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## REGIONAL FREIGHT TRANSPORTATION PLANNING: AN OVERVIEW OF DEVELOPING METHODOLOGY

Noor Mahmudah<sup>1\*</sup>, Danang Parikesit<sup>2</sup>,  
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### ABSTRACT:

There is a parallel evolution of a political economy and the transportation system either in developed or developing countries. The growth of economic will increase the number of ton-km of freight transportation. As flows of freight and their impacts increase, transportation planners, managers, and operators have a more concern to develop a better methods for tracking and monitoring the flows of commodities and analyzing the impacts of these flows to the transportation infrastructures. Current estimation of freight flows and analysis methods have several problems, which are related to the data and the method itself.

This paper attempts to elaborate the relationship of the economics activities of commodities toward export - specifically the production of goods and services that generate freight transportation, the spatial data of commodities related to the economics' activities (resources, factories, and outlets), the transportation data (infrastructures, modes, and services), and government regulations, in formulating the method for freight transportation planning to produce an efficient freight movement to enhance sustainable mobility and economic development in the regional scale.

*Keywords: methodology; planning; regional freight transportation*

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## **1. INTRODUCTION**

There is a parallel evolution of a political economy and the transportation system either in developed or developing countries. The growth of economic will also increase the number of ton-km of freight transportation. The case of European Union and Indonesia showed that across all freight transport modes, road freight transportation remains dominant (Stead and Banister, 2006; [Lubis et al, 2005](#)). On the other hand, empirical studies also showed that the domination of road freight transportation caused economic loss, safety and environmental problems. Road deterioration and traffic accident due to overloaded truck, and adverse impact to the environment due to gas emissions and noise of truck, are the main problems raised from road freight transportation ([Kreutzberger et al, 2003](#)).

As flows of freight and their impacts increase, transportation planners, managers, and operators have a more concern to develop a better methods for tracking and monitoring the flows of commodities and analyzing the impacts of these flows to the transportation infrastructures. Current estimation of freight flows and analysis methods have several problems, which are related to the data and the method itself. The existing freight transportation planning methods, for instance, are generally adopted from the conventional four-stage model (Houguin-Veras *et al*, 2001; Southworth, 2002; [De Jong et al, 2004](#)).

To formulate an effective strategy for regional transportation planning, the planners or policy makers need to know the location of resources, processing or factory locations, and the final outlet (ports) to send their goods to the outside world. To do this, various characteristics of the different commodities and the available networks that can be used, need to be known. An understanding of how the relationships between commodities' activities and transportation are linked by spatial structure is essential. Therefore, this study attempts to elaborate the relationship of the economics activities of commodities toward export - specifically the production of goods and services that generate freight transportation, the spatial data of commodities related to the economics' activities (resources, factories, and outlets), the transportation data (infrastructures, modes, and services), and government regulations, in formulating the method for freight transportation planning by considering intermodality concept, to produce an efficient freight movement to enhance sustainable mobility and economic development in the regional scale.

In general, this paper aims to formulate the methodology for a regional freight transportation planning by employing the concept of inter-modality and spatial models in order to achieve the efficient transportation system. In more specific, the objectives of this paper are: a) to summarize the conceptual framework of the current models of freight transportation planning; and b) to elaborate the developing method of regional freight transportation planning.

## **2. LITERATURE REVIEW**

There is a strong relationship between transportation and regional economic development. Moreover, the availability and performance of transport infrastructures are very important in supporting freight transportation. According to [Lem \(2002\)](#), the relationship between transport infrastructure and economic development have, at least, three important implications for the goods movement and trade. Firstly, the relationship between transport infrastructure and regional productivity implied that the improvements of transport infrastructure are very important aspects of economic development strategy to increase regional productivity. Secondly, transport infrastructure that adequately facilitates the goods movement of industries within the region can reduce the production costs. Finally, transport infrastructure affects the location of industries. It is implied that a development strategy involving attraction of new industries to a region must ensure that regional transportation infrastructure is adequate for the targeted industries. The access of industries to supply routes must be evaluated in accordance with existing transportation infrastructure and the potential location of factories (plants) and distribution.

To enhance efficiency and quality in transportation development, it is necessary to improve the overall cost effectiveness and functioning of transportation operations and infrastructures. Nowadays, inter-modality is more and more realized to provide a better performing of transportation system ([Kreutzberger et al, 2006b](#)) because of environmental concerns, reasons of efficiency and the benefits of co-ordination of modes to cope with growing transportation flows (OECD, 1997 in [Bontekoning, 2000](#); [Bontekoning et al, 2004](#)). In addition, inter-modality is now widely used to enhance the freight transportation that is seamless, efficient, and sustainable to achieve specific goals ([Rodrigue, et al, 2004](#)).

The existing models of freight transportation planning, in general, are adopting from the ones used for passenger transportation like the four-stage-model ([Houguin-Veras et al, 2001](#); [Southworth, 2002](#); [De Jong et al, 2004](#)). [Southworth \(2002\)](#) introduced a model of freight transportation, which is known as a multi-step freight planning model. The conceptual framework of this model is originally consisted of: (a) freight generation/attraction; (b) flow modelling/trip distribution; (c) modal split; and (d) traffic route assignment respectively. When the planning process is intended to translate the commodity flows into vehicle movements so the fifth step is required, this is called modelling of vehicle load factors. This vehicle/fleet loading may occur as step four in the modelling process, which is conducted after mode split model or alternatively, it may occur at trip generation stage, producing truck trip forecasts that are suitable for direct application to the subsequent traffic route assignment stage. Where truck traffic is concerned, it is usual to carry out mixed freight-passenger travel assignments to capture the effects of traffic congestion on shipment times and hence freight delivery costs. In theory, these congestion inclusive costs can then be fed back through the freight flow modelling, modal split, and vehicle loading steps, and iterated until the system of model equations stabilizes on a set of transportation costs and flows. Variations on such process have been used to analyze corridor-specific, metropolitan area wide and state-wide freight movement systems ([Holguin-Veras and Thorson, 2000](#); [2003a](#); [2003b](#)).

[Holguin-Veras and Thorson \(2000\)](#) and [Holguin-Veras et al \(2001\)](#) have promoted the models of freight transportation planning which are known as commodity-based and trip-based models. Both models have been identified as the appropriate models for the New York Metropolitan Region that has specific location and transportation demands. In general, these two freight transportation models have been built on either of two platforms: vehicle (trip)-based or commodity-based modelling. These platforms model vehicle trips and commodity type typically by size and weight respectively. The common approaches of both models are trip generation, trip distribution and traffic assignment.

