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Determination of Sea Transport Route for Staple Food Distribution to Achieve Food Security in the Eastern Indonesia

Kuncoro Harto Widodo, Yandra Rahadian Perdana, and Iwan Puja Riyadi

***Abstract*—**Effectiveness and efficiency of food distribution is necessary to maintain food security in a region. Food supply varies among regions depending on their production capacity; therefore, it is necessary to regulate food distribution. Sea transportation could play a great role in the food distribution system. To play this role and to support transportation needs in the Eastern Indonesia, sea transportation shall be supported by fleet which is adequate and reliable, both in terms of load and worthiness. This research uses Linear Programming (LP) method to analyze food distribution pattern in order to determine the optimal distribution system. In this research, transshipment points have been selected for regions in one province. Comparison between result of modeling and existing shipping route reveals that from 369 existing routes, 54 routes are used for transporting rice, corn, green bean, peanut, soybean, sweet potato, and cassava.

***Keywords*—**Distribution, Sea Transportation, Eastern Indonesia (KTI), Linear Programming (LP).

I. Introduction

SEA transportation plays great role to support distribution mobility of both passengers and goods in Indonesia. As part of national transportation system, sea transportation shall be capable to drive national and regional development, particularly for eastern Indonesia, by prioritize regularity of ship visit to support staff and staple distribution and food security.

The support of sea transportation will ensure smooth distribution of goods, particularly staff and staple to regions in which land or air transportation unavailable. Therefore, sea transportation will have greater access. Food commodity shall be made available anytime in terms of quantity and quantity, safe, nutritious, and affordable for the community. Achieving this condition will require policies which support smooth distribution of staff and staple and food security.

Food security has several aspects to be taken into account. Among them are food availability, food affordability, and consumption sufficiency. Food availability is closely related with food supply which is affected by food production and food trade in national as well as international scale.

This current research will focus in eastern Indonesia areas. This research is conducted based on the fact that sea transportation has not been optimal in supporting the success of food security in the areas. Sea transportation sector is expected to act as stimulator which plays a lot of role in regional development by providing reliable distribution mobility in the Easter Indonesia Areas. In addition, problems of food production fluctuation do exist. The fluctuations are in terms of production number, facility and infrastructure capacity of production material transportation from production centers to the market places.

Therefore, it is necessary to have a policy which may be used by related stakeholders to effectively, efficiently, right-on-target plan the benefit of sea transportation development in the eastern Indonesia areas. This study will provide policy recommendations for the development of sea transportation in the eastern Indonesia areas to support staple food distribution and to support food security.

II. Literature Review

A. Food Security

Food security refers to a condition in which food is sufficiently available for a country until an individual, reflected from the availability of food in sufficient number and quality, safe, various, nutritious, prevalent, affordable, and in line with religion, faith, and culture of the community for healthy, active, and productive live in sustainable manner [1]. The concept of food security generally includes the five interrelated main concepts as follows:

a. Food availability, which refers to the availability of food in sufficiently safe amount and nutritious for everybody in the country which may come from self production, import, food reserve, and food aids.
b. Food access, which refers to capability of all households and individuals with their resources to get sufficient food to meet their nutritious needs which may be gathered from self food production, buying or food aid.
c. Food utilization, which refers to the use of food for healthy life needs which may include energy and nutrition needs, water and environmental health.
d. Food stability, which refers to time dimension of food security which is divided into chronic food insecurity and transitory food insecurity.

Kuncoro Harto Widodo is with The Dept. of Agro-Industrial Technology, Fac of Agricultural Technolgy and The Center for Transportation and Logistics Studies, Gadjah Mada University, Indonesia (phone: 6274- 563948; fax: 6274-552229; e-mail: kuncorohw@ugm.ac.id).

Yandra Rahadian Perdana is with Industrial Engineering Departement, State Islamic University Sunan Kalijaga, Indonesia (e-mail: yrperdana@gmail.com). He is also work with The Center for Transportation and Logistics Studies, Gadjah Mada University

Iwan Puja Riyadi is with The Center for Transportation and Logistics Studies, Gadjah Mada University, Indonesia (e-mail: iwanpuja@yahoo.com).

e. Nutritional status, which refers to the outcome of food security which reflects life quality of an individual. In general, nutritional status is measured using life expectation rate, toddler nutrition level and toddler mortality.

B. Food Security in the Perspective of Supply Chain Management

In the effort to realize food security, all sectors shall take active role and all stakeholders (Central Government, Province Government, Regional/City Government, Village Government and community) shall coordinate to improve strategy for realizing national food security. To make food evenly available, distribution of food to all regions or even households is needed. Therefore, realization of food distribution will require a development of land, sea and air to which the system passes through management on security improvement of food distribution.

