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INTERMODAL HUB-AND-SPOKE TRANSPORT NETWORK FOR AN ARCHIPELAGIC COUNTRY, THE PHILIPPINES

A Dissertation

Submitted to the Department of International Development Engineering

Graduate School of Science and Engineering of Tokyo Institute of Technology

in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

Anita II Alvarez Odchimar

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Ad majorem Dei gloriam, for Him who makes all good things possible.

INTERMODAL HUB-AND-SPOKE TRANSPORT NETWORK FOR AN ARCHIPELAGIC COUNTRY, THE PHILIPPINES

Anita II Alvarez Odchimar
Tokyo Institute of Technology, 2016

ABSTRACT

For archipelagic regions, physical isolation is a development challenge. Especially for developing countries where uneven progress among the islands occurs, communities in small islands with small trade sizes and situated far from large cities would pay more to send and have access to needed goods. The challenge therefore is to build the region's infrastructure in a manner conducive to distribute goods and commodities efficiently using economies of density, while not aggravating other current problems the region is facing.

The Philippines is a developing country with archipelagic characteristics that could benefit from a seamless spoke-hub transport network design. An intermodal road–Roll-on Roll-off (RoRo) transport has been in use and promoted by the government to provide seamless transport; while, the use of hub-and spoke has been advocated by the private sector. While the country's capital city's port has the highest cargo throughput, it is not ideal to be a transport hub since the additional cargo traffic will increase the truck presence in the already congested roads of the metropolitan. Therefore, this study i) presents the current position of intermodal road-RoRo transport in the Philippines, ii) develops a hub-and-spoke network model suitable for an archipelagic region, and iii) explores the use of hub-and-spoke network while shifting cargo from Manila to adjacent port of Batangas to lessen the presence of trucks that contributes to road congestion in the capital.

The intermodal transport of the Philippines is unique from the motorways of the sea of other regions (e.g. Europe) since the self-powered cargo carrying vehicle traverses chains of islands and seas by RoRo vessels. As starting point, this study clarifies the current position of intermodal transport in the country by conducting a

questionnaire survey with freight forwarders as respondents. The survey tackles the shares of the following domestic cargo transport modes i) container vessel transport, ii) intermodal road–RoRo transport and iii) air transport; and the attributes that affect shippers' mode preferences. Survey results show that the top influential attributes to the choice of intermodal road-RoRo transport are transport time, transport cost, frequency of vessels and reliability in terms of delay. Transport times and transport costs are estimated for several origin-destinations for both intermodal road-RoRo and container vessel transport choices. The following could be drawn from the results: i) dominance of intermodal transport for destinations along the western seaboard (Mindoro, Panay and Negros) from Manila could be attributed to lower transport time and transport cost, and high frequency of vessels; ii) lower container transport costs from Manila to farther destinations more than 600km away, and the daily container vessel's regular trips to some destinations, could have led the higher share of inter-island container vessel; and iii) estimated transport cost and transport time for intermodal transport are lower for Manila to Tacloban in the eastern seaboard but the higher share of container vessel transport could be due to the poor quality of road.

Next, a hub-and-spoke network suitable for archipelagic setting is developed incorporating intermodality of land mode (truck) and sea modes (container vessel and RoRo vessel modes), and the properties of multiple allocations, non-restrictive networking policy and general hub network topology; all of which have not been tackled simultaneously in one network model by other studies. The model here allows direct origin-destination calls without going through hubs thus coined as "mixed-network". The Philippine scenario is considered for the numerical data and the large network problem of 25 nodes and up to 6 hubs cases is solved using Lagrangian relaxation heuristic. The model is able to locate hub ports where cases of intermodal road-RoRo and container transport could transship and be used complementarily. The proposed mixed-network model results in considerable total network transport cost savings compared with only direct transport case.

Lastly, a mixed hub-and-spoke network is modeled taking Batangas, Cebu and Bacolod as locations for hub ports. With this strategy, 11 to 23% of cargoes intended for Manila port would be shifted to Batangas port while there would be transport costs saving by shippers, as well as shipping costs reduction by shipping lines when

operation is restructured from multi-port calling to direct calls within hub-to-hub. Shift in cargoes entails that the presence of trucks in the metropolitan area adjacent to the ports would be lessened and thus help decongest the roads in the area. From the results, policy suggestions are drawn such as improvement of port facilities for quick operations of multimodal transport and providing incentives in using Batangas port in the form of discounts or port fees elimination.

This study therefore contributes (i) knowledge on intermodal road-RoRo transport for archipelagic geography and its choice basis, (ii) on the development a hub-and-spoke network suitable for an archipelagic setting, and (iii) on the feasibility utilization of a hub-and-spoke network and cargo shifting in reducing the number of trucks intended for Manila port and, thus, lessen the presence of trucks in the capital that contribute to road congestion.

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LIST OF ABBREVIATIONS

ADB	: Asian Development Bank
ARRM	: Autonomous Region of Muslim Mindanao
ATS	: Aboitiz Transport Systems Corp.
BCDA	: Bases Conversion Development Authority
CEZA	: Cagayan Economic Zone Authority
CPA	: Cebu Port Authority
DOTC	: Department of Transportation and Communication
ECMT	: European Conference of Ministers of Transport
FCL	: Full Container Load
GCR	: Greater Capital Regions
HS	: Hub-and-Spoke
IFO180	: Intermediate Fuel Gas Oil 180
IPA	: Independent Port Authorities
JICA	: Japan International Cooperation Agency
LGU	: Local Government Unit
Lo-Lo	: Load-on load-off or conventional liner system
LSC	: Lorenzo Shipping Corporation
LTL	: Less Than Truckload
MARINA	: Maritime Industry Authority
MCPT	: Mindanao Container Port Terminal
MGO	: Marine Gas Oil
MMDA	: Metro Manila Development Authority
NCR	: National Capital Region
NEDA	: National Economic Development Authority
NSO	: National Statistics Office
PIA	: Phividec Industrial Authority
PHP	: Philippine Pesos
PPA	: Philippine Ports Authority
PTP	: Purely Point-to-Point
RoRo	: Roll-on Roll-off
RRTS	: Road-RoRo Terminal System
SBMA	: Subic Bay Metropolitan Authority
SEC	: Security and Exchange Commission
SFOC	: specific fuel oil consumption
SLEX	: Southern Luzon Express Way
SRNH	: Strong Republic Nautical Highway
SSS	: Short Sea Shipping
STAR	: Southern Tagalog Arterial Road
TEU	: Twenty-foot Equivalent Unit
V/C	: Volume-Capacity ratio

Chapter 1: Introduction

1.1 Background

A country with islands geography, especially that of a developing one, faces challenges in terms of trade and transport. Uneven development is common for a developing country which entails that some island communities are small and marginalized and could even be situated far-flung from the large cities. These islands would have small trade sizes thus pay more to send or have access to their needed goods. The challenge therefore is in finding a way to build the country's infrastructure in a manner that will efficiently distribute goods and commodities using economies of density.

A country facing such challenges is the Philippines. The Philippines has a unique geography characterized by 7,107 islands of which around 2,000 are inhabited. The archipelagic characteristic demands an especial approach to connectivity – *(1)* the ability to not just enable seamless transport for cargoes and people but also *(2)* facilitate transport cost efficiency of which one manner is by realizing economies of density. Pienaar (2013) defines economies of scale as existing "when an expansion of the output capacity of a firm, fleet or plant causes total production costs to increase less than proportionately to the increasing output capacity". And since ships often operate as separate business entities, economies of scale in transport (or shipping) often refers to vehicle rather than firm, fleet or plant size. Hence, two types of economies of density are distinguished by Jansson and Shneerson (1985), economies of scale of the size of the firm and economies of density. In this study, the falling average cost is attributed to the increase in utilization of existing vehicle fleet (in this case container vessel) for a particular route, which is within the definition of economies of density.

Thus, this study's goal is to aid the two demands mentioned by exploring the combination of intermodality *to provide seamless transport* and hub-and-spoke (HS) transport *to facilitate economies of density*.

High cost of domestic cargo transport has been a prevalent issue in the country. Many could not understand why it is more expensive to ship containers domestically, from Mindanao (the largest island in the south of Philippines) to Manila, than from the capital to Hong Kong. Later on, it was identified that the cost and inefficiency of the cargo handling charges in the conventional container transport system was the major factor in the high cost of domestic transport (Basilio, 2008). The Roll-on Roll-off (RoRo) policy was issued in

2003 of which key features encouraged the use of intermodal transport by land (using truck) and by sea (truck loaded into RoRo vessels) as alternative or competition to the conventional container vessel transport. This is facilitated by the development of the Road-RoRo Terminal System (RRTS), a network of RoRo ferry terminals linked all over the country by RoRo ferry ships. Initial assessments of Basilio (2008) and ADB (2010) report that the policy brought positive impacts; however, the paper of Kobune (2008) shows that the advantage of RRTS is overemphasized only for its quick procedure at terminals (because transport through RoRo does not require cargo handling), and is competitive to the inter-island shipping in terms of total transport cost only within a specific distance (200km). A study is therefore needed to present greater knowledge on the current position of intermodal road-RoRo transport in the Philippines, its advantages over the conventional or container means of inter-island shipping, and the attributes that influence mode choice by providing literatures reviews, conducting field survey and survey interviews with freight forwarders.

There are several studies about RoRo as part of an intermodal system (Paixao and Marlow, 2002; Torbianelli, 1999, 2000; Woxenius, 2012), and advantages of the system over container transport have been cited. However, these studies are in the context of short sea shipping (SSS) and motorways of the sea (e.g. in Europe, Asia-Europe, North America and Australia) where intermodal systems generally only involve one sea leg and are in competition with land-based transports. The intermodal system of the Philippines is unique in that the vehicles in road-RoRo intermodal shipments traverse chains of islands and seas, or several land and sea legs, to compete with the long-distance container shipping. The preference for and the advantages of this system in an archipelagic context over the container transport mode has not been clarified.

Moreover, a more recent act, the Republic Act (RA) no. 10668, was signed by the President in July of 2015, which allows foreign vessels to transport and co-load foreign cargoes for domestic transshipment and other purposes. This amends the 50-year-old Cabotage law and eyes at creating a more level playing field on competition and offer cost reductions in domestic shipping. The act allows foreign vessels, arriving from a foreign port to a port of entry, to carry foreign cargo, originally its own or by another foreign vessel calling at the same port of entry, to any port in the country. Moreover, it also authorizes foreign vessels to take cargo intended for export at any Philippine port, and convey the same cargo upon itself, or by another vessel calling in the same intermediary transshipment port, to a foreign port. The act is in its very early stages of implementation and would take time for its full effects to be felt.

RA 10668, though to an extent anticipated, is a latter policy; this research has been conceptualized before it was signed. The act will indeed increase competition, but on one hand, could harshly affect the domestic shipping players if they do not improve their services. One way to be competitive is to modernize their fleets and operations. Another way is to facilitate economies of density which could be done by employing a hub-and-spoke transport network.

Furthermore, the use of hub-and-spoke network is advocated by the private sector. The Joint Foreign Chambers of Commerce of the Philippines suggests that to increase the country's competitiveness among neighboring countries, a hub-and-spoke system should be in place with developed ports for larger ships and with cargoes delivered from smaller production centers by truck or small RoRo (JFC, 2010). Hub-and-spoke network models have been developed but some of common properties often employed in existing studies are not favorable to an archipelagic country, such as 'strict and restrictive hubbing policy' and 'single allocation' properties. There is a lack of studies that applies hub-and-spoke to an archipelagic context, thus this study attempts at providing suitable model that also incorporates intermodal transport.

The Philippine Development Plan 2011-2016 pointed out the 'lack of integrated and coordinated transport network', thus the planning focus is to come up with a seamless multimodal system by upgrading the quality and capacity of existing transport infrastructures based on a strategy that takes modal complementarity into account (NEDA, 2011). The developed model could be used to identify which ports are best to be allocated investments for upgrade.

The developed network model is then applied as part of a solution to alleviate the congestion of Manila roads. Manila ports have 51% and 84.2% share of domestic and foreign container throughput, respectively, which exceed the ports' capacities (Philippine Ports Authority (PPA), 2012). A truck ban imposed in 2014 for the purpose of decongesting the roads in Manila led the already over-utilized port to be more congested, which in turn led to big economic loses (Cruz, 2014). Thus, cargo flow shift to the adjacent port in Batangas in combination with hub-and-spoke transport configuration is explored as a solution to lessen the presence of trucks in the highly congested roads adjacent to the Manila port.

1.2 Research Objectives

The aim of the study is to design a cargo transport network model suitable for a country with archipelagic geography that, in parallel, would enable seamless transport by intermodal transport and cost efficiency brought by density economies of density. The concept of hub-and-spoke provided by the model would in turn used to alleviate traffic in Metro Manila. To achieve this aim, the following objectives are drawn:

1. To clarify the current position and mode share of intermodal road-RoRo transport in the Philippines over the conventional or container means of inter-island shipping, and the attributes that influence mode choice .
2. To model a hub-and-spoke network suitable for an archipelagic geography which incorporates transport intermodality.
3. To explore the use of hub-and-spoke network and cargo shifting from Manila to adjacent port of Batangas as hub port to help reduce the presence of trucks in Metro Manila which contribute to road congestion.

1.3 Scope and Limitations of the Research

The study considers cargo transport only and does not tackle passengers. While air transport has market share as determined in Chapter 3, it is relatively small and is not considered in the estimation of transport costs and travel times in the same chapter as well as in the network models of Chapters 4 and 5. Only sea-base modes (container and Roll-on Roll-off vessels) and land base transport (20-footer container in chassis maneuvered by prime mover and 10-wheeler truck) are considered.

In Chapter 3 survey for mode share and attributes influencing mode choice, the survey is limited in the number and classification of respondents but the results are able to offer an overview of the current situation of intermodal road-RoRo transport and its competition with inter-island shipping.