Commodity-based models focus on modelling the amount of freight measured in tons, or any other unit of weight. It is accepted that the focus on the cargoes enables commodity based models to capture more accurately the fundamental economic mechanisms driving freight movements, which are largely determined by the cargoes' attributes (e.g. shape, unit weight). Commodity based modelling is comprised of the process: (a) generation models that are used to estimate the total number of tons produced and attracted by each zone in the study area; (b) distribution models, where the tonnage moving between each origin-destination pair is estimated using gravity models and other forms of spatial interaction model; (c) mode split model that is intended to estimate the number of tons moved by the various modes and is done by applying discrete choice models and/or panel data from focus groups of business representatives; and (d) finally, in the traffic assignment phase of commodity-based models, a combination of vehicle loading models and complementary models that capture empty trips, applied to origin-destination matrices by mode, are used to assign vehicle trips to the networks. Trip-based models focus on modelling vehicle-trip, which presupposes that the mode selection and the vehicle selections were already done. Therefore, trip-based models do not need mode split or vehicle loading models. The advantages and disadvantages of each model can be summarized as depicted in Table 1.

TABLE 1. The advantages and disadvantages of commodity-based and trip-based models

Model type	Advantages	Disadvantages
A. Commodity-based Freight Model	<ol style="list-style-type: none"> <li>1. Focus on modelling the amount of freight (measured in tons)</li> <li>2. Capture the economic mechanism driving freight movement</li> </ol>	Unable to capture empty trips
B. Trip-based Freight Model	<ol style="list-style-type: none"> <li>1. Focus on modelling vehicle-trip</li> <li>2. Able to track the vehicle movement</li> <li>3. Capture empty-trip vehicle</li> </ol>	<ol style="list-style-type: none"> <li>1. Cannot capture mode choice process</li> <li>2. Difficult to identify economic and behavioural mechanism of freight demand</li> </ol>

### 3. METHODOLOGY

The conceptual framework used in developing methodology for regional freight transportation planning is as illustrated in Appendix 1. The regional economic activities, especially related to the production of goods and services, is considered as the freight driven. The goods movement and transportation services will be analyzed further through spatial location and transportation modelling. The spatial location model will be simulating and then mapping of the optimum access/location of factories and outlets of selected commodities in term of distance. Furthermore, transportation model analyze the freight' flows originated from the resources to the factories and from the factories to the desired outlets (ports) by considering the optimum generalized cost as the indicator of transportation performance. The flows of these commodities are supposed to be transported by specific transportation modes through particular route of available transportation networks. Moreover, the vehicle ownership status will also be considered as the attributes/factors influencing the generalized cost of these flows. The type and location of transportation infrastructures (networks and ports) are applied as strategy (scenario) in the model to achieve the efficient transportation system (infrastructure and service). Hence, the expected valuable output of these models are the optimum generalized costs resulted from the optimum location of resources, factories, and transportation infrastructures to enhance freight mobility either for production or distribution activities in the regional scale.

The proposed methodology for regional freight transportation planning is as depicted in Appendix 2. In general, this method consists of two parts. The first part is desk study on socio-economic development of particular region and selection of important commodities in the region using Regional Income (RI) model. In this part, all data used in analysis is already available (given) in form of secondary data. The second part is the process of freight transportation planning, in which spatial location and transportation models are part of it. The data that will be used in model building should be obtained from the research. This part consist of qualitative survey on goods production and movement (flow) of selected commodities, mapping of (optimum) spatial location of selected commodities using ArcGIS, and modelling of freight transportation using FlowMap and ArcGIS to determine the generalized cost (GC), which is used as an indicator of efficient transportation system. Identification of type and location of infrastructures are then considered as strategies or scenarios that are applied in transportation modelling in order to achieve an optimum model, which is reflected into optimum generalized cost. The transportation planning processes can be illustrated as follows:

- a) The first stage is conducting desk-study on socio economic condition and regional development in study area by analyzing the available secondary data. Selecting of specific commodities that is influencing the regional economic growth in particular region is conducted by analyzing secondary economics data using Regional Income (RI) approach. Afterward literature study on process of goods production and goods transportation activities of selected commodities is conducted. This

aims to prepare the good quality of questioner to be used as a tool in qualitative survey on goods production and goods movement.

- b) The second stage is conducting qualitative survey on goods production and transportation of selected commodities in study area. It is primarily directed to the shippers. However, it may also need to survey on carriers to obtain more precise models representation of the actual conditions. The data obtained from the survey are then refined and selected as the attributes considered in transportation model either using ArcGIS or FlowMap. In general, the expected data from this survey are: (1) economic activities of selected commodities, especially the activities related to goods production and services (annual production, economic value, logistics chain, technology); (2) spatial data related to commodity and infrastructures (e.g. location of resources, factory, outlet of produced commodity, and transportation networks); (3) transportation data such as transport infrastructures characteristics (road and river networks, river and sea ports), vehicle characteristics (type, capacity, speed, ownership), and transportation services (transport cost/fare, travel time, and reliability); and (4) policy such as government regulations and regional master plan.
- c) The third stage is mapping of spatial location of selected commodities using ArcGIS. The data required as the input are spatial data of resources (raw materials), outlet for sending the produced goods, transportation networks (road and river), and available policy/regulations. The location of factories is then simulated by considering the accessibility of such factories to the available transportation networks. Regional master plan will be considered as the constraints to the model. Shortest route (in term of distance) between particular factory to certain networks (road, river, or both road and river) is considered as the optimum spatial location of selected commodities.
- d) The fourth, fifth, sixth, and seventh stages are actually attached with transportation modelling as well as spatial location of selected commodities. Modelling of freight transportation using ArcGIS and FlowMap is considered as the fourth stage. The data required in this stage are spatial data of selected commodities (location of resources, factories, and outlets), transportation availability (networks, ports, and vehicle characteristics), and policy/government regulations. In addition, to capture the shippers or carriers preference and intention to specific attributes of transportation such as modes, destinations, or service quality, so the quantitative survey (the fifth stage) is required to conduct. The outputs of freight transportation model are utility and generalized cost models. Generalized cost is also used as indicator of transportation system performance. To improve transportation performance, identification of type and location of transport infrastructures (sixth stage) are then applied as strategy or scenario in the model. The transportation system performance is checked again by comparing the value of generalized cost before and after applying such strategy. This procedure is conducted iteratively until the satisfied model - with optimum generalized cost, is achieved. Model calibration and validation (seventh stage) will be done by using statistical analysis (significance test or t-test, goodness of fit statistics or  $R^2$ , and root mean square error or RMSE) and by testing the models to other areas or commodities. The valid model obtained is accepted as the optimum model.