Uncertainty in food security may happen anytime in all entities of supply chain. Therefore, efforts to realize food security, including all activity from the upstream to downstream such as production, manufacture, distribution, transportation and consumption, are in end users' hand. This process is closely related to supply chain management (SCM) concept. The core of SCM is integration, collaboration in the management of information, production, service and finance flow with all involved parties in the business. Fig. 1 presents the scheme of SCM concept [2].

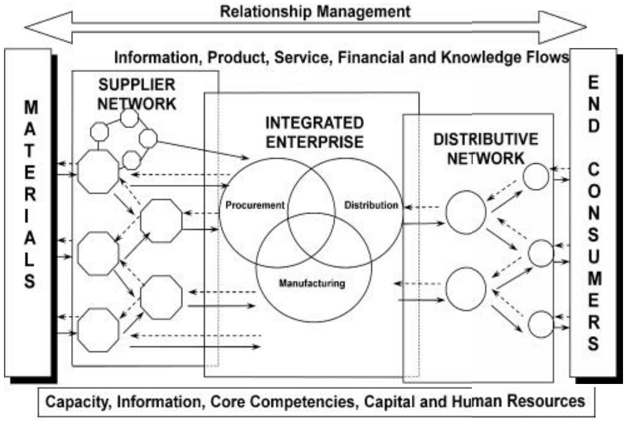

Fig. 1 Concept of Supply Chain Management

Distribution includes all aspects of product delivery from producer to consumer, starting from supply problem, selection of warehouse to transportation planning. A business is frequently faced with problems related to distribution system as well as inventory system. The problems also exist in food trading. There is gap between supply and demand which is resulted from the following problems:

a. minimum actual information regarding supply level in the resource of fishery production.
b. consumers are located in geographically different area with the production resource.

The gap becomes one substantial problems in distribution of goods which may be figured out as a routing problem with objective to find the shortest route from production resource to a group of demand locations which is geographically separated, for example province, regency/city. Routing problem has become an important problem which is found in transportation system which is aimed at making total mileage minimum to reduce vehicle operation cost [3]. There are several objectives which shall be considered in routing problem, as follows:

a. Minimizing transportation cost
b. Optimizing transport facility utilization
c. Balancing route, for travel time and vehicle load

In this study, determining route does not only view from the side of optimal route research but also from the side of food supply-demand level of each region. Routing optimization in needed to ensure food distribution could run optimally. Vehicle routing problem (VRP) method will be used. This method is used to regulate distribution from the origins which provide the same product to the marketplaces which demands optimally.

Important decision in vehicle routing problem (VRP) is optimization of optimal delivery route from one or several depots to several cities or customers which are geographically spread [4]. VRP is an integer programming problem categorized as non-polynomial hard (NP-Hard Problem), meaning that computation will be more difficult and numerous in line with the increase of scope of problem.

VRP can be implemented using balanced load distribution and added with the frequency of equal travel will avoid driver dissatisfaction problem [5]. In addition, VRP can be used to optimize supply system network and blood distribution [6]. This method also can be applied to optimize catfish allocation [7].

The core of VRP is optimization of distribution process and consumption of product in right quality, quantity, time, and price. This method is subsequently adapted in the development of sea transportation in the Eastern Indonesia Areas in the distribution of staff and staple and food security.

III. METHODOLOGY

A. Areas of Research Object

Food availability indicator used in the analysis of composite food security is per capital normative consumption toward food production [8]. The indicator is illustrated in Fig. 2. The ratio indicates whether a region suffer cereal or tubers production surplus. According to identification of food production and consumption, it is suspected the need of transportation development, i.e. in East Nusa Tenggara (Kupang), Maluku (Ternate), North Maluku (Ambon), Papua (Jayapura), and West Papua (Manokmari) Provinces.