The following are the limitations and assumptions taken in the development and application of the hub-and-spoke network model:

a. Capacity constraint for ports is not considered
    - Port capacity constraint is not considered because one of the purposes of the model is to identify the location of hub ports where future investments for capacity and facility upgrade will be allocated.

b. Capacity constraint for link is not considered
   - The model is based on volume of flow and not on vessel capacity and frequency. The aim of the model is to determine the allocation of volume flows with no consideration of the capacity of the link (vessel capacity x frequency).
c. Travel time constraint is not considered
   - Congestion may occur in a hub-and-spoke network, thus travel time is an important factor. However, since we do not consider constraints of capacity of hubs and links, which also affects travel time, we also do not consider constraint in travel time. Travel time would be affected by transshipment time at hub ports, which in turn is affected by factors such as port capacity, waiting time at anchorage, port facilities capability, size of vessel, etc. This is, however, considered for future study.
d. Only one cargo loading unit, 20-footer container, is considered for the whole network.
   - This is for the purpose of simplification. Though, it is acknowledged that other cargo units exist such as 10-wheeler truck, 10 footer container, 40 footer container, etc.
e. Similar to the most classical hub-and-spoke models, the discount factor (α) in transport cost brought by bundling of cargoes (economies of scale, or in this study we use the term economies of density) is only applied to inter-hub flows. It is the limitation of the study that one value for α is used for the whole network at one time, and the parameter is not cargo flow volume dependent. In the model, the bundling of cargoes is therefore an effect of the exogenous nature of the discount factor.

   This is somehow a necessary simplification since the cost minimization is for the whole network with many modes and fleets as players, and not with a single vessel only, thus the shipping cost for every mode and vessel type for every link as a function of cargo volume, in my opinion, would be highly challenging to construct.

   Moreover, shipping companies resist divulging their financial information thus it is difficult to estimate the amount of tariff discount shipping companies could offer with increase in volume. Thus, economies of density, as represented by the α parameter in the model is assumed to be 0.5, 0.7 and 0.9 for Chapters 4, and 0.6, 0.7, 0.8 and 0.9 for Chapter 5. However, Chapter 5 attempts at justifying the discount factors used in the assumptions by estimating the percent increase in profit gained by a shipping company for serving direct transport between a certain hub-to-hub route which could be translated to the percent discount they could give to shippers for inter-hub transport.
f. Only two-hub stop is considered in this study, and not allow one-hub stop, since the goal is to let even the islands with small trade volumes participate in trade in long distances.

The two-hub stop is deemed appropriate for this purpose at it consolidates volumes and enables economies of density for inter-hub transports. The one-hub stop would be appropriate in short distance as reported by Sasaki *et al.* (1999); however, it is the limitation of this study that we are not able to consider this case.

1.4 Outline of the Thesis

The thesis comprises of six chapters as shown in Figure 1.1. The details of which are as follows:

Chapter 1 introduces the background, the research objectives and the outline of the thesis.

Chapter 2 provides the reviews of literatures on the following topics: (a) shipping and ports industry in the Philippines, (b) intermodal transport with RoRo shipping and the choice theory for selecting Ro-Ro, (c) HS network modelling, its properties and the heuristics for solving large problems and (d) carriers shipping costs and economies of density.

Chapter 3 details the development of the intermodal road-RoRo transport in the Philippines and its current position in the domestic shipping market. This chapter presents the data from field survey namely shipping tariffs, port fees, port locations and cargo flow volumes. A questionnaire survey was conducted to determine the usage share of modes for selected destinations from Manila (the capital) as well as the attributes that influence the choice for the mode.

The data from the field survey in Chapter 3 are used as input data to the intermodal hub-and-spoke network model developed in Chapter 4. The model incorporates properties deemed suitable for archipelagic scenario. The model is then applied to the Philippines. The heuristic used to solve the large problem and the resulting savings in total network cost compared to the direct transport case are explained.

In Chapter 5, the concept of hub-and-spoke in conjunction with cargo shifting from Manila port to Batangas port as hub is employed as a solution to lessen the presence of trucks in Metro Manila and consequently help the traffic situation. The cost effects of transferring to Batangas port for shippers and shipping companies are estimated to infer the feasibility of employing the strategy and be able to suggest appropriate policies.

Chapter 6 summarizes the new findings of this research and details suggestions for further research.

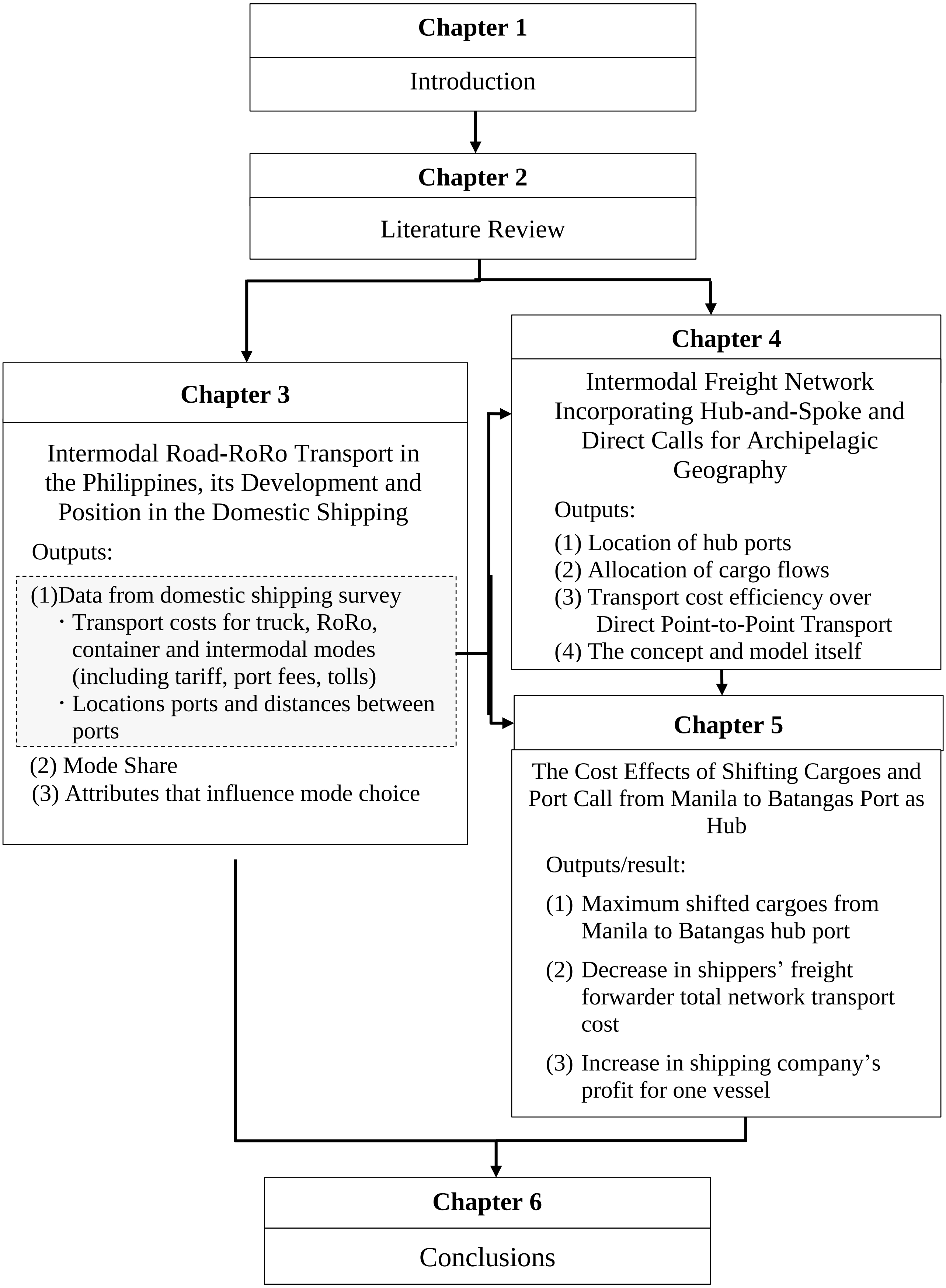


Figure 1.1 Organization of dissertation

1.5 Contributions of the Study

Firstly, this study clarifies the regulatory changes and emergent landscape of roll-on/roll-of shipping in the Philippines that helps build knowledge to this area. The study also provides the mode choice preferences for intermodal transport with RoRo shipping through a chain of islands that is distinct from those studied previously such as the short-sea shipping and motorways of the sea of other regions (e.g. Europe, Asia-Europe, Northern America and Australia).

Secondly, the developed hub-and-spoke network model establishes a basepoint for future research on the topic for archipelagic geography settings, since the application on archipelagic context has not been delved into previously. The model also could be a reference for the government or social planner in determining the location of hub ports as to appropriate investments for infrastructure development and guide in drafting policies that would encourage both shippers and carriers to make use of hub ports and facilitate the hub-and-spoke transport.

Lastly, this study also explores the application of the hub-and-spoke network concept to help reduce the presence of trucks in Metro Manila which contributes to road congestion, which concept could also be considered as future strategy to make domestic vessels competitive with international vessels amidst the new more laxed cabotage law. The findings could aid domestic liner shipping companies for their future strategy and the government in future policy-making.

Chapter 2: Literature Review

2.1 Introduction

Fundamental concepts from existing literatures are reviewed as starting point. The succeeding sections tackle the following: 2.2) reports and studies on cargo shipping existing in the Philippines and the maritime modes that are in use; 2.3) studies on the concept of intermodal transport, types of intermodality existing in other regions and the choice preferences on intermodal transport involving RoRo mode, as this supports the discussion about the intermodal transport in the Philippines which is presented in Chapter 3; 2.4) the hub-and-spoke network concept and modelling; 2.5) the road congestion of Metro Manila; 2.6) shipping lines cost function and concept of economies of density. Lastly, Section 2.7) presents the gaps in literature which this study intends to fill.

2.2 Maritime Transport in the Philippines

Because of the archipelagic characteristic of the country, maritime transport has been the major means by which cargoes are moved between islands. From the National Statistics Office (NSO) 2013 data of Commodity Flow, 99.80% inter-regional commodity trade is done by water, with the remaining percentage done by air transport. This section provides literature review on the two sectors relevant to maritime transport of cargoes: the shipping and ports industry.

2.2.1. The Domestic Shipping Industry

There are several types of shipping services at work for the domestic cargo and passenger transport in the Philippines as presented in Table 2.1.

Liner, tramper, RoRo and industrial carriers are among the shipping service types that handle cargoes. Of the 10,694 merchant fleets registered in 2014, 28.53% or 3,051 are cargo vessels. The breakdown of the fleets is shown in Table 2.2.

In 2013, 2,497 domestic operators serve 14 primary routes which handle domestic volume of national significance and usually cover the major ports of the country, 102 are secondary routes which handle domestic volume of regional significance and are linked to ports of lesser throughputs than major ports, and 1,600 are tertiary routes or feeder routes that handle cargoes consolidated and destined for primary and secondary ports (MARINA, 2013).

Table 2.1: Services provided by the domestic inter-island shipping industry (Source: Llanto, *et al.*, 2007)

Shipping Service Type	**Description**
Liner	Follows fixed sailing schedules, regular ports of call (routes) and frequency of travel. These handle both passengers and cargoes.
Tramper	Do not follow a regular route and schedule, and are contracted (chartered) by shippers to deliver cargoes from port to port. These only handle cargoes.
Tanker	These specialized vessels transport oil, chemicals, and LPG.
Fast craft, ferry, and wooden boat	These vessels travel short distances. They mainly cater passengers.
RoRo	These are vessels used for short distance travel, and can accommodate passengers, vehicles and cargo-carrying vehicles. The service has a fixed schedule and a regular route. There is no cargo handling involved since the cargoes are "moving" (self-propelled) cargoes
Industrial carrier	Vessels owned and used by companies to transport their cargoes and, in many cases, are using their own ports.
Tugs, barges	Used in ship-to-shore loading and unloading of cargoes.

Table 2.2: Domestic merchant fleet profile for Cycle Year 2014, Source: Borci, 2015

Type Of Service	**Number**
Passenger	6,555
Cargo	3,051
Tanker	249
Tugboat	566
Pleasure/Yacht	33
Others	118
Dredger	28
Special Purpose Ship	16
Miscellaneous Ship	78
TOTAL	10,694

According to Llanto *et al*. (2013), the primary routes are served by four major shipping lines operating 17 long haul vessels. These major shipping lines are not specified in the study, but Figure 2.1 shows the domestic cargo shipping market share published in 2011. In the same year, Negros Navigation Co. Inc. and ATS Consolidated Inc. had a merger and branded their company as 2Go Group Inc.