The freight transportation planning models, which are promoted by Southworth (2002), Holguin-Veras and Thorson (2000) and Holguin-Veras *et al* (2001), give more attention to the transportation modelling with several stages to be conducted. The freight movements, which are determined from certain economics activities in particular location, are then converted to the tonnage of goods (flows) and transported from certain origin to particular destination by using trip distribution, modal split and traffic route assignment models respectively. The locations of industries or economic activities applied in the transportation modelling are using a given data. In fact, the spatial location of these activities may differ one to another or change rapidly and this will have significant influence to the transportation model obtained. As a new innovation in freight transportation planning, this new method does not only consider

the transportation modelling but also involving the spatial location modelling/mapping, especially in determination of factories/industries' location, and considers the government regulations as the constraint, in formulating the freight transportation planning for regional scale. Thus, it is expected that this method can produce the more realistic/practical transportation model because of the location of economics activities that generate freight transportation is considered in the model and can be changed dynamically over time. This new method also offers a more efficient stage of transportation modelling where the distribution, modal split, and route assignment models are conducted in the same time. All simulation models will be built on the basis of up-to-date GIS software that is now widely used in the spatial location modelling (and mapping) and transportation modelling. However, this method faces with the great challenges in data collection (by using disaggregate data) and database construction because it requires large data to be formatted and converted into GIS database.

#### **4. FREIGHT TRANSPORTATION MODEL**

The field of freight transportation modelling has developed very fast into different directions all over the world. As noted by Tavasszy (2006), since the commencing of transportation modelling, freight demand modelling has gone through a number of major development stages. In general, freight transport demand modelling can be distinguished by considering the decision problem (e.g. production and consumption, trade, logistics services, network and routing), typical modelling challenges (e.g. trip generation and facility location, mode choice, intermodal transportation, and the relationship of freight economy), and typical techniques employed (e.g. discrete choice models, network assignment, and simulation).

This research is intended to utilize the *freight network simulation*, especially using ArcGIS and FlowMap softwares by considering spatial and transportation factors as the input, and government regulation as the constrains, to modelling intermodal freight transportation in regional scale by considering the generalized costs as efficiency indicator of optimum transportation system. It is important to be noted that spatial location and transportation models that are then constructed in this modelling are part of proposed methodology for regional freight transportation planning as the general objectives of this research. The considered factors in building the models among others: the type of commodities; transportation services (travel cost, travel time, and climate); the type of transportation modes (truck, barge/ship, truck-barge combination); and status of vehicle ownership (own-vehicle and hired vehicle). The expected output of the research is the optimum generalized cost resulted from the optimum location of resources, factories, and outlets, and the type and location of transportation infrastructures to support the freight flow either for production or distribution activities of specified commodities in the regional scale. The framework considered to model freight transportation for the regional scale is as depicted in Figure 1.

To address the objectives as stated earlier, however, this research is limited and is only considering: (a) commodity to be used in the model is a primary commodity toward export and is selected by considering the added value. Other derivations of this commodity are not considered in this model; (b) The model is only considered the simple logistics chain that consists of the resources, factories (including storage), and ports (sea and river ports) as the outlets; (c) The specific area considered in the model is that it should be consisted of road and river networks that can be used for freight transportation. Due to the river networks are highly dependent on climate thus their reliability will also be considered in the model; (d) Transportation cost (in term of economic value), travel time, and climate are the attributes/factors of utility considered in determining the probability of choosing transportation modes (truck, barge, and combination of truck-barge) in the first analysis of transportation model (namely transportation cost 1 or TC1); (e) Transportation cost (in term of economic value), travel time, climate, and status of vehicle ownership (own or hired vehicle) are the attributes/factors of utility considered in determining the probability of choosing transportation modes (own-truck, hired-truck, hired-barge, and combination of hired-truck-barge) in more detailed analysis of transportation model (namely transportation cost 2 or TC2); and (f) Generalized cost, which is a combination of transportation cost and travel time cost, is used

as the indicator of an efficient transportation system in the shippers' point of view. The optimum generalized cost is the optimum of total cost spent from origin to the final destinations.

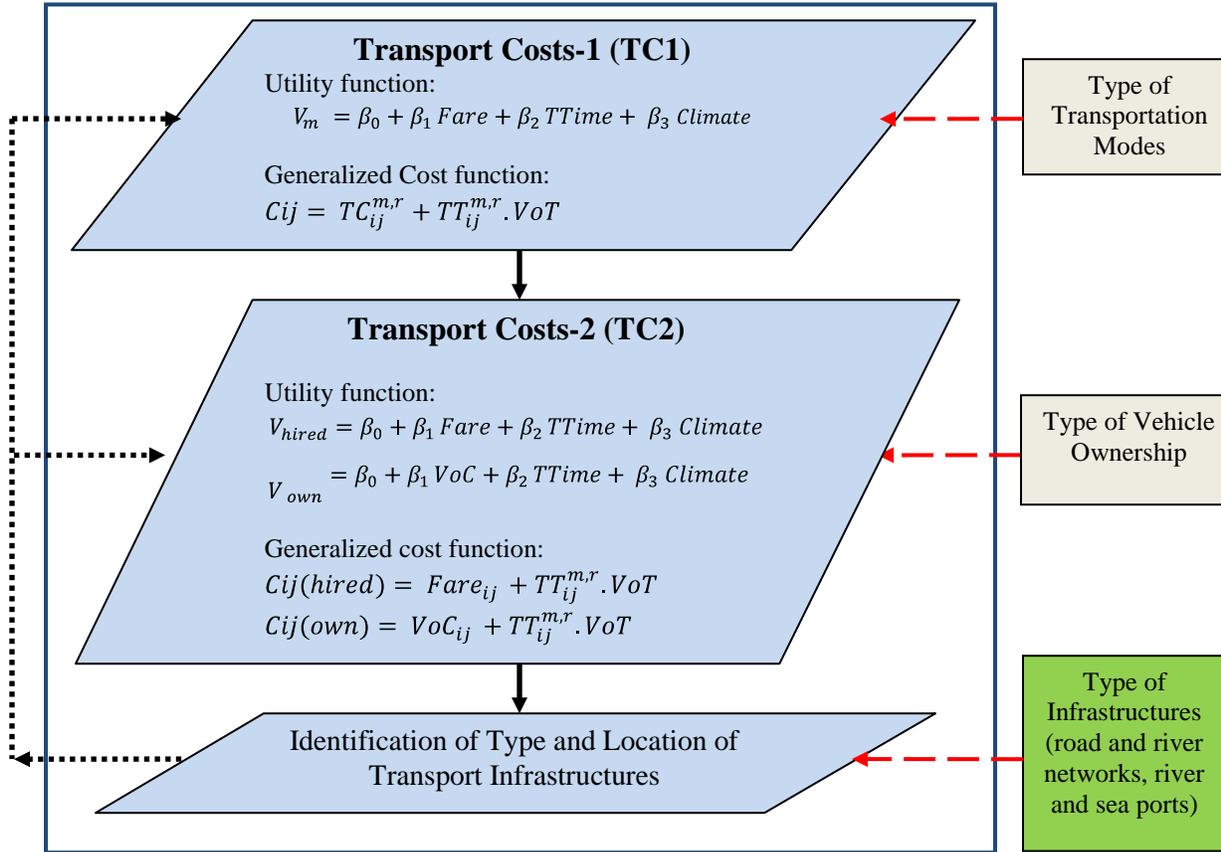


FIGURE 1. Framework of regional freight transportation model

The specification of freight transportation model can be distinguished as: 1) Mode split model at the first layer and so called transportation costs 1 (TC-1); and 2) Mode split model at the second layer and so called transportation costs 2 (TC-2).