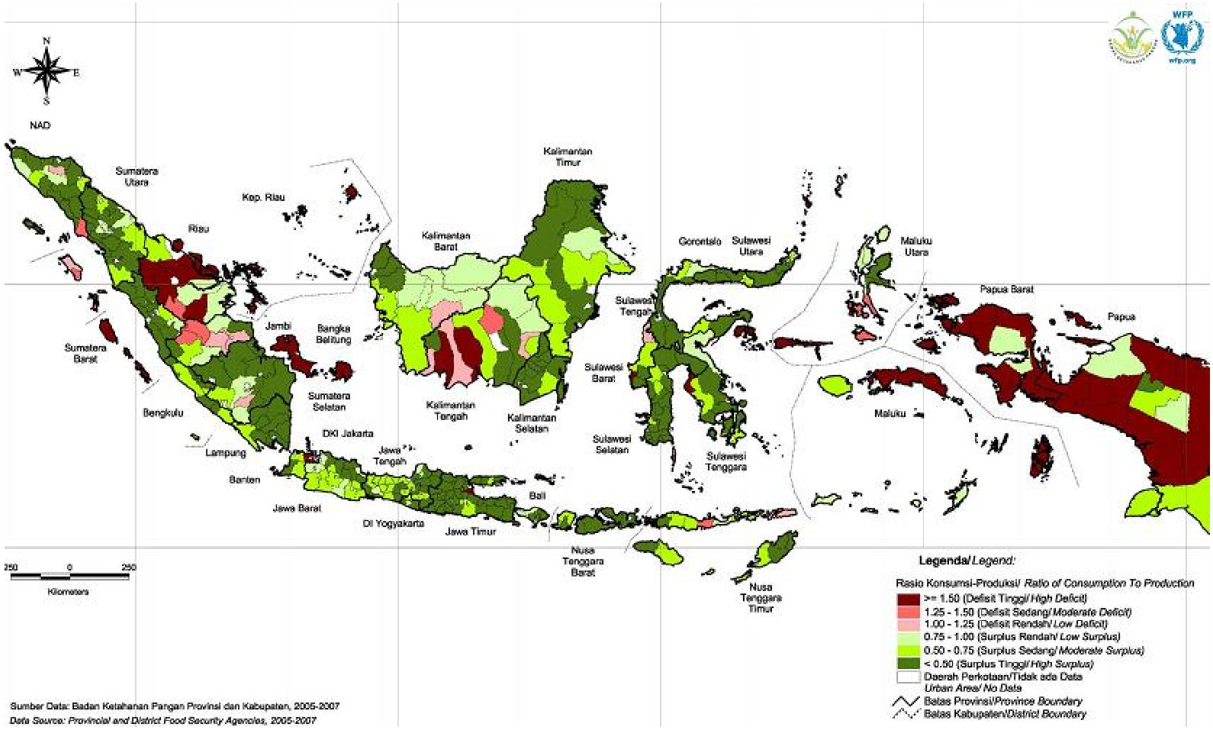

Fig. 2 Surplus and Deficit Maps of Cereals in Indonesia

B. Types of Commodity

Commodities as the objects of this research include rice, corn, green bean, peanuts, soybean, sweet potato, and cassava.

C. Research Phases

Needs analysis of sea transport facility and infrastructure development and analysis of food distribution route are conducted using sub-phases as presented in the following Fig. 3.

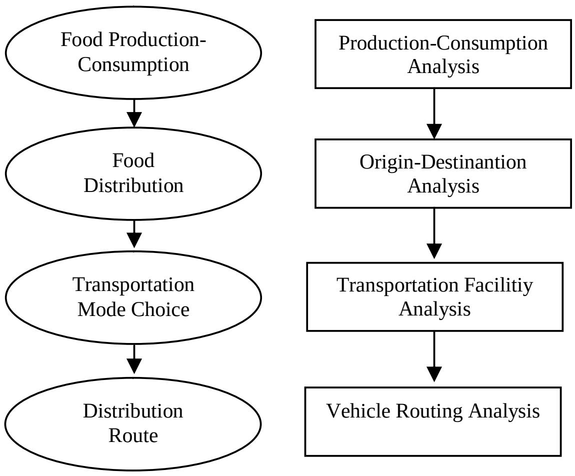

Fig. 3 Steps of Needs and Route Analysis

The followings are the detail description of each phase.

a. Phase 1: Conducting production-consumption analysis. The analysis will result regional potential map of food production and regional potential map of food consumption.
b. Phase 2: Conducting Origin-Destination analysis. This analysis will result volume of food to be distributed from Region A to Region B or Region C.
c. Phase 3: Conducting analysis of transportation means. This analysis will utilize the output of Phase 1 and Phase 2 to calculate type design and facility needs to be used in the distribution process.
d. Phase 4: Conducting vehicle routing analysis. Determination of port location and distribution route is the result of optimum optimization of various alternatives proposed in this research. Optimum here refers to cost, time, and safety.

D. Research Variables

The analysis of transportation facility and infrastructure development needs uses the following variables.

1. OD Cost Matrix Analysis for Transshipment

OD cost matrix analysis investigates and measures cost (distance/time) along the network from several origins to several destinations using ArcGIS Network Analysis. In transshipment, this analysis is used to determine location of destination port for each regency based on the shortest distance in the road network access. Each regency has opportunity of access to all ports in Indonesia. Based on the shortest distance, however, each regency will choose the port.