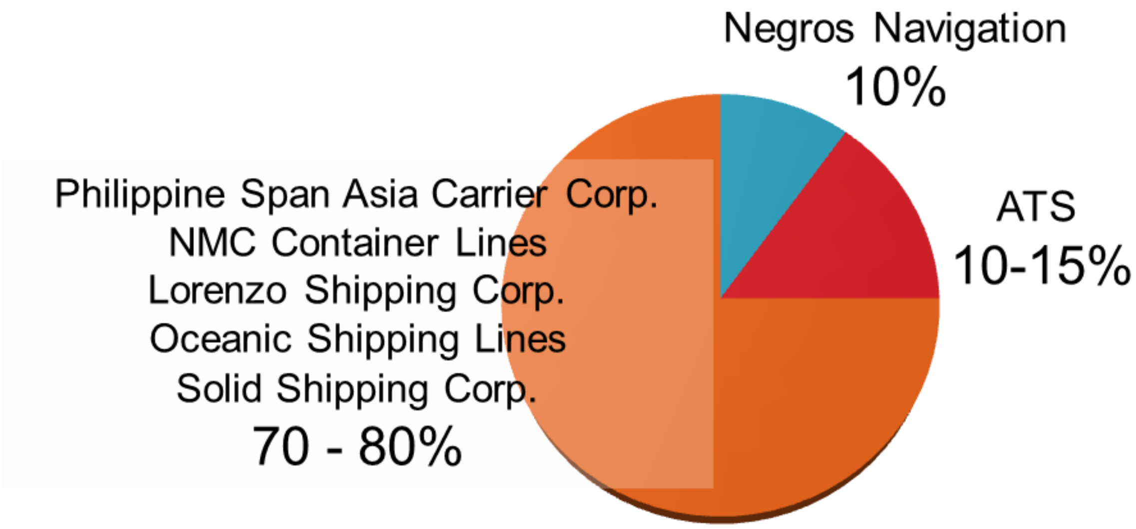


Figure 2.1: Domestic shipping cargo market share in 2011

Source: Marina Maritime Review, 2011

In 2014, 2Go Group Inc. has 33% of the freight market as presented in their 2015 Maritime Committee Meeting. From the 2014 annual report of Lorenzo Shipping Corp. (LSC), the other containerized cargo shipping companies they consider as competitors are 2Go Group Inc. (Aboitiz Transport Systems Corp. (ATS) and Negros Navigation Corp.), Philippine Span Asia Carrier Corp. (a.k.a. Sulpicio Lines Inc.), Solid Shipping Inc., NMC Container Lines, Inc. and Oceanic Container Lines, Inc. As can be deduced from the preceding statement, there are several shipping lines competing for market share in the domestic cargo shipping.

While the primary routes are serviced dominantly by container vessels, the secondary routes are served by RoRo vessels operated by 34 shipping companies (Llanto *et al*., 2013). Among these are listed in Table 3.1 of Chapter 3.

The Maritime Industry Authority (MARINA) is the shipping government agency with both developmental and regulatory functions. It regulates all carriers and shipping companies, including those in logistics. MARINA exercises its regulatory functions through the issuance of a Certificate of Public Conveyance defining the routes and safety regulations, and fixing the rates of passenger fares and cargo freight. The other stakeholders of the domestic shipping industry are presented in Table 2.3

Table 2.3: Domestic shipping stakeholders (Source: Llanto, *et al.*, 2007)

Institutions	**Description/Function**
MARINA	Government agency tasked to oversee the development and promotion of the shipping industry. Vested with economic regulatory powers.
Philippine Coast Guard	Together with Philippine Ports Authority (PPA) and MARINA, tasked to implement safety shipping-related marine pollution rules and standards, maintains and operates aids to navigation, and enforces maritime laws and regulations.
Shipping companies	Domestic and foreign shipping companies calling at Philippine ports.
Shippers	Private cargo owners; port users (exporters/importers, domestic manufacturers, traders,).
Forwarding companies	Provides cargo consolidation and freight forwarding services.
Trucking companies	Inland trucking service providers.
Forwarding companies, customs brokers, and 4th party logistic providers	Provide services to shippers, by addressing all requirements at every stage of the logistics chain, including tracking, documentation and customs clearance.
Consumers/passengers	The general public whose interest the MARINA is supposed to protect.
Ship classification	Applies ship inspection rules for vessels 500GRT and above, in accordance with International Association of Classification Societies.
Pilotage service companies	Offers pilot services at major ports.
Department of Environment and Natural Resources	Regulates all kinds of environmental pollution, including marine (e.g., oil spillage, garbage dumping).
Seafarers	Ship officers and crew.

Commission on Higher Education, Maritime Training Council, TESDA, other private and public maritime schools	CHED regulates all specialized schools, including those that offer maritime education and training of various types of seamen.
National Telecommunications Commission	Regulates all forms of telecommunication, including grant of radiofrequencies for vessels whether ship-to-ship, ship-to- shore, or ship-to- global satellite network.
Professional Regulatory Commission	Licensure (marine engineering / marine transport)

2.2.2 Port System in the Philippines

The Philippines Ports Authority (PPA) is the national authority that administers and manages the country's ports including the establishment and operation of ports. The vast port system of the Philippine is categorized into four as shown in Figure 2.2 and is summarized subsequently as presented in Llanto, *et al.* (2007).

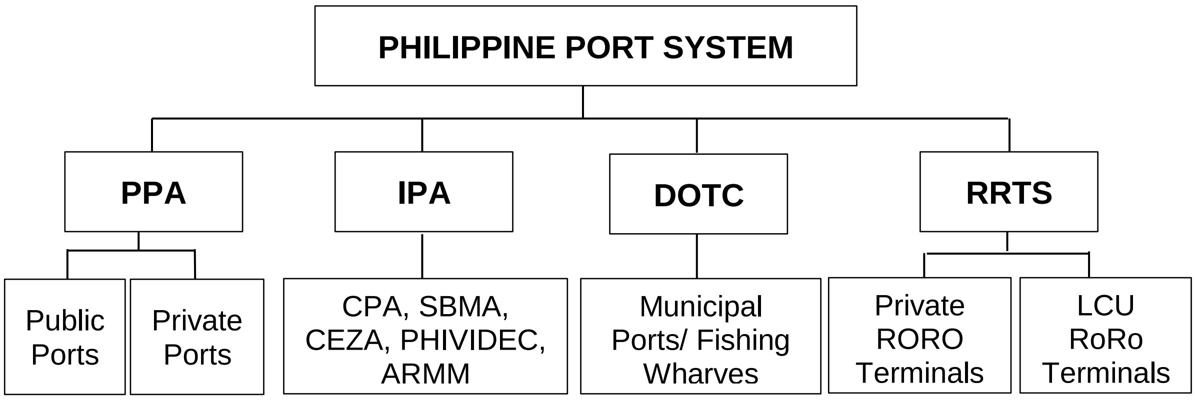


Figure 2.2: The Philippines Port System (Source: Llanto *et al.*, 2007)

a. PPA port system

This is the most important and extensive ports network existing, with 239 public ports and over 349 registered private ports in PPA administrative and operational jurisdiction (Javier, 2008). PPA-owned ports are also developed and maintained by the PPA on top of being under its supervision.

Private ports are mostly for industrial use, with around 30 ports that are for commercial use as of 2007, of which one is the BREDCO in Bacolod. The PPA has no investment in private ports but receives 50% share from usage/berthing fees and wharfage dues. The PPA is financially autonomous from the government and earns its revenues from concession fees from lease of ports, ports charges and the share from the private cargo handling operators and the share it receives from private operated ports. PPA remits 50% of its net income as mandated by a 1992 law.

b. Independent Ports Authorities (IPA)

These were created to decentralize control of PPA, to create more competition among the ports, and allow the local government unit (LGU) to have greater control of its port. There are six IPAs, namely, Cebu Port Authority (CPA), Subic Bay Metropolitan Authority (SBMA), Cagayan Economic Zone Authority (CEZA), Phividec Industrial Authority (PIA) which manages the Mindanao Container Port Terminal (MCPT) in Cagayan de Oro, Autonomous Region of Muslim Mindanao (ARRM) and Bases Conversion Development Authority (BCDA) which supervises the port in San Fernando, La Union and manages the ports in Clark Field, Pampanga.

c. Department of Transportation and Communication (DOTC)-developed feeder ports

These are small fishing ports, landing stages and feeder ports developed and funded by DOTC and eventually handed over to LGUs. There are about 427 ports of this type in 2007.

d. Road-RoRo Terminal System (RRTS)

This is a network of terminals all over the country linked by RoRo vessels. This was established in 2003 through the Executive Order 170 with the goal of providing greater access to the island provinces and better integration among the different regions. This was created as a response to the private sector’s clamor for a solution to the high cost of transport from Mindanao to Luzon. Executive Order 170 as well as its enhancement, the EO 170-A, make intermodal transport of a self-powered vehicle by road and RoRo vessel favorable as they introduce the nautical networks as an integral part of the national highway system. Transport through the system is not anymore burdened by any costs and procedures that are not required in land-based transport systems. The regulatory changes are: removal of cargo handling charges and wharfage fees, freight is based on lane meter, documentary requirements are simplified, among others. Transport through RRTS has been promoted as an alternative and a complement to the conventional container transport by container vessel.

2.3 Intermodal Transport

Intermodal transport is the movement of goods in the same loading unit or vehicle by successive modes without handling of goods when changing modes (Bontekoning *et al*., 2004). This differs to *multimodal transport* defined by European Conference of Ministers of Transport (ECMT, 1996) as the carriage of goods by at least two different modes of transport. The ECMT (1996) also defines the term *combined transport* to be based on intermodal transport but is characterized by two important supplement items; *i)* the major part of the journey is by rail, inland waterways or sea, and *ii)* any initial/final leg carried out by road is as short as possible (Andersson *et al*., 2005). Existing studies often use the term intermodal transport in the same meaning as combined transport, for the reason that intermodal transport policy has been strongly advocated especially in European regions as a remedy to road transport concerns related to reducing congestion and pollution, and improving safety (Andersson *et al.*, 2005, Bontekoning *et al*., 2004).

2.3.1 Difference between Intermodal Transport of the Philippines and other Regions

Existing studies on intermodal logistic policy in other regions, namely, EU, U.S. and Japan, have the following policy directions: EU's main concerns are environmental issues, highway congestion, and technology improvements and innovations. U.S. stresses on global connectivity and trade, leading role of industry, market treatment of modes, and energy problem. Meanwhile, Japan aims at competitiveness, increasingly in the Asia-Pacific market, and environmental and societal needs (Horn and Nemoto, 2004). The commonality among the policies is their aim for sustainable development (i.e. economic growth and environmental progress with global competitiveness as a primary goal). The intermodal transport in these regions involve rail, inland waterways or sea as the major part of the journey and road for the initial/final leg, which is as short as possible.

The intermodal policy in the Philippines meanwhile is geared toward greater efficiency and lower cost in the inter-island good transport by establishing the RRTS (as referred to 2.2.2d of this Chapter). It was created to answer the clamor of the business community for a solution to high cost of transport form Mindanao (the largest island in the south) to the capital Manila located in the northern region by the removal of cargo handling charges and wharfage dues (Basilio, 2008). The policy only covers self-powered carrying vehicles that are simply rolled in and off a RoRo vessel by their own wheels. The intermodal transport in the archipelago is posed as an alternative long-distance mode to the inter-island container shipping by container vessels. To compete in the long-distance, the cargo carrying vehicle unit traverses through chains of highways and seas (as loaded in RoRo vessels) which are linked by the network of RoRo terminals. This characteristic makes the advocated intermodal transport of the Philippines unique among the other intermodal transports of other regions.

Moreover, the intermodal policy in the country is still concerned about efficiency through seamless operations in the domestic level, while the other regions' pursue global competitiveness, environmental sustainability, and innovation in facilities and operations toward international standardization (Horn and Nemoto, 2005). The inclusion of chassis-RoRo as part of the RoRo service is still a policy recommendation. This means that loading container on chassis to a RoRo vessel still incurs cargo handling charges since the policy only covers self-powered vehicles. To include this into the policy will enhance the country's competitiveness since domestic transshipment of export and import cargoes will be reduced.

There are very few study about intermodal transport in archipelagic regions. Russ *et al.* (2005) and Yamada *et al.* (2009) designed a model for multimodal freight-transport networks for Indonesia and the Philippines that selects a suitable set of investment actions from a number of possible actions. They presented the overall transport network model as a leader-follower game, the transport planners as the leader and the network users as the follower, using bi-level programming for the determination of optimal improvement actions and user assignment.

2.3.2 Impacts of the Road-RoRo Intermodal Transport in the Philippines

The establishment of the RRTS enables the operation of the road-RoRo intermodal transport in the country. ADB (2010) and Basilio (2008) have written impact assessments of RRTS. The reported positive impacts are area development, restructuring of inter-island shipping, changes in cargo mobility, logistics operations and strategy, increased agricultural productivity and enhancement in tourism since the implementation of RRTS. The succeeding paragraphs detail these impacts.

In Roxas, Oriental Mindoro, new commercial establishments mushroomed after the port of Dangay came into operation. Real estate prices increased from P500-P1,000 to P5,000-P10,000 in 2010. From 2003, tax collections from business enterprises amounting to P2 million per year were added to the municipal total income. Meanwhile, port-related revenues in Pilar, Sorsogon increase by 84% when Montenegro shipping started its RoRo operation connecting Pilar to Masbate island.

Market developments brought by the RoRo policy heightened the level of competition which pushed existing players to restructure their operations. For example, the then Aboitiz Transport System (ATS) launched its RoRo service (former 2GO company). Also, Manila as inter-island gateway port was significantly reduced. There are no longer liner vessel servicing Mindoro from Manila, and the long-distance shipping from Manila to Panay has been reduced to just the port of Iloilo.

Vehicle numbers passing through SRNH also significantly increased (Figures 2.3 and 2.4), more notably for the Western Nautical highway. Aside from the RoRo policy, other factors also contributed to the shift in the cargo shipment to the intermodal road-RoRo alternative, namely, increases in fuel prices which prompted operators to sell old and less fuel efficient vessels; vessel accidents which caused suspension of shipping lines (e.g. Princess of the Stars of Sulpicio Shipping Lines); and the higher frequency of RoRo vessels trips which allows little lead time.