- 1) At the first layer, transportation model is constructed by considering the mode split of truck, barge, and combination of truck-barge. The attributes, which are represented utility, are total travel time, vehicle operation cost, and climate. The probability in choosing specific transportation mode is calculated using Multinomial Logit Model. The framework of mode split as illustrated in Figure 2.

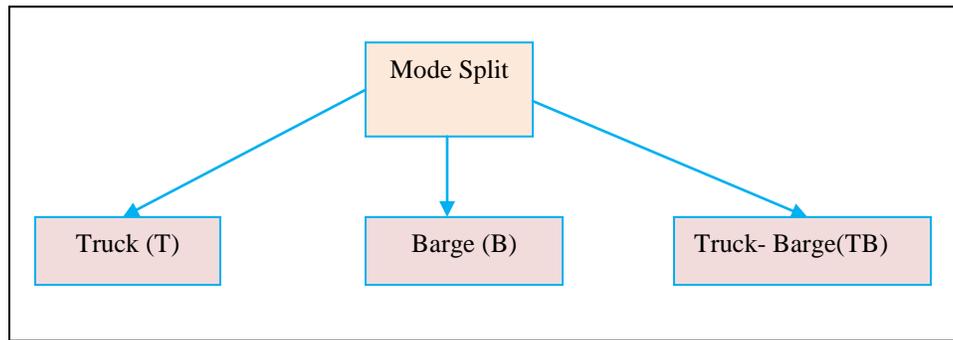


FIGURE 2. Framework of modal split model at first layer

Utility functions is using linear form that is expressed as follows:

$$V_m = \beta_0 + \beta_1 \text{Fare} + \beta_2 \text{TTime} + \beta_3 \text{Climate} \quad (1)$$

Generalized Cost is expressed as follows:

$$C_{ij} = TC_{ij}^{m,r} + TT_{ij}^{m,r} \cdot VoT \quad (2)$$

Where

- $V_m$  : utility function for mode type m
- $C_{ij}$  : generalized cost (Rp)
- $TC_{ij}^{m,r}$  : fare from  $i$  to  $j$  on link  $r$  for mode type  $m$  (Rp), measured in economic cost
- $VoT$  : value of time (Rp/hr)
- $TT_{ij}^{m,r}$  : total travel time spent from  $i$  to  $j$  on link  $r$  for mode type  $m$  (hr)
- $\beta_0, \beta_1, \beta_2, \beta_3$  : Constants to be obtained from the model
- Climate : Number of hours per year the road/river to each destination are restricted the circulation of particular mode

Multinomial logit model utilized in the model are:

$$P_{Truck} = \frac{\exp^{V_{Truck}}}{1 + \exp^{V_{Truck}} + \exp^{V_{Truck-Barge}}} \quad (3)$$

$$P_{Truck-Barge} = \frac{\exp^{V_{Truck-Barge}}}{1 + \exp^{V_{Truck}} + \exp^{V_{Truck-Barge}}} \quad (4)$$

$$P_{Barge} = \frac{1}{1 + \exp^{V_{Truck}} + \exp^{V_{Truck-Barge}}} \quad (5)$$

- 2) In the second layer, transportation model is constructed by considering the differentiation in transportation modes (truck, barge, and combination of truck-barge) and vehicle ownership (own/hired vehicle). Firstly, the mode split of truck, barge, and truck-barge, will be established in the lower level. Moreover, in the upper level, these transportation modes are then grouped on the basis of their ownership (own or hired vehicle). Nested Multinomial Logit model will be used in analysis of mode split. The attributes considered are total travel time, travel cost, climate and vehicle ownership. The group of transport mode is as illustrated in Figure 3.

Calculation of utility function, generalized cost, and probability at lower level is as same as the calculation at first layer analysis. While at upper level analysis, utility function is using linear form and is expressed as follows:

$$V_{hired} = \beta_0 + \beta_1 \text{Fare} + \beta_2 \text{TTime} + \beta_3 \text{Climate} \quad (6)$$

$$V_{own} = \beta_0 + \beta_1 \text{VoC} + \beta_2 \text{TTime} + \beta_3 \text{Climate} \quad (7)$$

Generalized Cost is calculated as the followings:

$$C_{ij}(\text{hired}) = \text{Fare}_{ij} + TT_{ij}^{m,r} \cdot VoT \quad (8)$$

$$C_{ij}(\text{own}) = \text{VoC}_{ij} + TT_{ij}^{m,r} \cdot VoT \quad (9)$$

Where:

- $V_m$  : utility function for transportation mode type m
- $C_{ij}$  : generalized cost (Rp)
- $VoT$  : value of time (Rp/hr)
- $VoC$  : vehicle operation cost (Rp/Ton)
- $TT_{ij}^{m,r}$  : total travel time spent from  $i$  to  $j$  on link  $r$  for transport mode type  $m$  (hr)
- $\beta_0, \beta_1, \beta_2, \beta_3$  : Constants to be obtained from the model
- Climate : Number of hours per year the road/river to each destination are restricted the circulation of particular mode