In this analysis, origin represents centric points of each regency in Indonesia, and destination represents ports in the entire of Indonesia.

2. Inter-Port OD Cost Matrix Analysis

Inter-port OD cost matrix analysis is used to investigate routes for transportation from one port to other port based on the existing shipping and crossing route. In the software, table matrix and desire line among ports will appears.

E. Analysis Method

Linear Programming will be used as a Model to analyze food distribution pattern. This model will determine distribution model which generates total transportation cost from several origins to several destination (problem of minimizing transportation cost). Optimization (maximum and minimum) is referred as objective function of the linear programming. The objective function consists of decision variables. Furthermore, constrains are formulated into constraints function, consisted of decision variables which use limited resources (distance). Therefore, the linear programming will resolve the achievement of objective functions or cost minimum by considering constraint function (limitation and constraints) of the existing resources. The allocation will be performed using the following formula:

Proportional Minimum / Least Cost Allocation

This method is a modification of Least Cost Allocation but the allocation will consider all delivery destinations of the commodity. The idea is that all delivery destinations will receive allocation but will receive supply in accordance with proportional demand and distance (cost) although there is supply lack. The larger the demand the bigger the allocation; however, the longer the mileage the smaller the allocation. The allocation will be provided by using the following formula.

$$D_i^* = S_i \frac{D_i / d_{ji}}{\sum_{i=1}^{n} D_i / d_{ji}} \quad (1)$$

where:

- D_i Real Demand in city i
- S_i Supply in city i
- D_i^* Demand to be filled for city i
- d_{ji} Mileage of a location / city j which has supply to city i which has certain demand.

IV. Result and Discussion

Based on inter-port matrix OD, the next step is determining food distribution route based on transshipment passed through by existing shipping route. From the 369 existing shipping routes, there are 54 passed through routes based on this model. The result is presented in Table I.

TABLE I
Distribution Route Based on Modelling Passed Through by Existing Shipping Route

NO	FROM	TO	ALLOCATION	COMMODITY
1	Tenau	Talaud	7,143	Rice
2	Panajam	Makassar	33,245	Rice
3	Mborong	Kaimana	2,809	Rice
4	Parigi	Bere-bere	3.500	Rice
5	Bima	Tanah Merah	9,294	Rice
6	Aimere	Pulau Anus	15,592	Rice
7	Parigi	Larantuka	40,721	Rice
8	Polewali	Pulau Yamna	2,595	Rice
9	Talaud	Tenau	502	Corn
10	Makassar	Panajam	2,813	Corn
11	Marapokot	Mborong	6,360	Corn
12	Waikelo	Labuan Bajo	19,552	Corn
13	Wunlah	Sidangole	5,016	Corn
14	Maumere	Manokwari	7,361	Corn
15	Sulamu	Patani	1,388	Corn
16	Gorontalo	Teminabuan	1,382	Corn
17	Gorontalo	Babo	565	Corn
18	Gorontalo	Sorong	11,136	Corn
19	Teluk Gurita	Bintuni	426	Green Bean
20	Teluk Gurita	Tobelo	1,428	Green Bean
21	Tenau	Talaud	1,466	Peantus
22	Pertamina Gunung Sitoli	Wasior	14	Peantus
23	Talaud	Tenau	77	Soybean
24	Panajam	Makassar	18	Soybean
25	Sulamu	Kendari	576	Soybean
26	Bima	Tanah Merah	3,015	Soybean
27	Salakan	Wailei	4	Soybean
28	Teluk Gurita	Bintuni	206	Soybean
29	Larantuka	Waingapu	1	Soybean
30	Namilea (Namlea)	Maligano	422	Soybean
31	Pulau Yamna	Polewali	114	Soybean
32	Talaud	Tenau	6,158	Sweet Potato
33	Sulamu	Kendari	9,818	Sweet Potato
34	Wunlah	Sidangole	755	Sweet Potato
35	Talaud	Tenau	13,210	Cassava
36	Makassar	Panajam	12,643	Cassava
37	Mborong	Kaimana	801	Cassava
38	Bima	Sinabang	2,090	Cassava
39	Tahuna	Kuala Pembuang	2,199	Cassava
40	Wunlah	Sidangole	6,054	Cassava
41	Mborong	Calang	2,388	Cassava
42	Parigi	Bere-bere	5,418	Cassava
43	Maumere	Manokwari	7,053	Cassava
44	Lewoleba	Wasior	1,013	Cassava
45	Parigi	Ende	11,707	Cassava
46	Namilea (Namlea)	Elat	25,228	Cassava
47	Labuan Bajo	Meulaboh	19,503	Cassava
48	Teluk Gurita	Bintuni	1,990	Cassava
49	Larantuka	Waingapu	29,459	Cassava
50	Sulamu	Patani	3,548	Cassava
51	Semarang	Pertamina upms IV (tanjung emas)	19,078	Cassava
52	Tenau	Luwuk	7,912	Cassava
53	Sulamu	Babang	20,106	Cassava
54	Semarang	Singkawang	165.49	Cassava