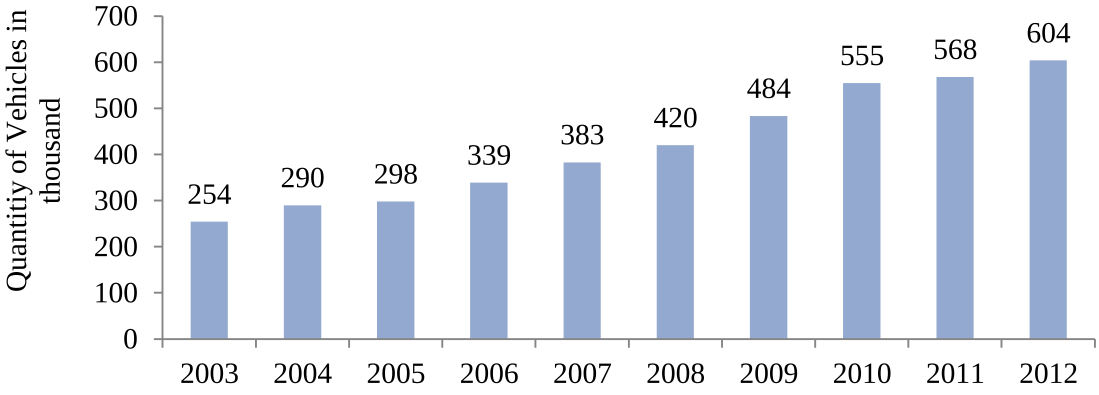


Figure 2.3: Number of Vehicles Passing through the Western Nautical Highway

Source: PPA Statistics

The developments brought by the policy also prompted some companies to change their logistics operations and strategy. For Nestle Philippines, because of the RoRo network they are able to make small, frequent and direct deliveries to clients ensuring product safety and shorter lead time. In turn they could reduce their distribution centers, closing 32 out of 36 of the centers around the Philippines, and minimize the need for inventories. On the other hand Universal Robina Corporation, a food manufacturing company, is enabled to deliver 12 trucks trips a day through SRNH from the previously one shipment a week via liner shipping. Gardenia Bakeries was also able to expand to new market when the Western Nautical Highway became operational. Each round trip from its Laguna plant to Iloilo only costs P21,000 using RoRo as opposed to P25,000 per 20-foot container by the traditional shipping. Frequent RoRo trips enables shorter lead time and faster deliveries giving them longer number of days to sell the bread products.

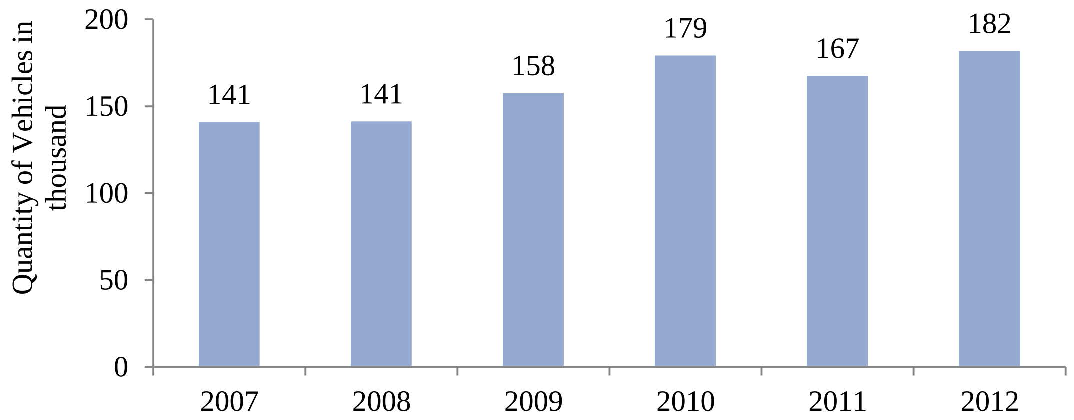


Figure 2.4: Number of Vehicles Passing through the Eastern Nautical Highway

Source: Estimated from PPA Statistics data

The efficiency in transporting by RoRo network also encouraged farmers to increase their production to take advantage of opportunities to increase income. SRNH, especially the Western Nautical Highway, opened up new markets to farmers. Fruits from Davao such as mangosteen and durian found new markets in Iloilo and Bacolod. Some of the vegetable shipments to Caticlan and Iloilo originate from Baguio. Fish shipments from Estancia to Manila increased from once a week using traditional shipping to daily via RoRo.

The RoRo links along the Western Nautical Highway enable easy access between tourism gems of the western Philippines. Dangay Port in Roxas, Mindoro Oriental links tourists from Puerto Galera to proceed further to Boracay Islands in Aklan (and vice versa). Greater accessibility and affordability are provided in travelling to Panay island, to Negros island and even down to Mindanao to visit tourism destinations in Dapitan.

Despite the assessed positive impacts, as mentioned in the Introduction, Kobune (2008) shows that the advantage of RRTS is overemphasized only for its quick procedure at terminals (because transport through RoRo does not require cargo handling), and is competitive to the inter-island shipping in terms of total transport cost only within a specific distance (200km). There is a lack of existing study to support and clarify the position of intermodal transport in the domestic shipping market. A study is therefore needed to present the existing market of intermodal road-RoRo and to what extent and distance range it competes with the inter-island container transport by container vessel.

2.3.3 Preference for Intermodal Transport with RoRo shipping

As prior mentioned, the intermodal transport in the context of archipelagic Philippines is unique such that the vehicles in road-RoRo intermodal shipments traverse chains of islands and seas (or several land and sea legs) to compete with the long-distance container shipping. This is contrary to the short sea shipping (SSS) and motorways of the sea employed in other regions (e.g. Europe, Asia-Europe, Northern America and Australia) where intermodal systems generally only involve one sea leg and often are in competition with land-based transports.

Several published studies tackle RoRo shipping as part of an intermodal system as well as the choice decision bases for this mode. In general, the advantages of maritime RoRo transport over container transport are *(i)* greater time efficiency since routes are shuttles and not intertwining as that of container vessels which causes frequent transshipment and waiting, *(ii)* less time consuming cargo handling at ports, *(iii)* greater loading conditions and dimensions (greater volume, refrigerated units etc.) used up by semi-trailer compared to containers, and *(iv)* able to allow transport companies a sole continual physical connection with their vehicle thus they could maintain economic and quality control of the whole transport chain Torbianelli (1999, 2000). Comparison by Woxenius (2012) states that the SSS ferries have very high commercial and technological flexibility as they have very open interface between cargo and passengers and accept virtually anything allowed on the road, while container feeder vessels have high commercial openness due to the small parcel size and the large adoption of containerization over the years but is specialized in its containment unit. Paixao and Marlow (2002) meanwhile report that both ships compete with land-based transports in different distance coverage partly due to logistics cost; RoRo on short distances with road transport and container ships on long distances with the rail mode. Containers are the least expensive mode of carrying goods while RoRo has higher inventory costs thus lack competitiveness over long distances. Moreover, the quick turnaround time of RoRo is critical for operation in short routes.

For the studies on mode choice, Puckett *et al*. (2011) reveals that shippers' choice between SSS and truck in the Atlantic Canada-US eastern seaboard market is strongly sensitive to cost and frequency of departure. Feo *et al*. (2011), using stated preference survey with Spanish freight forwarders with south-west Europe shipments, report that cost has the greatest effect with other significant parameters being transit time, delivery time reliability and service frequency. While D'Este and Meyrick (1992) found that the top factors in the choice of RoRo carrier are in the order of frequency, reputation for punctual delivery, transit time, price and response to problems being of particular concern. Their survey results largely confirm the findings of several earlier studies, while acknowledging that local conditions can affect the relative importance of particular decision factors. Meanwhile, Paixao-Casaca and Marlow (2005) identified the factors/service attributes essential for a more competitive multimodal service in Europe, namely, carrier logistic network design and speed, cost of service and reliability/quality, carrier's representatives sales and after-sales behavior, investment policy, corporate image, commercial/operational and carrier-shippers' relationship policies, involvement in the forwarding industry and service guarantee. Moreover, Lopez-Navarro (2013) shows evidence that shared planning between road transport firms and shipping companies positively benefits intermodal; citing the presence of incentives for collaboration, the importance of trust within the relationship, and the positive effects of adaptation of road transport firms to their shipping companies.

2.4 Hub-and-Spoke Transport Network

2.4.1 Definition, Classifications and Assumptions

In a hub-and-spoke network, cargoes are routed through hub facilities that serve as switching, transshipment and consolidation points that concentrate flows to take advantage of economies of density. With this network configuration, less connections are needed to serve O-D pairs than with a purely point-to-point (PTP) network where all nodes are fully connected. Fewer resources are necessary and demand pairs are served more efficiently. Maritime industry and freight transportation companies are activities that can take advantage of a HS concept (Farahani *et al*., 2013). In their study, Takano and Arai (2009) identify the hub locations for an 18-port containerized cargo transport network using the quadratic model of O'Kelly (1987) and concluded that cases of hubbing are more economical than adding more ships.

The basic classification of a hub network is with regard to the allocation of non-hub nodes to hub nodes, allowing for either single or multiple allocations as differentiated in Figures 2.5. Moreover, Alumur and Kara (2008) state that studies in this area often assume three things: (1) the hub network is complete with a link between every hub pair; (2) there exist economies of density when the inter-hub connections are used; (3) no direct service between two non-hub nodes is allowed. Karimi and Setak (2014) present other forms of a hub network which relax assumption (1) (Figure 2.6 a-c). A complete network has the form shown in Figure 2.6d. Meanwhile, Figure 2.7 shows an example illustration of "non-restrictive hubbing", which relaxes the assumption (3) and allows direct transport from a non-hub node to another non-hub node.

Single allocation property combined the application of assumption (3) is coined the "strict and restrictive hubbing policy" (Aykin, 1995a), where each node is limited to be assigned to a single hub for all inbound and outbound services. The same author further states that in many applications, this policy may impose undesirable and rigid operational restrictions.

The first mathematical formulation addressing the hub location problem by O'Kelly (1987), with the following formulation, is under the strict and restrictive hubbing policy and complete hub network. The same is true for a good number of subsequent works.

$$Min \ \sum_i \sum_j W_{ij}\left(\sum_k X_{ij}C_{ij} + \sum_m X_{jm}C_{jm} + \alpha \sum_i \sum_j X_{ik}X_{jm}\, C_{km}\right) \qquad (2.1)$$

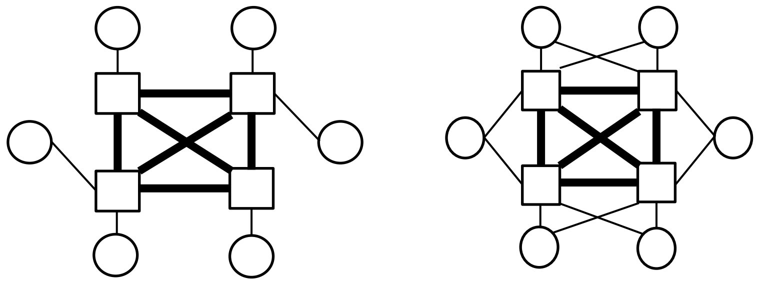
$$\text{s.t.} \quad (n-p+1)X_{kk} - \sum_i X_{ik} \geq 0 \qquad \text{for all } k, \qquad (2.2)$$

$$\sum_k X_{ij} = 1 \qquad \text{for all } i, \qquad (2.3)$$

$$\sum_k X_{kk} = p, \qquad (2.4)$$

$$X_{ij} \in \{0,1\} \qquad \text{for all } i, k. \qquad (2.5)$$

In the formulation of O'Kelly, The objective function minimizes the total network transport cost; with the first two terms representing the transport cost for origin to hub and hub to destination, and the third term represents the transport cost between hubs. The parameter α signifies the transport cost discount due to scale economies, or more appropriately in this study, economies of density. W_{ij} is the flow between nodes *i* and *j*, and C_{ij} is the transportation cost of a unit of flow between *i* and *j*. *X* are the decision variables. X_{ik} is 1 if node *i* is allocated to hub at *k*, 0 otherwise; X_{kk} is 1 if node *k* is a hub, 0 otherwise. Constraint (2.2) restricts that only single allocation of non-hub node to hub node exists. Constraint (2.4) restricts the number of hubs to *p*, and lastly, Equation (2.5) represents the binary condition.



(a) Single Allocation (b) Multiple Allocation

Figure 2.5: Allocation Schemes for HS Network

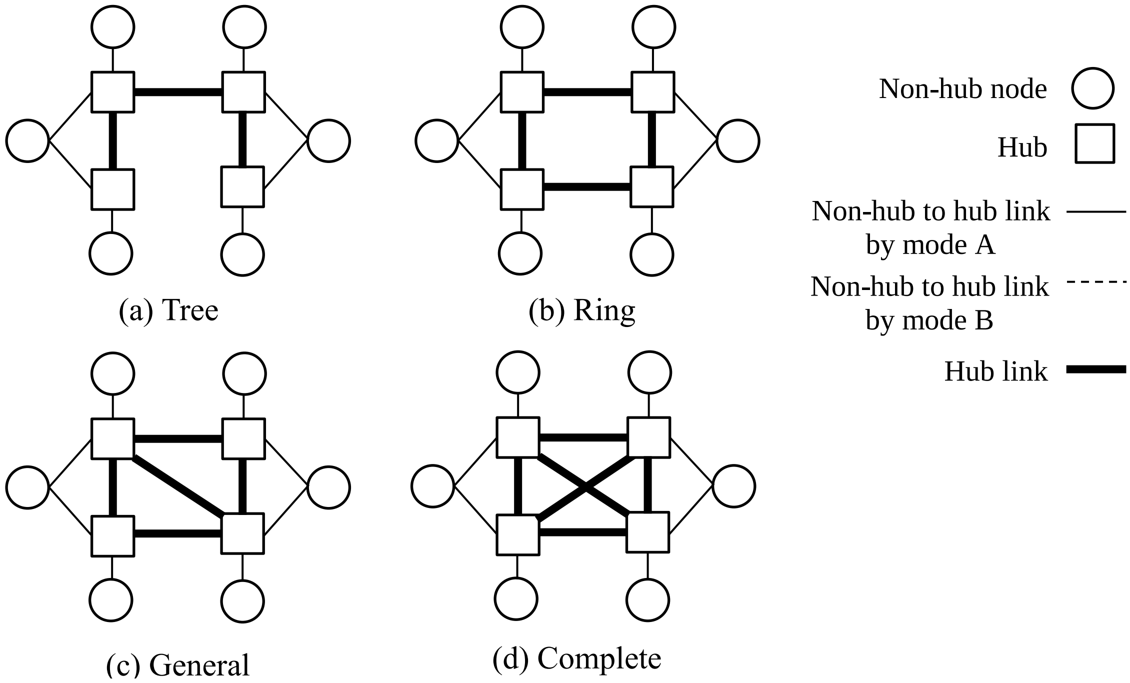


Figure 2.6: Examples of Forms of a Hub Network

(Source: Karimi and Setak, 2014)

