L_{ak}.

The relation between the main dimensions of ferry was obtained by using the statistical method to the collections of some ferry's main dimensions [24]. By the relation between the main dimensions of ferry, the height (H) and draft (T) of ferry can be obtained as follows:

$$H = (L_{bp}^{0,3208} * B^{0,6792})/5,2463 \quad (14)$$

$$T = (B^{-0,1601} * H^{1,1601})/1,1757 \quad (15)$$

By using the all formulas above, the main dimensions of the ferry for each route of ferry services are shown in Table 4.

Table 4. The main dimensions of the ferry based on the route of ferry services.

Main Dimensions	Ferry Service Route				
	A-JL	JL-PB	JL-SJ	SJ-LB	SJ-SM
Lbp (m)	48.00	29.00	43.50	45.00	28.00
B (m)	12.00	9.30	12.00	12.00	9.30
H	3.57	2.55	3.46	3.50	2.55
T	2.50	1.77	2.41	2.44	1.74

3.5.3 Car and accommodation deck plan

The deck of ferry is dived into two decks for passenger as the accommodation deck, and for cars as the car deck. Those decks are arranged based on the ferry's capacity and main dimensions that are obtained in the previous sections. In the car deck plan, the space includes car space, stairway room, warehouse, and toilet. Meanwhile, in the accommodation deck, the space includes passenger accommodation, public space or room, navigation stairway room, toilet. After arranging the decks, the deck plan for each route of the ferry services is shown in Figures 7 to 11.

3.6 Evaluation of the waterfront facilities in the existing port in accordance with the ferry services

The requirement of the waterfront facilities for the ferry services was obtained in accordance with the ferry main dimensions in each route of the ferry services. The requirement of the waterfront facility of the port for the ferry services in each route is shown in Table 5. The waterfront facilities in the existing port were evaluated in accordance with the requirement of waterfront facilities due to the development plan of the route of the ferry services. Here, the existing port means a port that can be suitable used to service a ferry or the specific port for only ferry services.

For the route of ferry services, only the quay length of the existing port of Sei Menggaris is larger than the requirement. Other waterfront facilities characteristics (water depth of quay, berthing area, turning basin, waterway width and depth, anchorage area) for all existing ports are larger than the requirements. For the new route of the ferry services, the quay length for Pulau Bunyu can be considered larger than the requirement.

Table 5. The requirement of the waterfront facility in port for the ferry services.

Description	Unit	Route of ferry services				
		A-JL	JL-PB	JL-SJ	SJ-LB	SJ-SM
Quay length	m	72	47	66	68	49
Berthing area						
d. Length	m	100	65	92	94	68
e. Width	m	83	55	77	79	57
f. Area	m^2	8344	3571	7023	7433	3905
Turning Basin						
c. Diameter	m	167	109	153	157	114
d. Area	m^2	21852	9354	18393	19468	10277
Waterway width	m	138	114	138	138	111
Water depth of quay	m	3,50	2,77	3,41	3,44	2,71

Anchorage area						
c. Radius	m	107	83	101	103	84
d. Area	m^2	35707	21646	32353	33414	22329