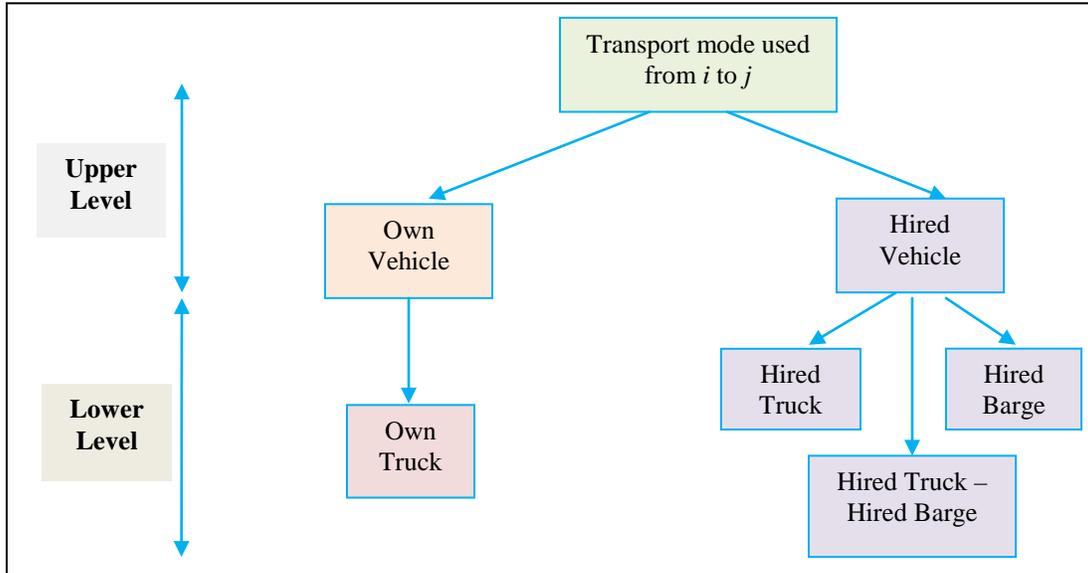


FIGURE 3. Framework of modal split model at second layer

To calculate the probability of particular transportation mode in upper level, so the Nested Multinomial Logit model adopted from Jiang *et al* (1999) is utilized:

$$P_{(hired)Truck} = \frac{\exp^{V_{Truck}}}{1 + \exp^{V_{Truck}} + \exp^{V_{Truck-Barge}}} \times \frac{\exp^{(V_{hired} + (\ln(\exp^{V_{Truck}} + \exp^{V_{Truck-Barge}}) + 1))}}{1 + \exp^{V_{hired} + (\ln(\exp^{V_{Truck}} + \exp^{V_{Truck-Barge}}) + 1)}} \quad (10)$$

Travel cost for hired vehicle is fare or tariff in term of economic cost, which is obtained from the qualitative survey. This assumption is taken because the transport cost of freight transport of hired vehicle is generally negotiable thus difficult to define precisely (Ortuzar and Willumsen, 1994; Friedrich *et al*, 2003). Further, the cost of freight transport of own-vehicle defined as vehicle operation cost that is calculated using economic cost. Freight transportation modellings are conducted using software of ArcGIS version 9.3 and FlowMap Educational Edition 7.3.1.

## 5. INITIAL RESULTS OF ANALYSIS

### 5.1. CASE STUDY OVERVIEW

Recently the government of Indonesia stated that palm oil industry plays more important roles, at least, in three areas of the economic development. Firstly, it contributes significantly to the creation of millions employment opportunities and the alleviation of poverty, especially in rural areas. Secondly, palm oil industry is also one of the engines of regional development. Many areas developed mainly due to the existence and expansion of this industry. Thirdly, palm oil industry has become major non-oil export earnings. In 2008, for example, the export earnings from palm oil valued at around US \$ 12.4 billion dollars, which is the largest contributor of export earnings non-oil exports (The Coordinating Ministry for Economic Affairs, 2009).

The Province of Central Kalimantan is the fourth-largest-palm plantation in Indonesia, after the Province of Riau, North Sumatra and South Sumatra respectively. In 2009, the total area of palm plantations in Central Kalimantan is 4,011,032.364 Ha but only 1,687,969.104 Ha that has been operated and licensed. Crude Palm Oil (CPO), which is the primary products of palm plantation, grew 13.5% by the period of 2000-2004 and it rose up to 15% in 2007. The current productivity of palm plantation to produce CPO in Central Kalimantan is around *0.205 ton CPO/ha/year* (Provincial Government of Central Kalimantan, 2009). Investment and consumption are the main activities of activator economy in Central Kalimantan. By considering the foreign and domestic investment in the last five years (2005 to 2009) - as reported by Central Bank of Indonesia, the growth of investment in plantation, which is mostly to support CPO industries, is as illustrated in Figure 4.

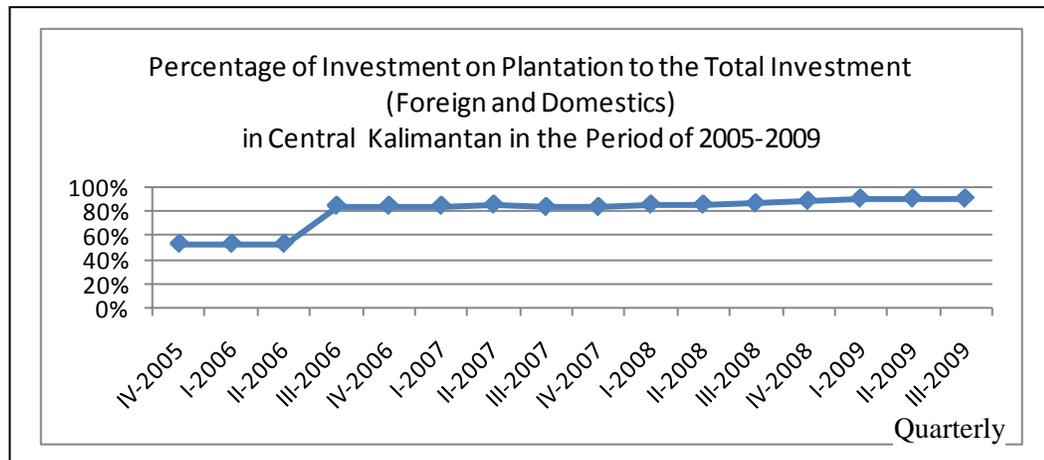


FIGURE 4. Investment on plantation in Central Kalimantan  
Source: Central Bank of Indonesia, 2009

Nowadays, most of national and provincial roads in Central Kalimantan, which are used as the main access for CPO production and distribution, are in poor condition. According to the Public Works Office of Central Kalimantan Province (2006), it is estimated more than 50% of the existing roads, which consist of 1,707.57 km-long national road and 1,050.26 km-long of provincial road, are in bad condition due to truck-overloaded. Most of the trucks transporting CPO are loaded up to 12 tons although maximum of the prevailed axle load is only 8 ton. This circumstance is not only affecting the transport infrastructures (like road deterioration) but also the transportation services as well (like longer travel time and higher transportation cost due to low speed of vehicle). Therefore, an appropriate method of freight transportation planning (including modelling), in relation to the spatial location of commodities' activities

is required to achieve efficient freight flow in the region. The data used in the model analysis and vehicle characteristics are presented in Table 5 and 6.