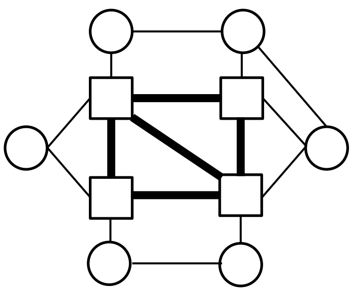


Figure 2.7: Example of Non-Restrictive Hubbing

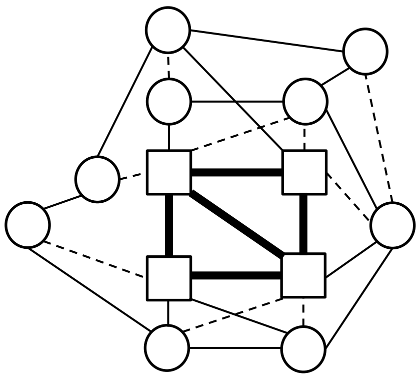


Figure 2.8: Model incorporating properties deemed suitable for archipelago

There are only a few papers tackling the hub location problem with two-hub-stop adopting the non-restrictive hubbing policy. Blumenfeld *et al.* (1985) and Klincewicz (1990) consider the combination of direct and indirect shipping but with only one consolidation terminal. Aykin (1995a, 1995b) consider one-hub-stop, two-hub-stop and, when permitted, direct services. Sung and Jin (2001) build a basic mixed logistics network model with hubs selected from predetermined clusters of nodes. In their model, each node cluster has one hub node to consolidate and switch all traffic from the terminal nodes in the cluster, thus, this is also a single allocation problem. The paper considers an integer-programming model for the problem and constructed the solution from its associated dual solution. Wagner (2007) proposes a new (exact) solution procedure and a new model formulation of the non-restrictive policy hub network introduced by Sung and Jin (2001), offering a faster solution to the problem. Yu *et al*. (2009) develops a model to locate urban transit hubs with the objective of minimizing total travel time. They make the assumption of non-restrictive policy but also of the cluster-based single hub allocation policy. For the two-hub-stop cases in these models, a flow can be either transported via non-stop service or hub service depending on which service will provide the lower cost for that certain flow.

The combination of direct and HS shipping is referred to as mixed system by Liu *et al.* (2003) and Li and Lindu (2011). The term mixed network, as opposed to the purely point-to-point (PTP) or direct network, is adopted in this study for the same definition. Finally, Figure 2.8 shows a representation of the model incorporating the properties of intermodal transport, multiple allocation, non-restrictive hubbing and general network configuration.

Moreover, there are also some studies that tackle one-hub stop network. Sasaki *et al.* (1999) state that the conventional model of hub-and-spoke usually assume that trips enable two stops as mass transport between hubs usually helps to reduce the transport cost. Nevertheless, they consider the one-stop model as they deem it most appropriate especially for distance between each origin-destination pair is not very long.

2.4.2 Economies of Density and How it is Embedded in Hub-and-Spoke models

Economies of scale is the common term to refer to the cost savings derived from concentrating flow densities on network links between hub locations (Horner and O'Kelly, 2001) and is incorporated to the HS model by the symbol/parameter α. But since the common notion for the term is associated with the entire firm or fleet, though in shipping this could applicable to a single vessel, we take the more specific term of "economies of density". This more specific term is defined by Jansson and Shneerson (1985) as the falling average cost attributed to the increase of utilization of vehicle fleet (in this case container vessel) for a particular route.

Discount factor α typically takes a fixed value in classical hub location problems (Alumur and Kara, 2008). Though, O'Kelly and Bryan (1998) point out that to assume that the discount factor is independent to the volume of flow miscalculates the total network cost and may erroneously select the optimum hub locations and allocations. Moreover, Horner and O'Kelly (2001) state that many HS network models make three key assumptions that over-simplify the problem, namely, (1) the bundling of flows on the inter-hub link is the exogenous nature of discount factor; (2) the number of hubs to be located is determined exogenously; (3) only flow on inter-hub links may receive discount when in reality, discount could be earned at any portion of a route with sufficient volume.

Several studies have attempted to overcome these modelling limitations and simplifications. O'Kelly and Bryan (1998) and Klincewicz (2002) employ a non-linear cost function by a piecewise-linear concave function. Horner and O'Kelly (2001) and Bryan (1998) use another non-linear cost function based on the Bureau of Public Roads (BPR) function of Sheffi (1985), and which could be earned along any portion of the route with sufficient volume. As opposed to the BPR, the discount would be based on decreasing function of link flow, $D_l = \left(1 - \theta x_l^{\beta}\right)$, where D_l is the discount on a given link l is dependent on link flow x_l, raised to some power β which represents the decay of the function and multiplied to a scalar θ.

While specific functional forms for the cost function as used for cost minimization models have been identified such as the translog cost function, they are not commonly used for hub-and-spoke network models. Wu (2009) however utilizes a translog variable cost function to determine the optimal fleet capacity of shipping lines in Taiwan. The translog shipping variable cost function in the study is expressed in terms of the labor, fuel, intermediate materials inputs, stock of capital invested and technology. For the hub-and-spoke network models, the transport cost minimization is based on the volume of flow. As explained earlier in this section, commonly, only the transport cost for inter-hub links receive discount from the increase in flow volume. Moreover, also commonly, the inter-hub transport cost is calculated based on a fixed valued discount factor and is not based on a functional form cost function.

2.4.3 Heuristics used in solving Hub-and-Spoke Network Problems

Three are several heuristics solutions in literature being used to solve large problems in a short period of time. From the paper of Alumur and Kara (2008), the known methods used are simulated annealing heuristic (e.g. Ernst and Krishnamoorthy, 1996), tabu search heuristic (e.g. Skorin-Kapov and Skorin-Kapov, 1994), genetic algorithm and its hybrid (e.g. Abdinnour-Helm and Venkataramanan, 1998; Abdinnour-Helm, 1998). According to the same paper, for hub location problems, the use of Lagrangian relaxation is the most effective heuristic as presented in Pirkul and Schilling (1998) with maximal gaps of less than 1%.

Several other studies have applied the Lagrangian relaxation heuristic. Lu and Ting (2013) use the method in solving a capacitated hub location problem; while Ernst and Krishnamoorthy (1999) use it for a capacitated p-hub median problem, both studies considering single allocation. An *et al.* (2014) used the Lagrangian relaxation method to solve the difficult problem on reliable single and multiple allocation hub-and-spoke network considering disruptions at hubs. Aykin (1993) introduced a capacitated hub-and-spoke network problem in which hubs have limited capacity, and where direct and hub connected services between nodes ae allowed, and problem is reduced to a smaller routing problem where Lagrangian relaxation is then applied.

2.5 The Road Congestion Problem of Metro Manila and the Proposed Solutions

The transport and traffic problems of Metro Manila are linked primarily to economic development that has resulted in rising car ownerships (Regidor, 2007). Several studies have been conducted that examine and propose solutions to the road congestion. Regidor (2007) evaluates the effectiveness of three schemes namely, Unified Vehicular Reduction Program (coding scheme), the Truck Ban, and the U-turn Scheme and presents quantitative assessment of the programs as guide for administrators. Castro *et al.* (2003), meanwhile, discuss the impacts and evaluate the effectiveness of the implemented truck ban schemes in Metro Manila. Their results indicate that the "no truck ban" scheme is the most favorable way of improving the traffic environment, but state that this scheme may encounter resistance from private motorists and resident who will be affected by the lifting of implemented truck bans. Thus they offer the "all day truck ban at EDSA only" scheme which resulted to comparatively encouraging reductions in trucks travel distance. Another study by Castro *et al*. (2005) reveal that freight carriers cope with large truck restriction policy by mainly changing their delivery routes and or shifting the delivery times. A report by ALMEC Corporation (2014) on the roadmap for transport infrastructure development for GCR, among the proposed studies to be conducted toward the implementation of the short term projects is the feasibility of North Harbor Redevelopment. North Harbor in Manila has the highest share of domestic cargo throughput in the country. The redevelopment of the area into a mixed-use waterfront property would require the cargoes to be shifted from Manila to adjacent ports, of which the suggested one is Batangas Port. This shift is seen to provide a volume of exportable TEUs that may entice foreign vessels to call at Batangas Port. The move would free up the City of Manila which presents an opportunity to revitalize the city and regain its old glory. Moreover, it would also provide operating costs savings to shipping companies since domestic shipping is primarily from the south of Manila and Batangas is located south of Manila.

2.6 Estimation of Shipping Cost

In Chapter 5, we estimate the shipping costs of 2 vessels' voyages to determine the effect to the carrier of the strategy of using HS network with Batangas port as hub instead of Manila port. From McConville (1999), the costs structure of a hypothetical ship with breakdown in variable and fixed costs is shown in Figure 2.9, where the costs are defined in Table 2.4.

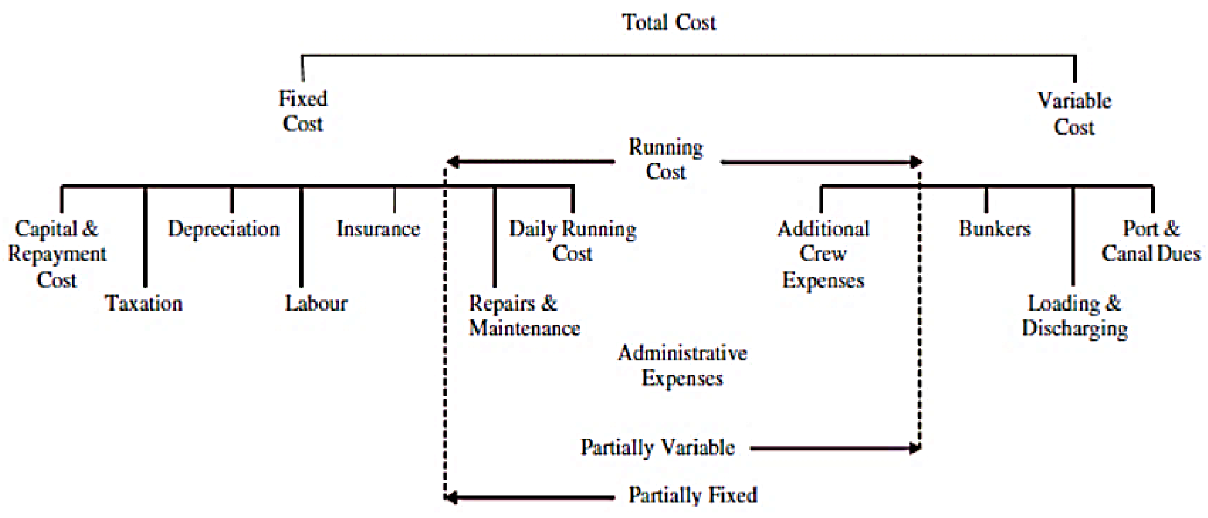


Figure 2.9: Cost structure of a hypothetical ship (McConcile, 1999)

Table 2.4: Cost structure of container shipping
(Lim, 1994; Gkonis and Psaraftis, 2010)

Fixed costs (running costs and capital costs)	
Crew expenses/ Labour	wages, overtime, pensions, accident/sickness insurance, traveling/repatriation, provisions, victualling and cabin stores, etc.
Vessel expenses	stores/spares, lubricants, maintenance/minor repair, annual survey, fresh water, communication charge, etc.
Insurance	hull / machinery, war risks, freight / demurrage defense, P&I, other marine risks, etc.
Depreciations	ship, container, chassis, trailer and other container related equipment, terminal property and equipment, etc.
Amortization	for long-term terminal, container, chassis and trailer leaseholds and leaseholds improvements, etc.
Variable costs	
Cargo-related expenses	
Cargo expenses	CFS charges (stuffing, stripping), measuring/weighing, tallying, cargo inspection, customs examination, documentation, non-containerized/overheight /overwidth/dangerous cargo surcharge, reefer cargo expenses (pre-trip inspection, pre-cooling, monitoring, storage), etc.
Terminal Handling Charges (THS)	loading/unloading/receiving/delivery (lift onto chassis for empty dispatch, lift off from chassis for receiving outbound load, load into vessel from stacking area for outbound cargo and discharge from vessel into stacking area, lift onto chassis for delivery, lift off from chassis for empty return for outbound cargo), shifting (from cell to cell, unload on the terminal and reload on the same vessel), transshipment (unload on the terminal and reload on another vessel on the same terminal), storage of full and empty container, stevedores or equipment stand-by charge, overtime surcharge, etc.
Haulages	railroad charge, rail ramp fee, inland depot charge, inland transportation, local drayage, port equalization, port, shuttle, feeder charge, etc.
One-way short-	for container, chassis and trailer

term lease	
Navigation expenses	
Port charges	pilotage, towage, dockage, wharfage, harbour/tonnage/light/buoy /anchorage dues, mooring/unmooring and running lines, customs/quarantine fee, watchman/agency/cana1 fee, etc.
Bunker expenses	fuel and marine diesel oil
Overhead	
Administrative expenses	compensation of officers and directors, salaries and wages of employees, fringe benefits, rental expenses, office expenses, communication expenses, dues and subscription, travel expenses, advertising, entertainment and solicitation, legal fees, taxes, etc.
Non-operating revenues	interest income, dividend income, revenue from non-shipping operations, foreign exchange gains, income from affiliated companies, etc.
Non-operating expenses	interest expenses, foreign exchange losses, donations and contributions, miscellaneous losses, etc.

According to Hsu and Hsieh (2005), shipping cost can be divided into three main categories: (1) capital and operating costs, (2) fuel costs, and (3) port charges. Table 2.5 relates these 3 main categories to the container shipping cost structure of Table 2.4 and Figure 2.9.