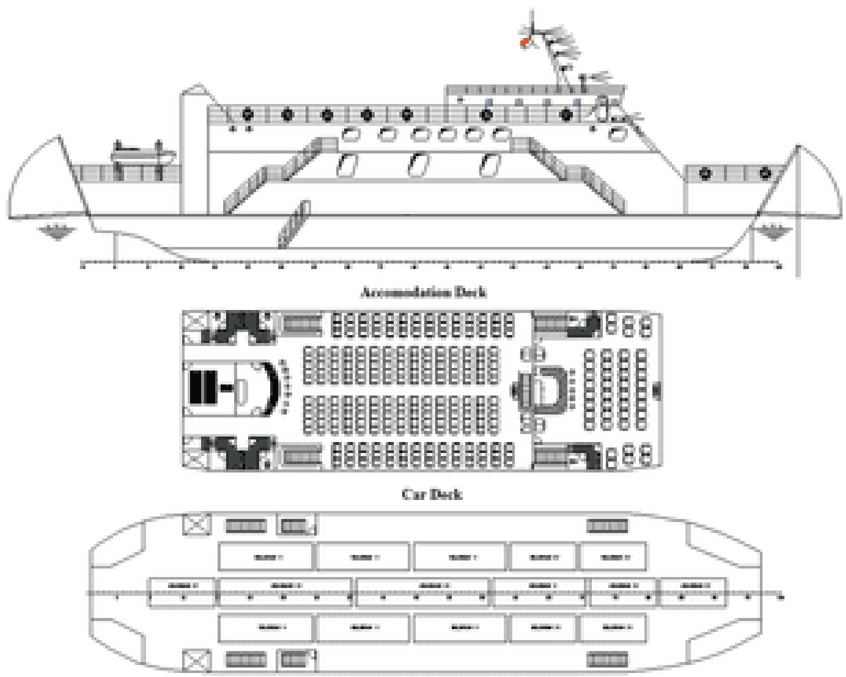

Figure 7. Deck plan of the ferry for the route of Juata Laut – Ancam.

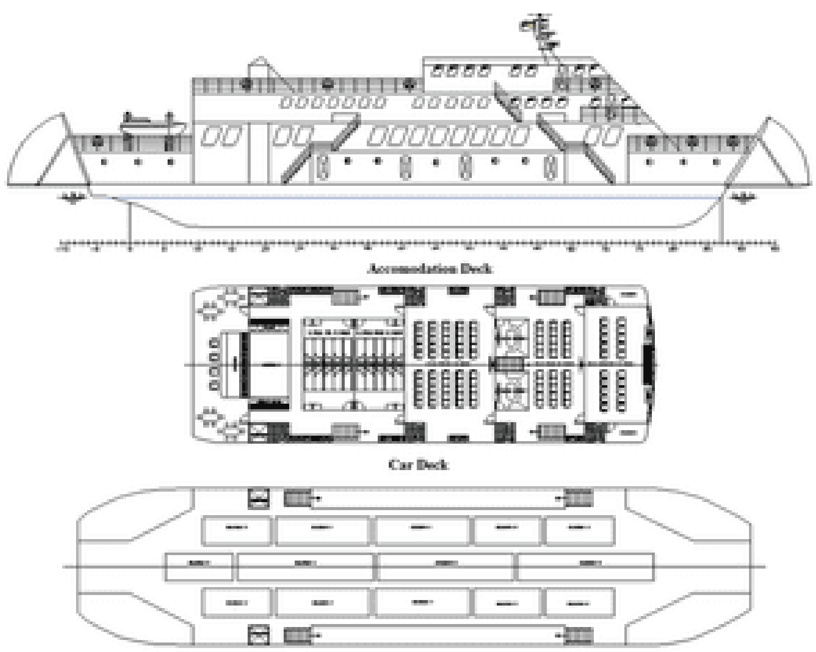

Figure 8. Deck plan of the ferry for the route of Juata Laut–Sei Jepun.