Based on the modeling results, it can be explained that the distribution pattern of rice indicates to spread with inter-island or inter-city movement within the area of Indonesia. This pattern is dominant experienced in Java, Sumatera and Kalimantan islands, while the pattern of distribution of corn indicates to spread out to all regions within Indonesia area. The corn distribution pattern is dominated by inter-island movement in Java, Sumatra and Kalimantan and Nusa Tenggara islands.

The distribution pattern of the green bean is spreading out to all regions within Indonesia area but this pattern is dominant experienced on the major islands of Indonesia such as Java, Sumatera, Nusa Tenggara, Kalimantan, and Sulawesi islands. This pattern is also experienced by peanut commodity with the dominant pattern of inter-island movement which is still experienced in Java and Sumatera islands.

The distribution patterns of soybean is spreading all over Indonesia regions and the movement is dominated in almost all major islands in Indonesia such as Sumatera, Java, Kalimantan, Nusa Tenggara, Sulawesi, and Papua islands.

The distribution pattern of sweet potato is also spreading out from all regions within Indonesia area and is experienced in Java island. While the distribution pattern of corn is spreading throughout all regions in Indonesia and it is dominated in Java, Sumatera, and Nusa Tenggara islands. The modeling results are illustrated in Fig. 4 to 10. This figure illustrates a superimposed between the modeling results for the allocation of each commodity with existing routes.