Table 2.5: The three main categories of shipping cost

Capital and Operating costs	total expenses paid for using the ship each day; cost of owning the ship, crew wages and meals, ship repair and maintenance, insurance, materials and supplies, and so on. In this category would also include all the running costs. **Fixed costs + Overhead costs**
Fuel costs	expense of the fuel consumption by a ship sailing at sea and dwelling in port **Bunker expenses**
Port charges.	hull / machinery, war risks, freight / demurrage defense, P&I, other marine risks, etc. *All Cargo-related expenses* + Port charges

The following notations are used to formulate the three cost categories shown in Equations (2.6)-(2.8) which are also taken from the paper of Hsu and Hsieh (2005).

C_t^m	total shipping cost for route *m* for a ship type *t*
m	route where *1* is the multiple calls route and *2* is the hub-to-hub route
i	port of call on route *m*, where MLA stands for Manila, BAT for Batangas, BCD for Bacolod and ILO for Iloilo
t	ship type
f^m	sailing frequency per season of route *m*
Q_{ij}^m	flow from port *i* to port *j* on route *m* per one round voyage (TEU)
O_t	average daily capital and operating costs for a ship of type *t* (PhP per day)
D_i^m	shipping distance between port *i* and port *i*+1 (nautical mile)
F_t^m	fuel cost at sea per nautical mile for a ship of type *t* on route *m* (PhP per nautical mile)
F_{it}^m	fuel cost at port *i* by a ship of type *t* on route *m* (PhP)
V_t^m	average service speed for a ship of type *t* (nautical mile per day)
R_i	average gross handling rate in port *i* (TEU per day)
G_i	average handling rate in port *i* (PhP per TEU)
W_i^m	time a ship spends at port *i* on route *m* (day)
δ_{it}^m	charge at port *i* for a ship of type *t* (PhP)

Total capital and operating costs for shipping all container flow on route *m* per season *f*: (the product of the average daily capital and operating costs, O_t, the total shipping time per round voyage, $\sum_i \left(W_i^m + \frac{D_i^m}{V_t}\right) + \frac{1}{f}\sum_i \sum_j \left(\frac{Q_{ij}^m + Q_{ji}^m}{R_i}\right)$)

$$f\,O_t \sum_i \left(W_i^m + \frac{D_i^m}{V_t}\right) + O_t \sum_i \sum_j \left(\frac{Q_{ij}^m + Q_{ji}^m}{R_i}\right) \qquad (2.6)$$

Fuel costs are the expense of the fuel consumption by a ship sailing at sea and dwelling in port for sailing frequency *f*:

$$f \sum_i (F_t^m D_i^m + F_{it}^m) \qquad (2.7)$$

The port charges include the charge for the ship (servicing the ship, including pilotage, towage, line handling fee, and berth occupancy charge, etc.) and the stevedoring charges (cargo handling, including a container loading and unloading fee, equipment charge, and rent of container yard, etc.).

$$f \sum_i \delta_{it} + \sum_i \sum_j \left[\left(\frac{\beta_{it}}{R_i} + G_i \right) \cdot \left(Q_{ij}^m + Q_{ji}^m \right) \right] \tag{2.8}$$

Thus, the total shipping cost function of a ship type *t* for a season *f* on route *m* is:

$$C_t^m = f \sum_i \left[\delta_{it} + O_t W_i^m + F_{it}^m + D_i \left(\frac{O_t}{V_t} + F_t^m \right) \right] + \sum_i \sum_j \left[\left(G_i + \frac{\beta_{it}}{R_i} + \frac{O_t}{R_i} \right) \left(Q_{ij}^m + Q_{ji}^m \right) \right] \tag{2.9}$$

2.7 Chapter Conclusion

The preceding sections provide the basic knowledge supporting the objectives of this study as well as the summary of existing literatures on the study's topics. The following are the gaps in literatures that this study intends to fill:

a) Section 2.3 presents the positive impacts of intermodal road-RoRo transport based on initial assessment reports (ADB, 2010 and Basilio, 2008). Among the reported impacts is the shift of shipments from the convention container transport using container vessel to intermodal transport and the transport cost reduction for long-distance transport, e.g. Laguna to Iloilo, made when using intermodal transport. However, the study by Kobune (2008) state that the advantage of RRTS is overemphasized only for its quick procedure at terminals and is competitive to the inter-island shipping in terms of total transport cost only within 200km. Because of the archipelagic characteristic, the intermodal transport in the country is unique in that the vehicles traverse chains of islands and seas (or several land and sea legs) to compete with the long-distance container shipping. This is contrary to the SSS and motorways of the sea employed in other regions where intermodal systems generally only involve one sea leg and often are in competition with land-based transports.

   A study therefore needs to be conducted to clarify the current position and mode share of intermodal road-RoRo transport in the Philippines, its development and the regulatory changes that shaped it to its present state, its advantages over the conventional or container means of inter-island shipping, and the attributes that influence mode choice. These information would be useful as baseline data for future plans/ studies regarding intermodal transport improvements in the Philippines.

b) While there are a number of studies on hub-and-spoke network modelling, few if none exist/s where the application is on an archipelagic region. Moreover, some of the policies followed in earlier models could be limiting and restrictive for an archipelagic topology to realize a more transport cost efficient network. A study is therefore necessary to model a HS network suited for an archipelagic geography, which relaxes some of the common assumption of previous models and incorporates the properties of multiple allocations, non-restrictive networking policy, general hub network topology, and intermodality, all of which have not been tackled at once in previous studies. The developed HS model establishes a basepoint for future research on the topic for archipelagic geography settings, since the application on archipelagic context has not been delved into previously.

c) Solutions have been proposed to alleviate the road congestion problem in Metro Manila, one of which is to shift cargo from Manila ports to Batangas port to free up the city of Manila from trucks (JICA, NEDA, 2014). The study mentioned the operating costs savings advantage to shipping companies when they call in Batangas because domestic shipping is primarily from the south of Manila. However, it is more likely the shippers will incur additional costs in transporting their cargoes from Manila to Batangas port, thus might not be beneficial to the shippers.

This study therefore explores the feasibility of implementing cargo shifting in conjunction with a hub-and-spoke network scheme where Batangas port is one of the hubs. Being a hub, there is consolidation of cargoes which would bring economies of density for inter-hub transport. The study presented in Chapter 5 explores if the discount brought by a hub-and-spoke network would give shippers an overall savings to their total transport costs. Moreover, the vessel's shipping cost savings of a shipping company from changing its operation to direct interhub calls from the existing multi-ports calling is estimated as it would justify the tariff discount the company could provide the shippers due to economies of density in interhub cargo flows.

The study then provides policy suggestions on how to cargo shifting and hub-and-spoke network could be facilitated.

Chapter 3

Intermodal Road-RoRo Transport in the Philippines, its Development and Position in the Domestic Shipping

3.1 Introduction

As the general aim of the dissertation is in presenting an intermodal hub-and-spoke network model that is applicable for an archipelagic geography; thus as a starting point, this chapter's goal is to provide details on the existing intermodal road-RoRo transport in the country, its development, current position in the domestic shipping market and the attributes that influence the choice for this mode against the other modes in the market. The topic has not been presented in other literatures in this approach. Though could be seen as primary research on the topic, the chapter's contents help build knowledge to the field in which future researches could bank on.

In that, also the outputs of the chapter are the components of transport costs such as truck's and vessels' tariff, tolls and port fees, and locations and distances between ports which are input to the network models of the succeeding chapters.

3.1.1 RoRo Transport Prior to Road RoRo Terminal System (RRTS)

RoRo vessels started arriving in the Philippines in 1970s, the first could have been the Millennium Uno from Japan in 1973 (Baylon, 2015). Since then, the Millennium Uno has been servicing Millennium Shipping and is plying the Liloan-Lipata route of the Eastern Nautical Highway. In 1978, "Northern Samar" of Eugenia Tabias Shipping Lines also started sailing the Sorsogon-Samar route (Baylon, 2015). RoRo ferry service between Batangas City and Calapan, Mindoro island also began operations in the 1970s, which facilitated the supply of food products from Mindoro to the capital Metro Manila (Kobune, 2008).

The concept of RoRo ferry service as part of the highway system was first introduced in the Pan Philippine Highway, which was conceptualized in 1965 (Basilio, 2008). Pan-Philippine Highway, also known as the Maharlika Highway, is a network of roads, bridges and ferry services across the eastern part of the Philippines connecting the islands of Luzon, Samar, Leyte and Mindanao. However, it was only in the 1980s when RoRo ports along this Highway, namely, between Matnog (Sorsogon, Southern Luzon) and Allen (Northern Samar), and between Liloan (Southern Leyte) and Lipata (Surigao del Norte), were built for the exclusive use of RoRo service. In 1983, Maharlika I and Maharlika II started operations in these links. However, it is known that even before then, the private sector already utilized RoRo vessels by using existing and makeshift ports and wharves, some of which were privately built. Examples of these were the prior mentioned Millennium Shipping and Eugenia Tabias Shipping Lines that serviced the links of the Eastern Nautical Highway even in the 1970s (Baylon, 2015).

Other RoRo routes soon followed. Manila International Shipping and Viva Lines pioneered the services between Southern Luzon through Batangas and Lucena with provinces of Mindoro, Romblon and Marinduque. Short-distance services across the islands of Visayas were pioneered by Gothong Shipping, Aznar Shipping and Maayo Shipping that primarily carried vehicles. In the 1980's, liner companies such as Negros Navigation, Sulpicio Lines, Gothong Shipping, and Trans-Asia Shipping already had RoRo vessels that served overnight and short-distance routes (Baylon, 2015). Non-vehicle cargoes were commonly shipped as loose cargoes or in pallets loaded into the vessel using forklifts. Perhaps wheeled cargoes such as trucks were not popular then because the freight charges for self-powered vehicles were in cubic meters; contrary to the present where, by RRTS policy, charging is made in lane meters. Thus, a significant amount would be paid for the volume of the vehicle, in addition to the intended cargo. It would be more economical to transport the cargoes to and from the ports by trucks but unload/load them to and from the ship at ports.

Though RoRo services were present in the two sea links along the Pan-Philippine Highway which could have seamlessly connected Luzon to Mindanao, long-distance intermodal transport could not been used in its full potential because of the then poor condition of some roads. In 1997, further improvement of the Pan-Philippine Highway had to be done with the addition of 600 kilometers of road from Sto. Tomas, Batangas to Matnog, Sorsogon (ADB, 2010).

The 1980s also saw the surge of containerization in the domestic shipping, which began with 10-footer and 20-footer containers. In the 1990s, 20-footers dominated, with 40-footers present mainly for transshipments for foreign ports. Containers are also carried by RoRo vessels and are loaded and unloaded using forklifts or mounted on trailers and pulled by tractor heads to speed up the process. The latter is also a form of intermodal transport. However, container with prime mover in RoRo vessels is charge higher than the other vehicles (e.g. 10-wheeler truck) and is not charged per lane-meter because of its heavier material composition (Montenegro Lines, 2014). Container on chassis is not considered a self-powered vehicle thus, as per Executive Order 170, could still be burdened by transport procedures and additional costs in loading into a RoRo vessel. Moreover, container vessels have the capacity of stacking containers on top of each other to realize density economies whereas RoRo vessels commonly only have one deck for loose, palletized and rolling cargoes, and have the upper decks for passengers.

Prior to the inception of the RoRo policy in 2003, the predominant method for domestic shipping is by container vessel, which uses the load-on load-off system facilitated by cranes and dock equipment (ADB, 2010). This system presented significant cargo handling and wharfage costs.

3.1.2 Inception of the RoRo Policy

According to an ADB (2010), during the various conferences held in Mindanao in 2002, one of the persistent issues raised by shippers was the high cost of transport from Mindanao to Manila. Many could not understand why certain domestic shipping is more expensive than shipping from Manila to Hong Kong, China or Bangkok. Cost and inefficiency of cargo handling charges were identified as the major factor in the high cost of domestic logistics transportation, as they attribute to up to 30% of the sea transport costs. Extensive use of RoRo shipping is recommended as the most appropriate for an archipelagic country because it goes away with port-related activities (ADB, 2010). However, the RoRo recommendation was not readily implemented. Various reports attribute this to the lack of interest from PPA (Basilio, 2011).

PPA is vested the role to own, develop, maintain, operate and generate income from its ports. PPA as the operator outsources terminal operations such as cargo handling to the private sector and in turn collects 10-20 percent shares from cargo-handling revenues. As per PPA approval, cargo-handling rates increased annually from 1998-2008. PPA is said to be biased with cargo handling such that the more cargoes handled and the higher the rates, the higher is the income of PPA (Basilio, 2011). In effect, most shipping lines converted their RoRo ships to accommodate cargo handling, and some of them even went to cargo handling business themselves. In addition, cargo handling was imposed even though no cargo-handling service was actually provided; only the false pretense that the ports are not equipped to handle RoRo ships.

There was then a strong clamor for reform from the business sector. Thus in 2003, the Execute Order 170 was enacted that orders the elimination of any costs and procedures that are not required in land-based transportation systems such as cargo handling charges and wharfage dues. The order also promotes RRTS by changing the basis of freight charge to lane meter, by simplifying documentary requirements, waiving port authorities' share in port revenues, encouraging privatization of public RoRo ports, requiring only minimum permit in port construction and operation, and providing available financing from the Development Bank of the Philippines for investments related to this cause.

RRTS was also promoted as a solution to the absence of connectivity of rural islands to economic hubs such as Manila, Cebu, etc. Isolation and lack of connectivity of the island provinces are important factors that contributed to poverty and underdevelopment. They serve as major constraints to economic and social interaction and integration, giving limited incentives to increasing production (because of relatively small market). With inefficient transportation, increase in agricultural production only led to wastage and spoilage (ADB, 2010).