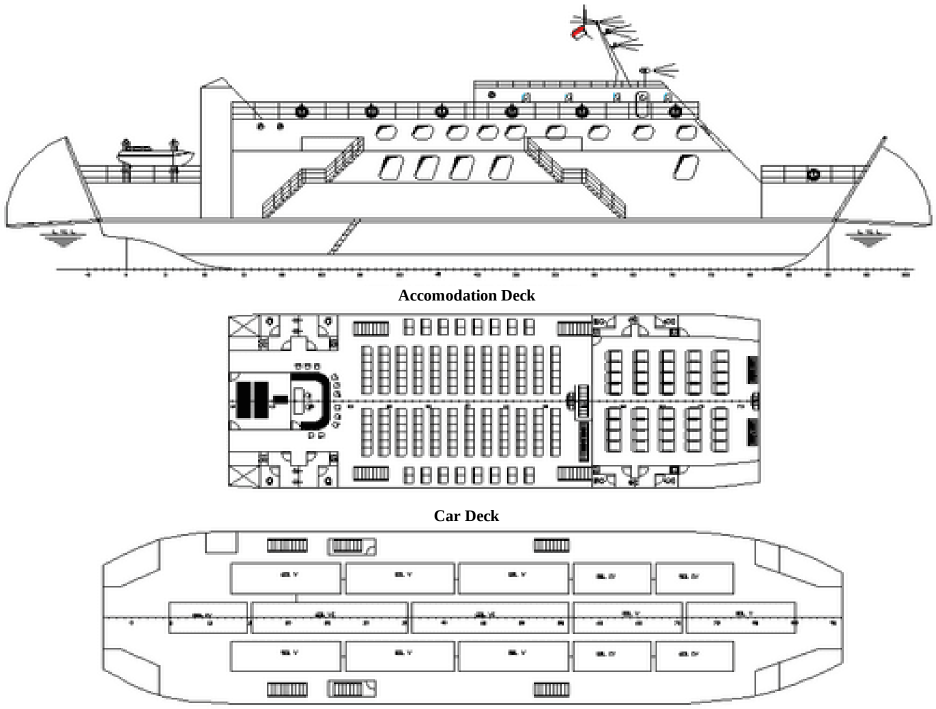

Figure 9. Deck plan of the ferry for the route of Sei Jepun-Liang Bunyu.

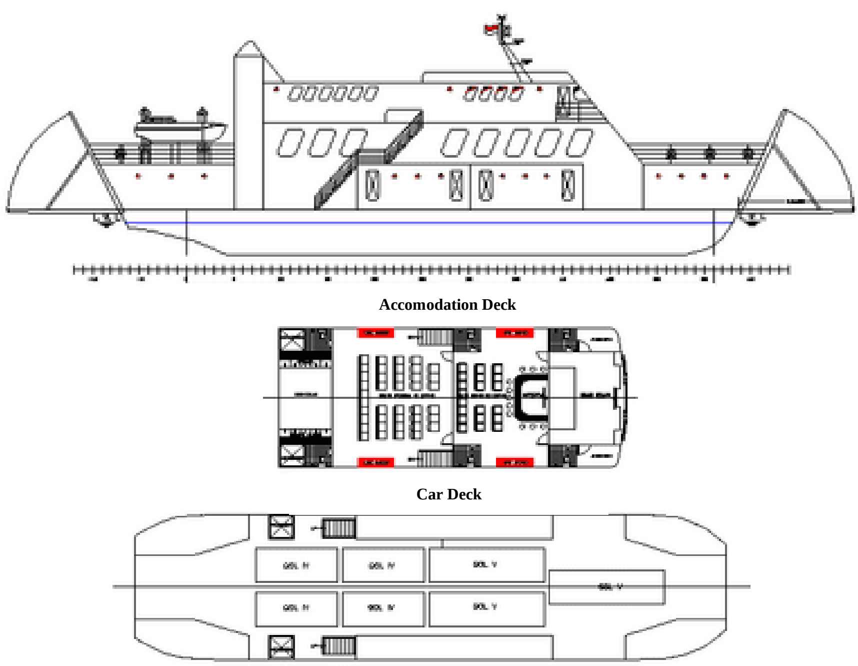

Figure 10. Deck plan of the ferry for the route of Sei Jepun-Sei Menggaris.