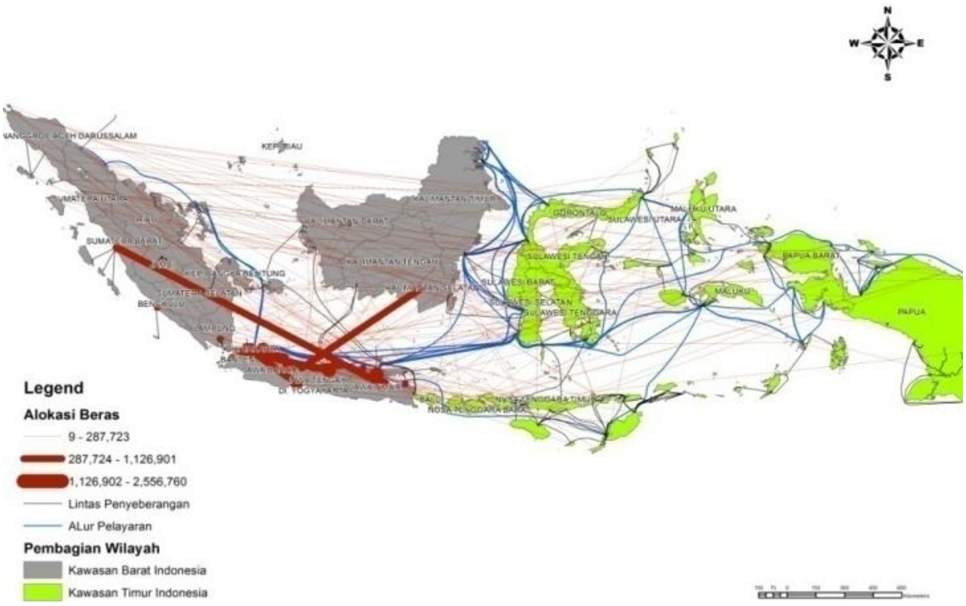

Fig. 4 Superimpose of modeling result for rice commodity with existing route

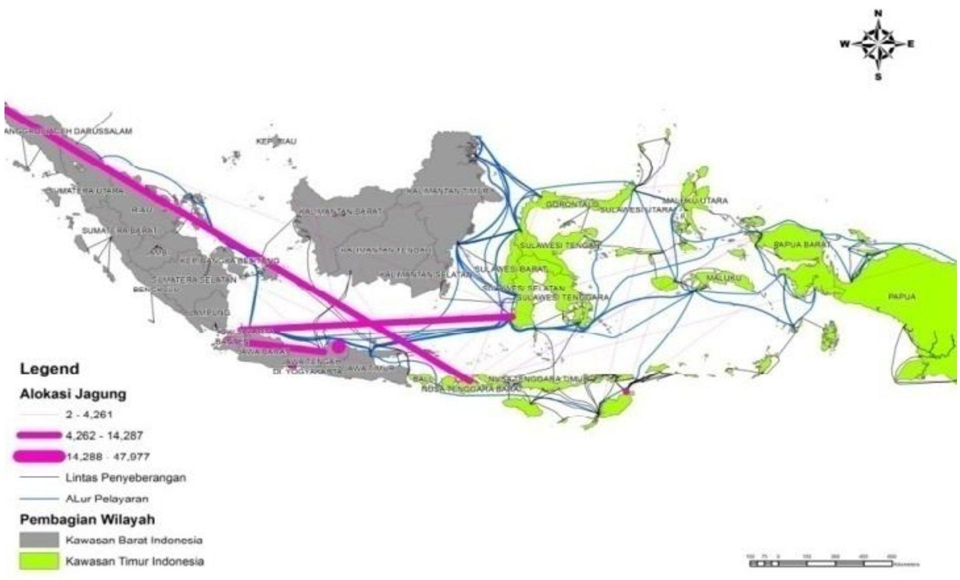

Fig. 5 Superimpose of modeling result for corn commodity with existing route

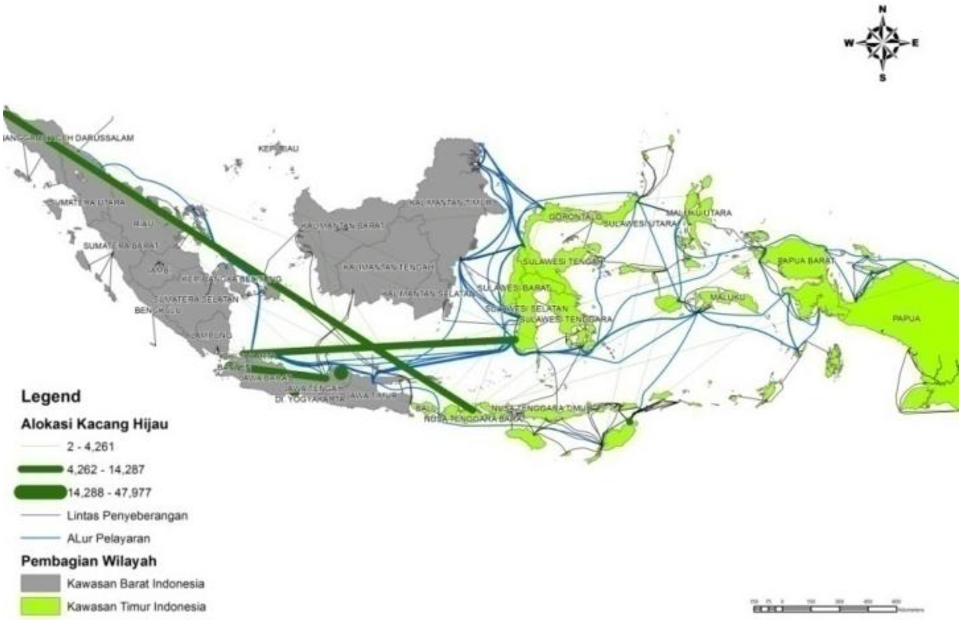

Fig. 6 Superimpose of modeling result for green beans commodity with existing route