3.1.3 RoRo Routes and Inter-island Shipping Routes

The RRTS also called the Strong Republic Nautical Highway (SRNH) has three main trunk lines –Eastern Nautical Highway, Central Nautical Highway and the Western Nautical Highway shown in Figure 3.1. There are also lateral RoRo links, examples of which are those connecting the islands in the Visayas as shown in Figure 3.2.

Moreover, RoRo links also connect the islands of Cuyo, Catanduanes, Romblon, smaller islands of Cebu and Southwestern Mindanao to the bigger main islands or urban economic nodes. Aside from the short distance RoRo links, there are RoRo vessels that sail long-distance such as the routes of Manila-Cebu-Cagayan de Oro, Manila-Cebu-Butuan, Manila-Cebu-Dumaguete-Zamboanga, Batangas-Calapan-Odiongan, Manila-Cebu-Davao-General Santos, Manila-Batangas-Iloilo-Bacolod-Cagayan de Oro, etc.

In 2008, there were 68 existing RoRo routes served by 49 shipping companies operating more than 250 RoRo ships (Basilio, 2008). The trunklines of SRNH alone serve 919 kilometers covering 17 cities, towns and islands. As of December 2013, the three trunklines have multiple trips per day as shown in Table 3.1.

As of December 2013 data, there is no operation between Pilar, Sorsogon to Aroroy, Masbate and Cawayan, Masbate to Daanbantayan, Cebu (MARINA, 2013). Alternatively, RoRo operations by Montenegro Lines for Pilar to Masbate City port, and Cawayan to Bogo, Cebu are listed in the Table 3.1. Moreover, there is also a daily RoRo service from Batangas directly to Caticlan by Montenegro Lines. The multiple trips per day of short-distance RoRo

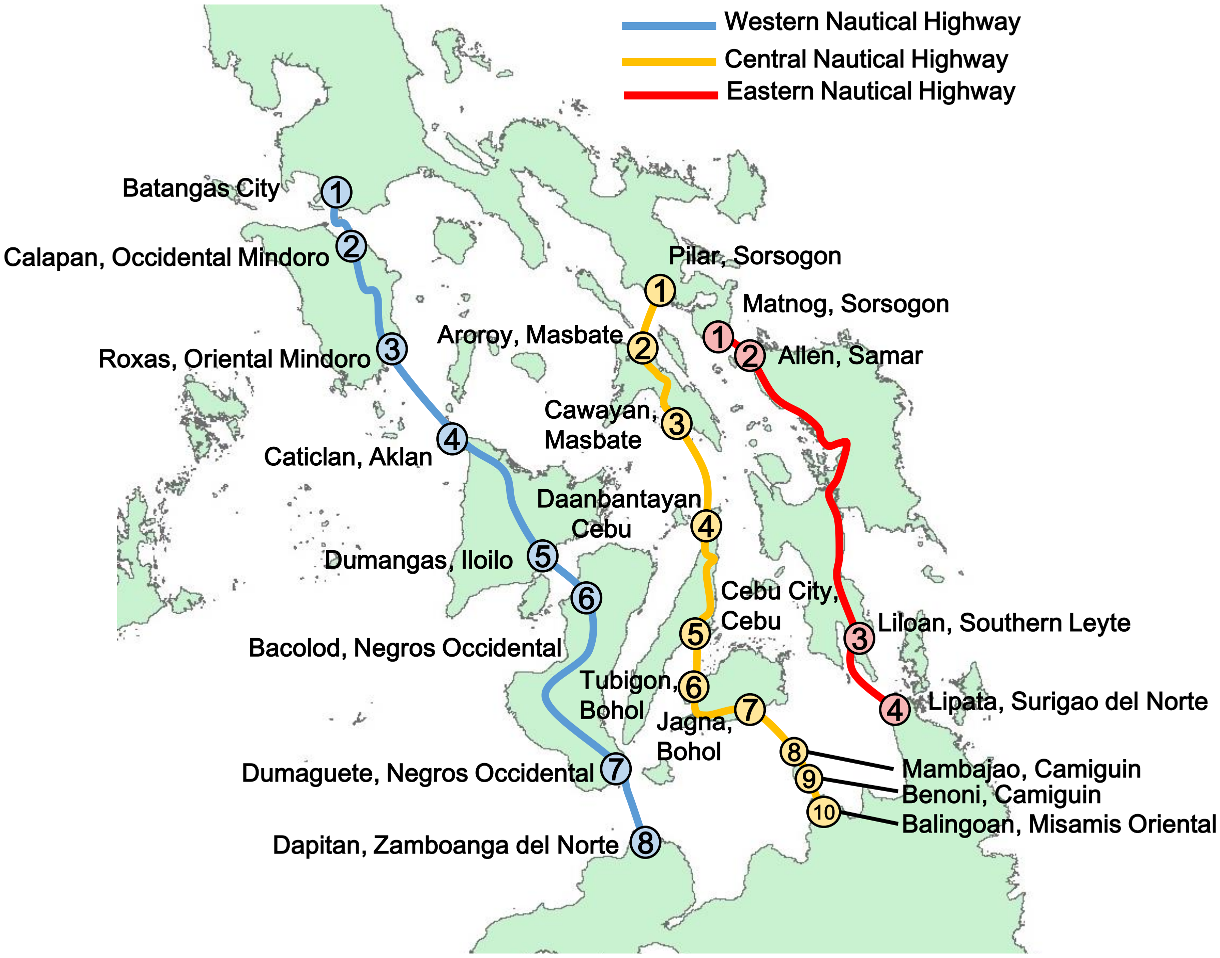


Figure 3.1: The three main trunklines of the Strong Republic Nautical Highway

is contrary to the less frequent trips of overnight and long-distance RoRo and container vessels that commonly only have at most one trip per day for each route per shipping company.

Gathered from PPA, Table 3.2 shows the weekly trip frequencies and available destinations served with Manila as origin by 9 shipping companies namely Aleson Shipping Co., Solid Shipping Lines, 2GO Group Inc., Carlos A. Gothong Lines, Gothong Southern Shipping Lines, Lorenzo Shipping Co., Moreta Shipping Company, Phil. Span Asia Carrier Corp. and Asian Marine Transport Corp. Escano Lines Inc., Loadstar Shipping Co., Seaford Shipping Lines, National Marine Container Lines and Oceanic Container Lines Inc. also service the ports of Manila but their information are not included in the Table. From Kobune (2008), daily services are available only along the routes of Manila-Cebu-Cagayan de Oro and Manila-Iloilo-Bacolod. The other routes only have 1-3 services per week.

Figure 3.2: Lateral RoRo Links in the Visayas

Table 3.1. Daily trip frequencies of short-distance RoRo links along the three nautical highways (Source: Maritime Industry Authority, 2013; and retrieved from interview)

Routes	Number of Operators	Trips per day
Western Nautical Highway:		
Batangas City – Calapan, Oriental Mindoro	4	37 toward, 36 return
Roxas, Oriental Mindoro – Caticlan, Aklan	2	6
Dumangas, Iloilo – Bacolod, Negros Occidental	3	19
Dumaguete, Negros Oriental – Dapitan, Zamboanga del Norte	3	5
Central Nautical Highway:		
Pilar, Sorsogon – Masbate City, Masbate	1	5
Cawayan, Masbate – Bogo, Cebu	1	2
Cebu City – Tubigon, Bohol	3	9
Jagna, Bohol – Balbagon, Mambajao, Camiguin	1	2
Benoni, Camiguin – Balingoan, Misamis Occidental	3	18 toward, 16 return
Eastern Nautical Highway:		
Allen, Northern Samar - Matnog. Sorsogon	3	7
Liloan, Southern Leyte - Lipata, Surigao del Norte	3	7

Table 3.2. Less frequent weekly trips of long-distance inter-island shipping originating from Manila (Source: Retrieved from shipping companies websites (September 2014))

Destinations from Manila	Number of Operators	Trips per Week
Cebu	6	22
Cagayan de Oro	5	14
Bacolod	4	8
Iloilo	3	9
Nasipit	2	5
Davao	3	5
General Santos	3	5
Zamboanga	3	4
Puerto Princesa	2	3
Tacloban	1	3
Ozamiz	3	3
Roxas City	1	2
Dumaguete	2	2
Iligan	2	2
Cotabato	1	2
Masbate; Romblon; Coron; Dipolog; Tagoloan, Misamis Oriental; Ormoc	1	1

3.2 Intermodal Road-Roro in the Current Domestic Shipping

3.2.1 Field Survey Method

To better understand the market of intermodal road-RoRo transport in the Philippines, a field survey was conducted in Metro Manila on 3-24 of July 2014. The first part is a questionnaire survey carried out with 17 freight forwarder respondents. The goal is to determine from these representative companies the share of their shipments done by intermodal road-RoRo and the transport attributes that influenced their choice of mode. The second part of the field survey investigates the transport costs and travel times of both intermodal road-RoRo and inter-island shipping for selected origin-destinations. Since freight forwarders are hesitant to divulge their shipment cost breakdown and strategy, the second part of field survey involved the collection of data such as shipment tariff from shipping companies, ports fees, road toll fees, as well as travel times, loading cut-off time, average times in container yards, etc. pertinent to the selected origin-destination cases.

Part I of the questionnaire survey gathered the percentages of shipments from Manila to 9 destinations via (i) inter-island sea shipping from Manila port, (ii) intermodal road-RoRo transport and (iii) air transport. Air transport is included in the questionnaire as it is among the 3 modes generally used for freight transport in the country. The 9 selected destinations, with the approximate straight line distance to the farthest point of the island or location, were (1) anywhere within Luzon island (within 400 km), (2) Mindoro island (300 km), (3) Panay island (500 km), (4) Negros island (650 km), (5) Samar island (650 km), (6) Leyte island (700 km), (7) Cebu island (630 km), (8) Zamboanga (850 km), and (9) Davao (950 km). The destinations such as Mindoro, Panay and Negros islands can be reached intermodally through the Western Nautical Highway, while Samar and Leyte can be reached through the Eastern Nautical Highway. Respondents were also asked to specify the route taken especially for the case of intermodal road-RoRo transport. Characteristics of the shipment in terms of travel time, total transport cost incurred by the company and the breakdown of cost (to include toll fee, shipping line tariff, port terminal fee, etc.) were obtained when permitted by the company.

The Part II of the questionnaire survey asked the respondents to rank from 1 to 5 (1 as highest) the top attributes that influence their choice of a specific mode over the other modes. A list of attributes was given. Since a percentage of cargoes are also transported through air, this mode is also considered in this part of the questionnaire. The result of this section gives us an insight on the factors that contribute to the freight forwarders preference of mode and the advantage of the use of mode over the others.

3.2.2 Questionnaire Survey Results

a. Respondents classification

Freight forwarder respondents can be further classified based on the services they cater or their service niche. For example, some companies offer both inter-island (specifically using container) and intermodal road- RoRo transport services while some only focus on one service. Some are dedicated truckers only of certain routes, and "co-loads" the shipment to other companies when they do not serve the specific area or when the shipment characteristic requires container transport. Such that, we were able to interview truckers catering only the Western Nautical Highway, covering the capital Manila to Negros island, and some providing transport only along the Eastern Nautical Highway up to Mindanao, etc.

Thus, we show in Table 3.3 the classifications of the interviewed freight forwarders based on the services they provide. Five out of the 17 has their own intermodal trucking services. Eight companies have international cargo export and import as their main niche and only do pick-up and delivery within a certain reach. They seek the services of intermodal trucking services when necessary.

Table 3.3: Classification of companies interviewed for the survey

Characterization of Services Provided	Number of Companies
freight consolidation, domestic forwarding, intermodal trucking services	5
freight consolidation, domestic forwarding	2
international and domestic forwarding	8
parcel/freight forwarding services	2
TOTAL	17

b. Shipment share of Modes

From Part I of the questionnaire survey, Figure 3.3 shows the cargo volume percentages transported by each mode for the 9 selected destinations. There are many cases when not all 9 destinations are serviced by a freight forwarder, thus we provided Table 3.4 to show the data sample size per destination.