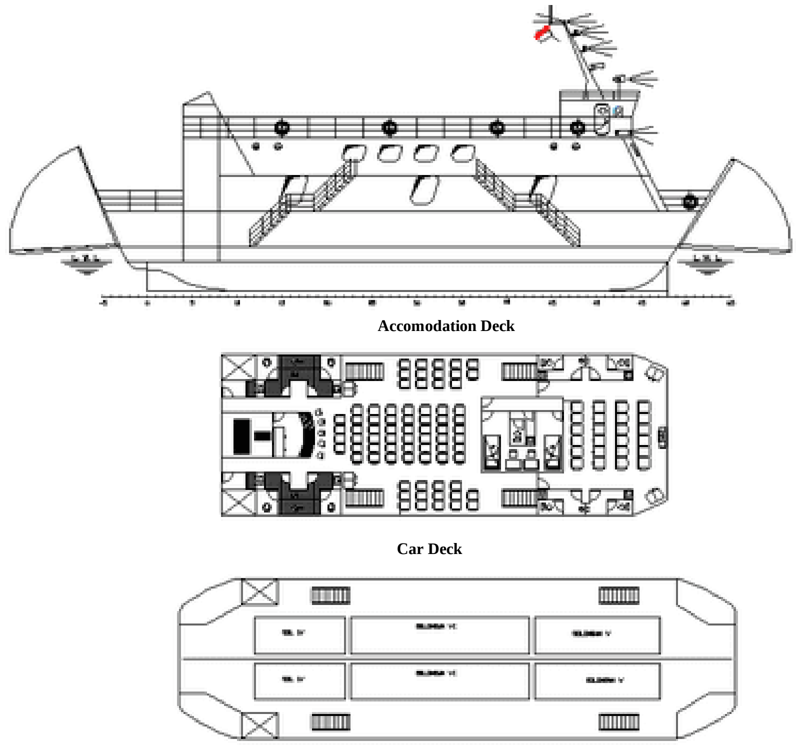

Figure 11. Deck plan of the ferry for the route of Juata Laut-Pulau Bunyu.

4. Conclusions

The concept of the sustainable development of the ferry services for integrating the inter-small islands connectivity were obtained by following several systematically stages that involve reviewing the transportation policy and spatial plan, analysing the potential area as the development plan, analysing the demand and capacity of the ferry services, surveying the hydro-oceanography characteristics, determining the conceptual design of passenger ferry, and then evaluating the waterfront facilities of port. The concept of the sustainable development of the ferry services is addressed to new route, port infrastructure, and ship capacity of ferry.

Furthermore, several stages were applied for the North Kalimantan in order to obtain the concept of the sustainable development of the ferry services. The development plan of the ferry services in North Kalimantan is subjected to the routes of Ancam (Bulungan)-Juata Laut (Tarakan), Juata Laut (Tarakan)-Pulau Bunyu (Bulungan), Juata Laut (Tarakan)-Sei Jepun (Nunukan), Sei Jepun (Nunukan)- Liang Bunyu (Sebatik), and Sei Jepun-Sei Menggaris (Nunukan).

By analysing the growth of passengers and cars, the multiple linear regression was used with two variables namely the population and gross regional domestic product (GRDP). Also, the mean growth model was used. The use of each statical model depends on the reasonable or logical results. The capacity of the ferry services that was obtained is then divided into three scenarios of the term of development plan that are short term 2018-2023, medium term 2024-2031, and long term 2031-204. In addition, several ship frequencies (ship trip per week) were considered as well. Then, the short term with the suitable ship frequency on the development plan was tried to be applied for obtaining the conceptual ferry design in each route of the ferry services.

Meanwhile, the waterfront facilities in each existing port including the quay length, berthing area, turning basin area, waterway area, water depth of quay, and anchorage area was measured. Also, the data that are provided by the related institution regarding the waterfront facilities in each existing port were collected. These data were used for considering the main dimensions of the conceptual ferry design and evaluating the waterfront facilities of the existing port in accordance with the main dimensions of the conceptual ferry design.

By considering the capacity of the ferry services for the short term of the development plan associated with the characteristics of the waterfront facilities, the main dimensions of ferry in each route of the ferry services were obtained with designing simultaneously the deck plan. Also, the main dimensions of ferry in each route were calculated by using some formulas derived from statistical analysis.

The requirement of the waterfront facilities for the ferry services in accordance with the ferry main dimensions in each route of the ferry services was obtained. The quay length of existing port of Juata Laut, Ancam, Sei Jepun, and Liang Bunyu must be larger than the requirement to anticipate the development plan. Other waterfront facilities characteristics (water depth of quay, berthing area, turning basin, waterway width and depth, anchorage area) for all existing ports are larger than the requirements. For the new route of the ferry services, the quay length for Pulau Bunyu can be considered larger than the requirement.

Finally, the present study can be a reference in order to resulting the concept of the sustainable development of the ferry services for other regions in integrating the inter-small islands connectivity. Here, several systematically stages are proposed.

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