TABLE 5. Data used for modelling CPO transportation

No	Data	Format	Year
1.	Administrative map	Geo-database	2006
2.	Road network	Geo-database	2006
3.	River network	Geo-database	2006
4.	Port map	Geo-database	2006
5.	Land use map	Geo-database	2006
6.	Regional spatial plan (RTRW Province)	Geo-database	2006
7.	Palm plantation map	Geo-database	2006
8.	Regional economic growth	Pdf file	2005-2009
9.	Documentation of CPO processing and economics activities	Pdf file	2006
10.	Documentation of port facilities and performance	Pdf file	2005-2008

TABLE 6. Vehicle characteristics of CPO transportation in Central Kalimantan Province

Transport Mode	Max	Des. Speed	Operational speed (kph)		Travel Cost	
	Capacity	(kph)	Range	Average	(Rp)	(US\$)
Medium Truck	7.5 T	60	35 - 50	40	Rp 3200/Ton/Km	US\$ 0.34/Ton/Km
Tanky Truck	6.8 T	60	35 - 50	40	Rp 6460/Ton/Km	US\$ 0.68/Ton/Km
Tanky Barge	400 - 800 DWT (1000 - 2000 T)	30-60		40	Rp 6000/Ton	US\$ 0.63/Ton

Source: Preliminary survey to CPO firms, 2009

## 5.2. MODELLING LOCATION CHOICE AND SPATIAL PATTERN OF CPO PRODUCTION

There are 2 steps considered in modelling location choice of CPO factory: identification of optimum location of CPO factory; and identification of the shortest route of CPO transportation from factory to the networks. Identification of the most likely location of CPO factories in this study is started from calculation of production capacity of palm plantation for every year. Production capacity of plantation was classified in three classes according to area service. Assumption used in this study is that every plantation should have minimum area 5400 ha to have a factory. Proximity analysis using nearest distance to closest factory is used to identify the un-served plantations.

Identification of the shortest route of CPO transport from factory to the road and river network that consist of: a) identification of intermediate points on the closest road and river networks from the factories; and b) identification of accessibility level of factories to the networks. Intermediate points are points in the road or river to transport CPO from factories to the final ports. Intermediate points are calculated from the shortest distance of factories to the road and river networks. The function of intermediate points in this process is to know the level of accessibility of factories to networks and to identify the starting points of transport route to the ports.

Accessibility levels show the ease to transport CPO from factories to the closest intermediate points in the road and river networks. To identify the level of accessibility, the assumption is based on average velocity of road transport mode (40 km/hour). The accessibility is classified as *good* if the distance is less than 10 km (15 minutes trip), 10-20 km for *moderate* and more than 20 - 30 km for *bad* accessibility. The results of this process are the map accessibility of factories to the road and river networks.

### 5.3. MODELLING REGIONAL FREIGHT TRANSPORTATION OF CPO COMMODITY

There are several processes required in modelling regional freight transportation for CPO commodity in Central Kalimantan Province by using network analysis of ArcGIS software. These processes consist of modelling distance, time, and cost of specific transportation mode, determining the nearest port, determining the shortest route of using road and river networks, and modelling of probability of choosing certain modes of transportation.

Identification of efficient CPO transportation from road and river networks by using various modes considers some criteria, which are distance, travel time, and travel cost. For these criteria, the calculation conducted by considering the average speed and travel cost of each modes. The average speed used, based on assumption that there is no different classes among networks either in road or river network, so that all segments in networks can be passed in the same speed without impedance. In terms of road network, the distance was calculated by considering the distance from the factories to road networks (intermediate points in road), based on a detour distance factor of 1,2 (1.2\*Euclidian distance). For river network, the calculation of these criteria is conducted by combination of both road and river networks. The combination is used because the factories are not directly attach to the river networks, so that for reaching the river network, CPO are transporting first to the river by using road networks.

The closest facilities analysis is conducted to identify the destination port where the CPO will be sent. The closest facility option in ArcGIS is used, based on the assumption that people tend to go to relatively closest facilities around them rather than to farther away facilities, because of distance, time and cost reasoning. Utility function measures the satisfaction level perceived by the decision-maker upon which he or she makes the choice decision. In term of transport, people consider time, cost, and other factors for satisfying them. This study only considers time and cost for determining utility that is indicated in linear function and is expressed as follows:

$$V = (Time, Cost) = \beta_1 (Travel Time) + \beta_2 (Travel Cost) \quad (11)$$

Generalized cost function is regarded as disutility or deterrence functions (Ortuzar and Willumsen, 1994) and it is considering the following formula:

$$Generalized Cost = C_{ij} = Travel Cost + Travel Time Cost \quad (12)$$

Estimation parameter is minus because it represents the disutility function of time and cost.

Probability of choosing certain modes is calculated by using the logit model from utility function of transportation by road and river. The logit model used for determining the probability of choosing certain mode is:

$$Pr obability_{road} = \frac{Exp(-V_{road})}{(Exp(-V_{road}) + Exp(-V_{river}))} \quad (13)$$

$$Pr obability_{river} = \frac{Exp(-V_{river})}{(Exp(-V_{road}) + Exp(-V_{river}))} \quad (14)$$

Where:  $V_{road}$ = utility of road network, and  $V_{river}$ = utility of river network

### 5.4. RESULTS AND DISCUSSIONS

According to the analysis, there are 113 of CPO factories identified. The factories are classified into 3 classes based on their production capacity: small (<60 ton FFB/hour); medium (60-90 ton FFB/hour); and big (>90 ton FFB/hour). From 113 factories, 80 factories are small (71%); 26 factories are medium (23%); and 7 factories are big (6%). According to the analysis, it is about 86 factories (76%) have good accessibility to the road networks (<10 km distance and 10 minutes time). The rest is about 20 factories

(18%) having moderate accessibility (10-20 km and 10-30 minutes time), and 7 factories (6%) have bad accessibility level to road (>20km and >30 minutes time). On the other hands, the accessibility level of factories and plantation served to the river network is mostly bad. It is about 43 factories (38%) are in bad accessibility. They need more than 30 minutes to reach the closest river. The rest is 34 factories (30%) have good accessibility, and 36 factories (32%) have moderate accessibility to river. Considering the accessibility on both road and river networks, the plantation accessibility to network can be determined. There are 91 factories (81%) are identified accessible to the networks, 19 factories (17%) are moderate, and only 3 factories (2%) are not accessible in both road and river networks.

The CPO is transported from factory to the 2 main ports, which are Kumai and Sampit. The CPO will be delivered to the closest ports as the destination. The closest port is identifying through both road and river networks. Using road network, 84 factories send their product to port 1 (Sampit), and the rest (29) send their product to port 2 (Kumai). However, by using river network, 91 factories send their product to port 1 (Sampit), and 22 factories to port 2 (Kumai). It is interesting in some cases, because the same factory has different closest port by using different networks (river and road). For example in the case of factory 1, the closest port by using road network is Kumai, on the other hands, by using river networks the closest port is Sampit. This condition is closely related to the factory location from road and river networks (accessibility level to network), and the travel distance by using road and river from factory to port. These conditions also considered on the latter step for determining the efficient routes from factories to ports, especially to which port and network the CPO will be delivered efficiently.