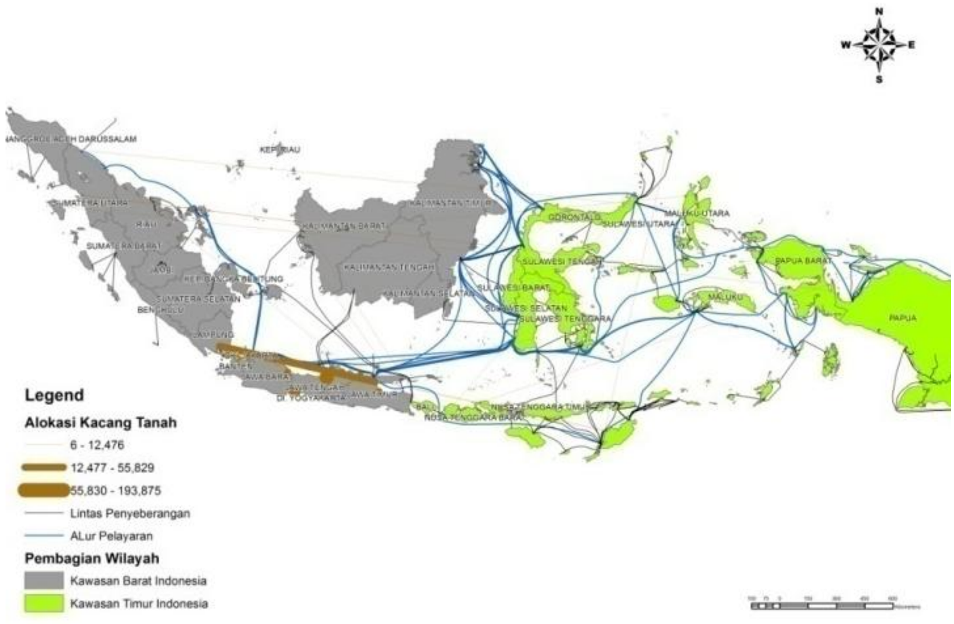

Fig. 7 Superimpose of modeling result for peanuts commodity with existing route

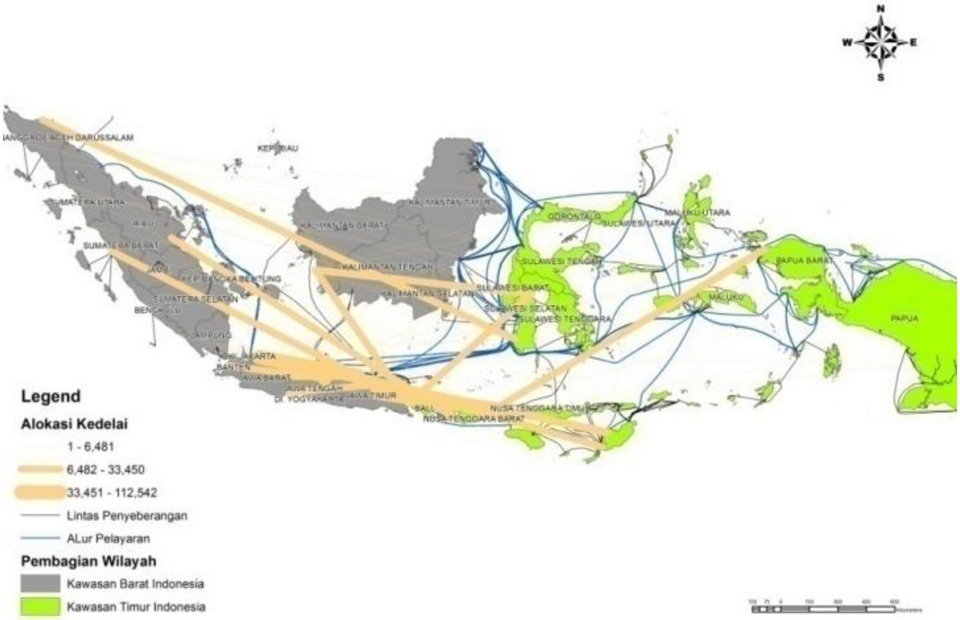

Fig. 8 Superimpose of modeling result for soybean commodity with existing route

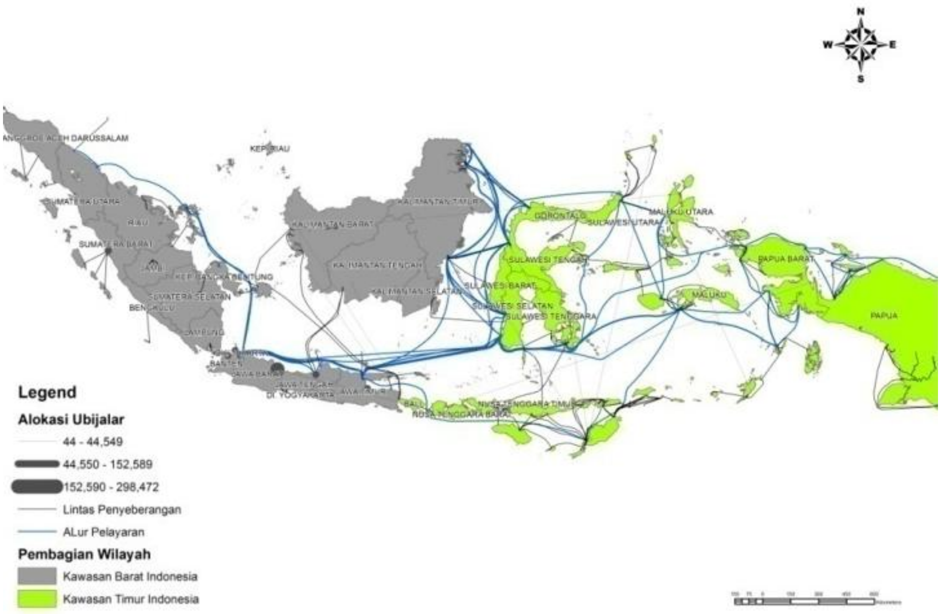

Fig. 9 Superimpose of modeling result for sweet potato commodity with existing

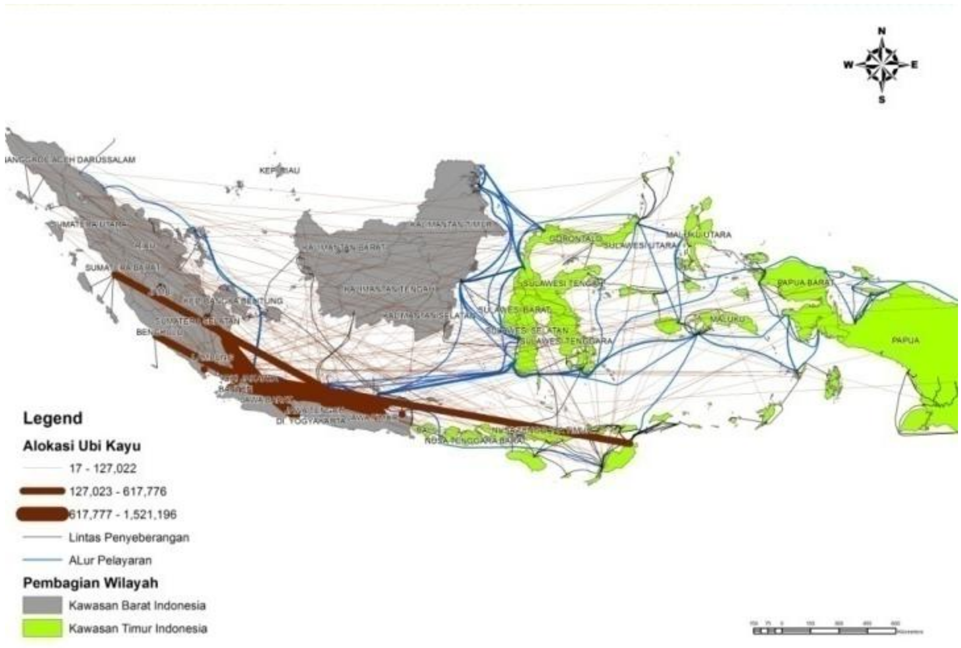

Fig. 10 Superimpose of modeling result for cassava commodity with existing route

Distribution policy objective is to ensure food security throughout the year and affordable evenly throughout society. To maintain the availability of food is necessary to buffer stock for the next 3 months. Bulog policy is the minimum amount of buffer stock of rice is equal to 1 million tons. While the NTB provincial government issued the Governor (gubernatorial) No. 33 of 2008 on Food Reserves Management NTB provincial government. Regulation was reinforced with NTB Governor Instruction No. 2 of 2009 dated May 6, 2009 regarding Management of Food Reserves NTB provincial government. Of the existing regulations, the NTB provincial government is obliged to provide rice as much as 60 percent of the total needs of the next three months. This policy can be used as a basis in the provision of marine transportation flow as a function of food distribution among regions.

V. CONCLUSION

Decisions about the development of sea transport network in eastern Indonesia requires connectivity between areas of food production to consumers. Based on the modeling results are known there are 54 route followed by the results of 369 pemhodelan existing shipping routes. Therefore, in the development of the service requires an integrated infrastructure between sea and land transportation. The integration of these modes must also be connected to its hinterland of a port.

Distribution of food through the ocean is strongly influenced by the weather, therefore it is necessary to buffer stock of food. The successful development of a buffer stock is strongly influenced by sea transport infrastructure, taking into account the allocation of resources in accordance with the amount of requests, including the use of technology.

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Kuncoro Harto Widodo was born at Yogyakarta, Indonesia and got bachelor degree of Agro-industrial Technology in 1994 from Universitas Gadjah Mada, Yogyakarta, Indonesia. The master and doctoral degrees of Industrial Engineering were earned from Osaka Prefecture University, Japan in 2002 and 2005, respectively.

He is lecturer and researcher at the Department of Agro-Industrial Technology and the Director of the Center for Transportation and Logistics Studies at Universitas Gadjah Mada. His current and previous interests are Operations and Logistics-Supply Chain Management.

Dr. Widodo is the member of Indonesian Logistics Association and Indonesian Association of Agro-Industrial Technology Profession.