The utility of each mode (river, and road) is defined by the equation considering travel time and cost, and the weighting factor of cost considered 4 times more important than time. The estimated parameters  $\beta_1$  and  $\beta_2$  are derived from trial and error process, considering former assumption in which people regard cost factor is 4 times important than time, because CPO is categorized into un-perishable goods. Hence the equation for utility either for road and river obtained are as follows:

$$V = (-1.000000) \text{ Travel Time} + (-0.000004) \text{ Travel Cost} \quad (15)$$

The decimal 6 used because of the different fraction in term of time and cost. Time uses units and cost uses hundred thousands, and even millions. In fact, there are other factors should be considered for utility calculation, such as reliability of river network that is influenced by climate and also error estimation, but this study only limits the analysis on travel time and cost.

The CPO flow is calculated by considering the probability of choosing modes, meaning that a factory probably will send CPO only by using river or road network to the nearest port based on this probability. It then yields the volume of commodity flow to certain port. Table 7 and Figure 5 illustrate the flow of CPO from factories using road and river networks to the Sampit Port and Kumai Port in Central Kalimantan Province.

TABLE 7. CPO flows on the road and river networks

No	Origin	Number of Firms	Volume of load (ton/day)	Total Load Per Port (ton/day)
1	Factory to port 1, using road flow	46	15,725.492 (33%)	33,732.208 (70%)
	Factory to port 1, using river	38	18,006.716 (37%)	
2	Factory to port 2, using road	14	8,669.2651 (18%)	14,561.800 (30%)
	Factory to port 2 using river	15	5,892.545 (12%)	
<b>Total</b>		<b>113</b>		<b>48,294.018</b>

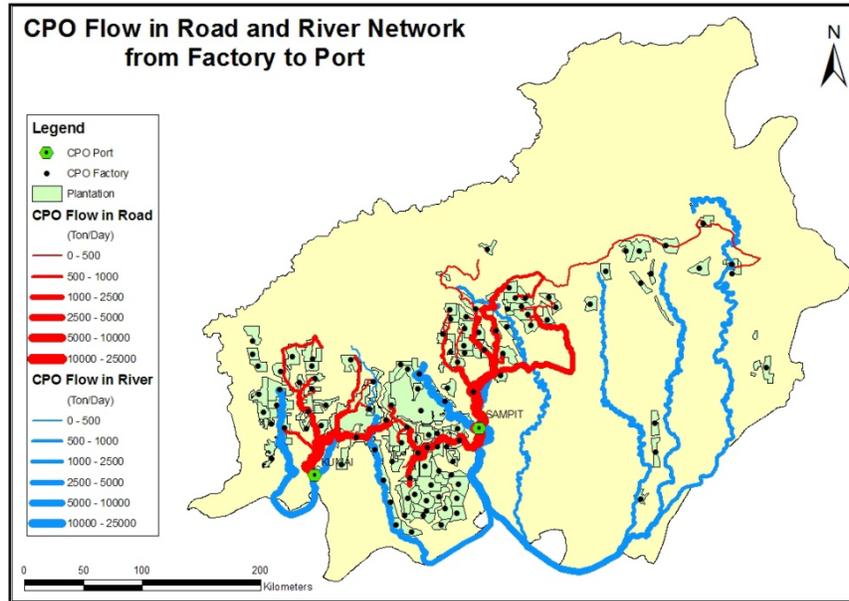


FIGURE 5. CPO flows on the road and river networks

The accessibility level depends primarily on the distance from factory to reach the closest networks. In term of road networks, the plantations with bad accessibility to road are located on the southern part of the study area, because of the lack of road infrastructures in this area. By considering the travel time and travel cost, the road network is more efficient for transporting CPO in the study area. It is also proved by the higher probability in choosing this transportation mode. However, the river network also has opportunity to compete with road network in term of travel cost. According to the result, there is little different between probability to choose road or river networks.

This study only considers travel time and cost for determining utility. In fact, there are other attributes should be considered for utility calculation such as reliability of river network that is influenced by climate and also error estimation. Moreover, the port (outlet) choice is only dependent on the shortest route in terms of distance, travel time and cost, and ignored other attributes such as the shipper or carrier preference, and other transportation service attributes (e.g. network reliability). Therefore, conducting quantitative survey is highly recommended to get more realistic and the better model in the future.

## 6. CONCLUSION

To formulate an effective strategy for regional transportation planning, the planners or policy makers need to know the location of resources, processing or factory locations, and the final outlet (ports) to send their goods to the outside world. To do this, various characteristics of the different commodities and the available networks that can be used, need to be known. An understanding of how the relationships between commodities' activities and transportation are linked by spatial structure is essential.

The existing freight transportation planning models, such as promoted by Southworth (2002), Holguin-Veras and Thorson (2000) and Holguin-Veras *et al* (2001), give more attention to the transportation modelling with several stages to be conducted. The locations of industries or economic activities applied in the transportation modelling are using a given data. As a new innovation in freight transportation planning, this new method does not only consider the transportation modelling but also involving the spatial location modelling/mapping, especially in determination of factories/industries' location, and considers the government regulations as the constraint, in formulating the freight transportation planning for regional scale. Hence this method can produce the more realistic/practical transportation model

because the location of economics activities that generate freight transportation is considered in the model and can be changed dynamically over time.

This new method also offers a more efficient stage of transportation modelling where the distribution, modal split, and route assignment models are conducted in the same time. All simulation models will be built on the basis of up-to-date GIS software that is now widely used in the spatial location modelling (and mapping) and transportation modelling. However, this method faces with the great challenges in data collection and database construction because it requires large data to be formatted and converted into GIS database.

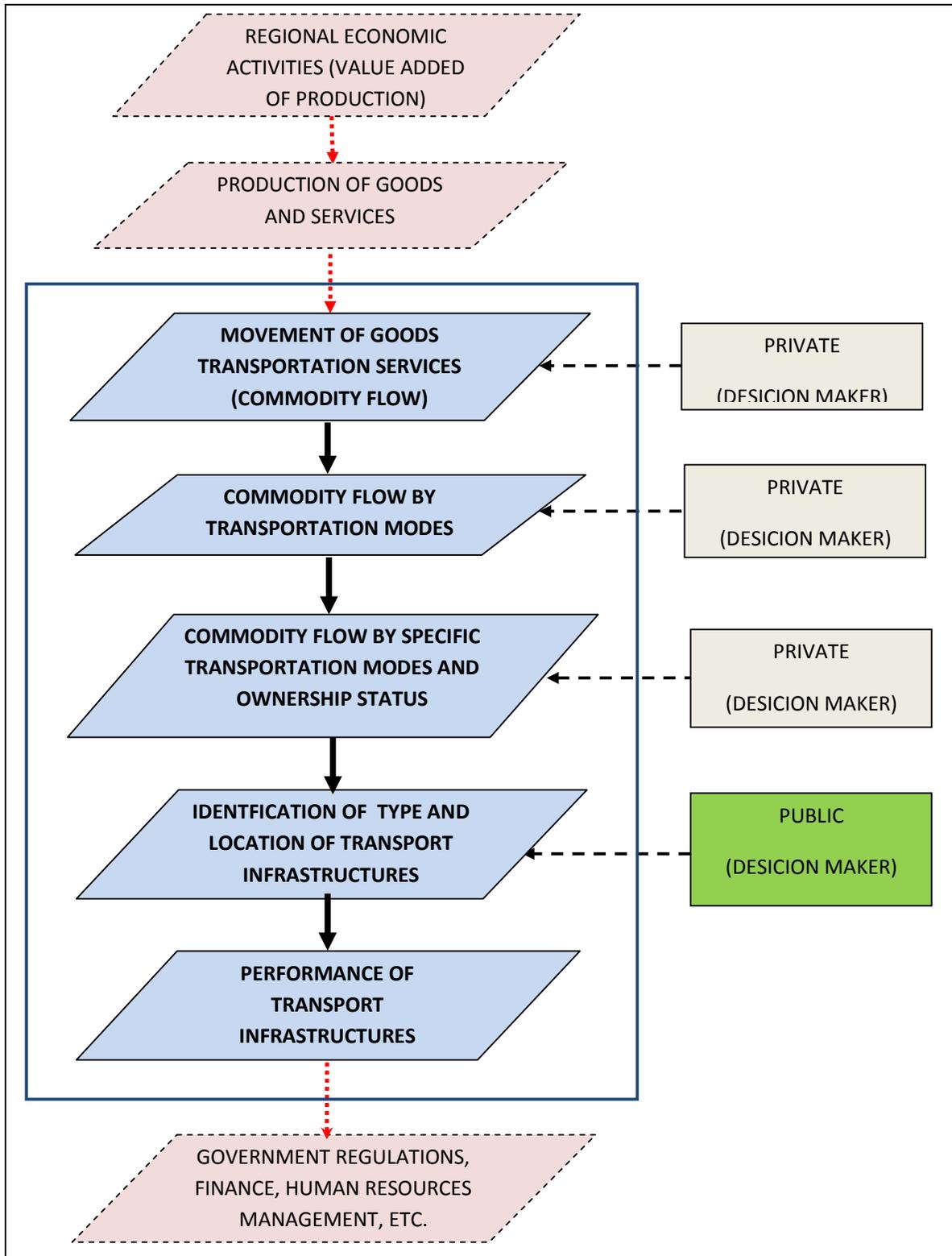
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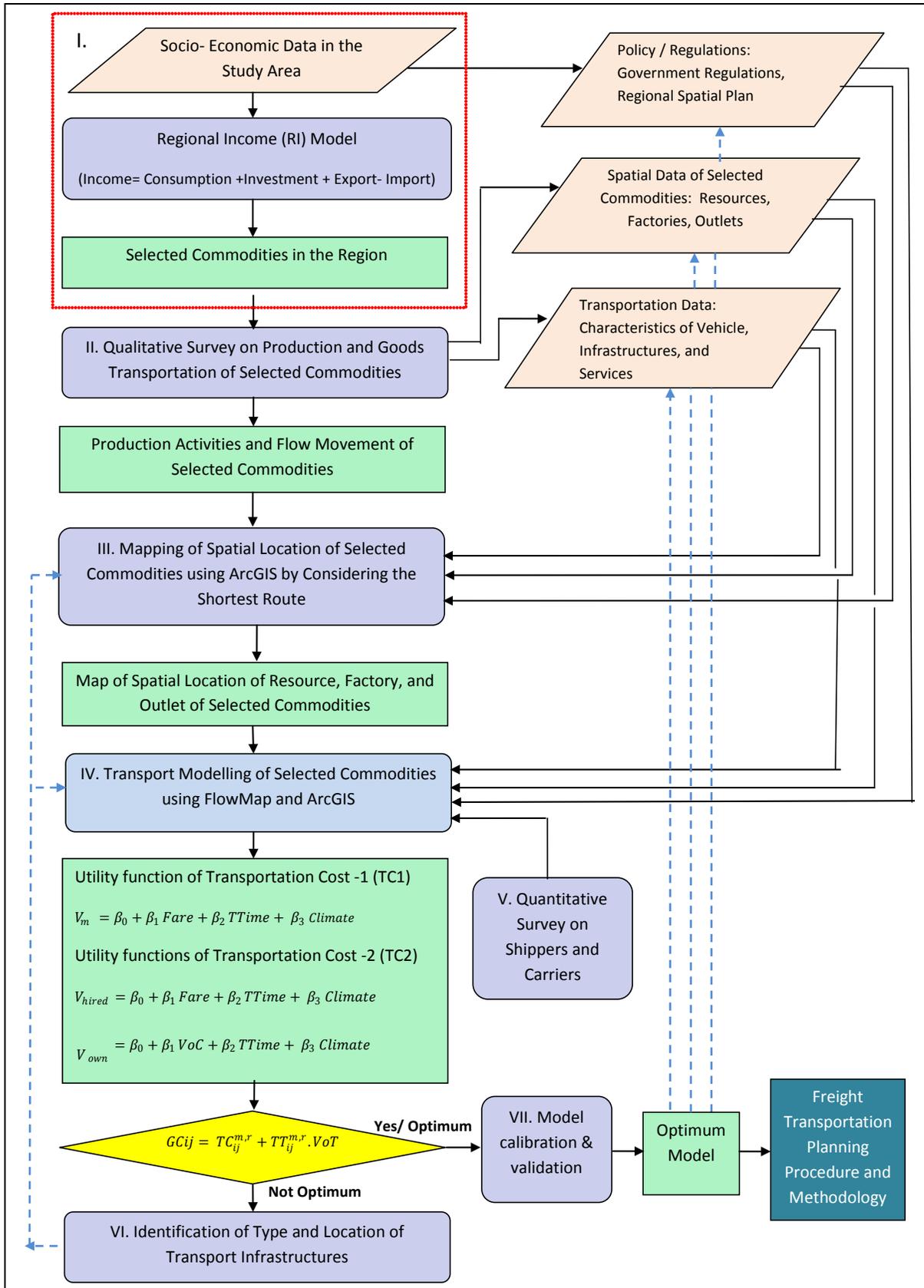
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APPENDIX 1. Conceptual framework



APPENDIX 2. Methodology for regional transportation planning