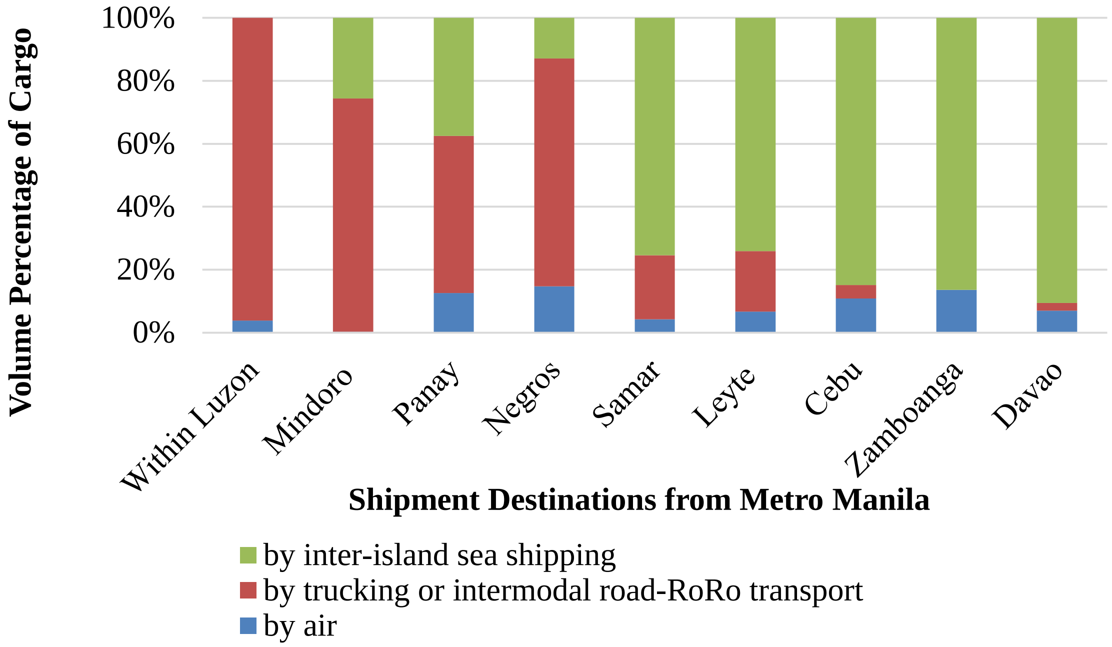


Figure 3.3: Percentages of cargo shipped by each mode type

Unlike in Europe, short-sea shipping, or sea transport along the coastline, is not popular in the Luzon main island. To ship to destinations outside the Manila, land transport is often used except for cases when the destination is another island in Luzon (i.e. Batanes) wherein air transport is an option because of the often unfavorable weather condition for sea transport. For the islands in the western seaboard (i.e. Mindoro, Panay and Negros), greater

Table 3.4: Sample Number per Destination

Destinations being Served by Freight Forwarders	Sample number
Within Luzon	7
Mindoro	7
Panay	11
Negros	3
Samar	7
Leyte	7
Cebu	13
Zamboanga	6
Davao	9

volume of cargoes are transported using intermodal road-RoRo transport than either inter-island sea transport or air transport. For Mindoro as destination, 74% is done by intermodal road-RoRo transport. This is not surprising since there currently is no liner vessel from Manila that serves Mindoro Island. The use of inter-island sea transport in this case is often for project cargoes, for example cargoes of a client building an industrial plant where the cargoes are bulky and oddly shaped that it is more suitable to transport them using tramper vessels. Moreover, interview with 3 freight forwarders with shipments to Negros Island revealed that more than 72% of their shipments are via intermodal road-RoRo transport. Meanwhile, high percentage of cargoes shipped in destinations along the eastern seaboard (Samar and Leyte islands) are transported using inter-island sea transport, despite that only Tacloban and Ormoc ports have vessels coming from Manila. The choice of mode may also have been affected by the condition of road network from Allen to Calbayog City, which has been categorized by travelers and bus operators as “bad” according to ADB (2010). Moreover, only around 4% of cargoes for Cebu Island are shipped intermodally, and even less for destinations in Mindanao Island (Davao and Zamboanga).

Also from the interview of 3 freight forwarders, intermodal transport and inter-island sea transport both carry every type of commodity from the following categories: (a) personal effects, (b) manufactured goods, (c) chemicals and related products, (d) mineral fuels, lubricants and related materials, (e) food and beverages, (f) crude materials, (g) machinery and transport equipment and (h) animal and vegetable oils, fats and waxes. Personal effects compose a substantial portion of commodities transported by intermodal transport, and these are often in the form of “balikbayan boxes” or boxes from overseas Filipino workers containing gifts and other effects intended for relatives in the Philippines.

c. Ranking of Important Attributes in the Choice of Mode

For each mode, the respondents were asked to rank the top 5 attributes (from a list of 18 attributes) which influenced them in choosing the particular mode (air, inter-island sea transport and intermodal road-RoRo transport). Tables 3.5 to 3.7 evaluate the ranking based on score, assigning scores 5, 4, 3, 2 and 1 to ranks 1, 2, 3, 4 and 5, respectively. The number of times the attribute is designated to a rank by the respondents is filled in the columns “B”, and these are multiplied to the corresponding score in column “A”. The sums of the AxB are the general weight of the attribute, which gives us the idea on the general ranking of attributes in the choice of mode. Note that not all of the freight forwarders respondents conduct shipping by all 3 modes; only 9 respondents ship using air transport, 14 by inter-island sea transport and 11 by intermodal road-RoRo transport.

Air transport has the advantage of speed, thus the choice of this mode is predominantly because of the short travel time and reliability in terms of delay, as indicated in Table 3.5. Among the highest in weighted score are security in terms of cargo losses and damage, flights availability and frequency. Air shipment charges the fee for insurance, and airline companies have extensive coverage of domestic cities destinations several of which have multiple flights per day. It is not surprising that transport cost is not among the top in weighted score since the tradeoff of having fast speed is high cost.

For inter-island sea transport, transport cost is the most important attribute for the choice of mode with 71% of the respondents ranking it in top 1, and which also garnered the highest weighted score. Travel time only follows second in weighted score. Suitability to the cargo characteristics also has a high weighted score because for 20-footer container full container load (FCL) in container vessel, the maximum load allowed is 18 tons, which is higher than the 13 tons limit commonly imposed for 10-wheeler FCL when loaded into short-distance RoRo vessels. This is despite that a 20-footer container has 33 cbm volume while a 10-wheeler truck has 45 cbm. RoRo vessels are relatively smaller and an instance of unbalanced weight of wheeled cargoes could make a vessel susceptible to overturning thus the strict weight limit. In effect, freight forwarders prefer to transport dense cargoes by container vessel because of the higher weight restriction.

Table 3.5: Scores of influential attributes for the choice of Air Transport

Rank	Score (A)	Attributes																							
		1		2		3		=4		=4		5		6		=7		=7		=8		=8		9	
		Travel time		Reliability in terms of delay		Security in terms of cargo losses and damage		Availability of flights		Frequency of flights		Quality of service		Suitability to the cargo characteristics		Transport cost		Qualiy of airports and their facilities		Safety in terms of accidents		Delay at consolidation warehouse for LCL cargoes		Availability of tracking service	
		#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB
1	5	7	35	1	5	0	0	0	0	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	4	1	4	2	8	2	8	2	8	1	4	0	0	1	4	0	0	0	0	0	0	0	0	0	0
3	3	0	0	1	3	1	3	1	3	0	0	3	9	1	3	1	3	1	3	0	0	0	0	0	0
4	2	1	2	1	2	0	0	0	0	2	4	1	2	1	2	0	0	0	0	1	2	1	2	0	0
5	1	0	0	2	2	3	3	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Sum		9	**41**	7	**20**	6	**14**	5	**13**	4	**13**	4	**11**	3	**9**	1	**3**	1	**3**	1	**2**	1	**2**	1	**1**

Table 3.6: Scores of influential attributes for the choice of Inter-island Sea Transport

Rank	Score (A)	Attributes																											
		1		2		3		4		=5		=5		=5		6		=7		=7		8		=9		=9		10	
		Transport cost		Travel time		Suitability to the cargo characteristics		Frequency of vessels		Security in terms of cargo losses and damage		Quality of service		Reliability in terms of delay		Safety in terms of accidents		Qualiy of port and their facilities		Availability of vessels		Delay at consolidation warehouse for LCL cargoes		Delay in transaction at ports for dangerous goods		Availability of tracking service		Availability of facilities along the route	
		#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB
1	5	10	50	1	5	1	5	1	5	0	0	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	4	1	4	5	20	2	8	0	0	1	4	1	4	2	8	1	4	1	4	0	0	0	0	0	0	0	0	0	0
3	3	1	3	2	6	2	6	3	9	1	3	0	0	1	3	1	3	0	0	2	6	1	3	0	0	0	0	0	0
4	2	1	2	0	0	2	4	2	4	2	4	1	2	1	2	1	2	1	2	0	0	0	0	1	2	1	2	0	0
5	1	1	1	1	1	1	1	1	1	2	2	2	2	0	0	0	0	1	1	1	1	0	0	0	0	0	0	1	1
Sum		14	**60**	9	**32**	8	**24**	7	**19**	6	**13**	5	**13**	4	**13**	3	**9**	3	**7**	3	**7**	1	**3**	1	**2**	1	**2**	1	**1**

Table 3.7: Scores of influential attributes for the choice of Intermodal Road-RoRo Transport

Rank	Score (A)	Attributes																															
		1		2		3		4		5		6		7		8		9		10		=11		=11		=11		=11		=12		=12	
		Travel time		Transport cost		Frequency of vessels		Reliability in terms of delay		Security in terms of cargo losses and damage		Capacity to deliver along the way		Availability of vessels		Availability of tracking service		Having sufficient cargo volume for the return trip		Safety in terms of accidents		Delay at consolidation warehouse for LCL cargoes		Delay in transaction at ports for dangerous goods		Quality of ports and their facilities		Quality of service		Quality of roads to be taken		Suitability to the cargo characteristics	
		#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB	#(B)	AxB
1	5	5	25	5	25	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	4	2	8	2	8	1	4	2	8	1	4	0	0	1	4	1	4	0	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0
3	3	1	3	0	0	2	6	2	6	2	6	2	6	1	3	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	2	3	6	1	2	1	2	0	0	1	2	1	2	0	0	0	0	1	2	0	0	1	2	1	2	1	2	0	0	0	0	0	0
5	1	0	0	1	1	2	2	0	0	1	1	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	2	2	1	1	1	1
Sum		11	**42**	9	**36**	7	**19**	4	**14**	5	**13**	3	**8**	2	**7**	3	**6**	2	**5**	1	**4**	1	**2**	1	**2**	1	**2**	2	**2**	1	**1**	1	**1**

For intermodal transport, travel time was ranked among the top 5 by all respondents (Table 3.7) and it has the top weighted score for the most important influential attribute. Transport cost only follows in second highest weighted score. Frequency of vessels comes third in the weighted score, higher than that in sea transport as more routes have more frequent vessel trips. Capacity to deliver to destinations along the way was also ranked among the top 5 by some respondents, an attribute unique only for this mode. Freight forwarder are enabled to fill one truckload faster since the load is composed of less than truckload (LTL) cargoes intended for different destinations along the route, thus also leading them to have more frequent trips. Tracking of cargoes is also easier for this mode since it often only involves contacting the truck driver or the truck's accompanying personnel using mobile messaging.

3.2.3 Transport Costs and Travel Times Comparison between Intermodal Road-RoRo Transport and Inter-island Sea Shipping

Transport cost and travel time are ranked at top 1 and 2 as most important attributes that influence the choice for intermodal and inter-island sea transport. Thus, we gather transport costs and travel times data for transport originating from Manila to 7 destinations reachable by both modes. These destinations are Tacloban and Davao (reachable from Manila through the Eastern Nautical Highway route), Cebu (reachable intermodally through the Central Nautical Highway) and Iloilo, Bacolod, Dumaguete and Zamboanga City (reachable through Western Nautical Highway) as shown in Figure 3.4.

Figure 3.5 shows the average tariff for port-to-port transport of 10 footer and 20 footer container from Manila to the chosen destinations as gathered from shipping lines. These do not include port fees and cargo-handling fees. Table 3.8 shows the port-to-port tariff for 10-wheer truck when transported through short-distance RoRo vessels of Montenegro Lines. The said shipping company caters for most of the links of the nautical highways. We do not consider the transport of 20-footer using long-distance intermodal road-RoRo transport because it is rarely used for this mode for the difficulty to maneuver a container trailer by prime mover for long-distance land travel (such as distance from coast-to-coast of an island). This is only commonly used for intra-city transport such as transport from consignee door to the port. Ten-wheeler truck is the common mode unit for intermodal transport using by the respondents. Twenty-footer container, meanwhile, is the standard unit for the domestic container transport.

Figure 3.4: Locations of selected destinations

To transport from Manila to the destination city's center, other costs should be considered such as land trucking to-and-from ports, port fees and cargo handling fees. We estimate the total transport cost to include these other said costs (also gathered from interviews) to the tariffs in Figure 3.5 and Table 3.8. Table 3.9 shows the additional costs for both modes.

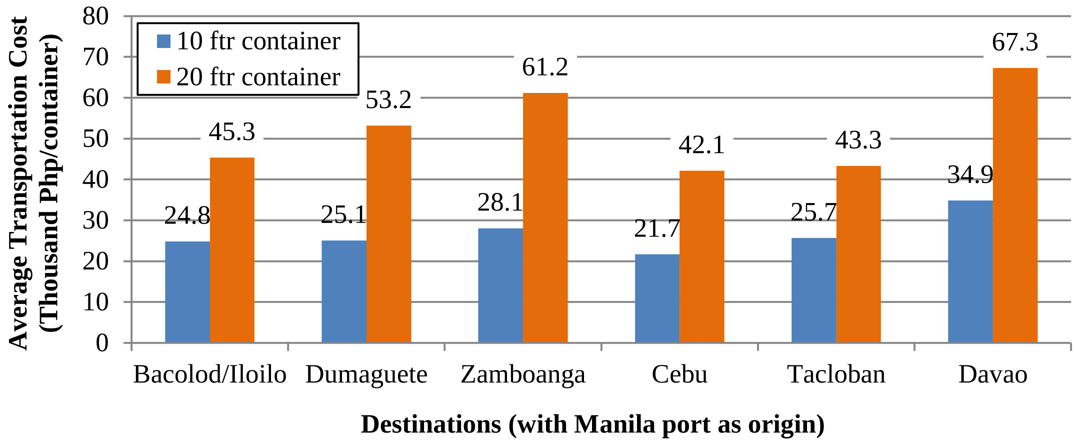


Figure 3.5: Average transport cost of 10 and 20 footer container by inter-island shipping (Source: interview, July 2014)

Table 3.8: Vessel Tariff for 10-wheeler truck (Source: Montenegro Shipping Lines website, September, 2014)

Route	**Tariff for 10-wheeler truck (PhP)** (as estimated to occupy 11.1-12 lane meters)
Batangas to Calapan	4,608.00
Roxas to Caticlan	8,832.00
Dumangas to Bacolod	3,072.00
Dumaguete to Dapitan	7,872.00
Matnog to Allen	2,880.00
San Ricardo to Lipata	5,040.00
Pilar to Masbate	7,776.00
Cataingan to Bogo	11,136.00

Table 3.9: Other incurred costs other than vessels tariffs for both inter-island sea transport and intermodal road-RoRo transport (source: interview with private sector)

Fees	Amount (PhP)
For inter-island sea transport:	
Trucking (Manila city center to Manila port)	5,950.00
Trucking from destination port to city center (average)	2,678.56
Arrastre/cargo-handling fee (average)	939.65
Wharfage	282.24
Document stamp	10.00
Weighing fee	80.00
For intermodal transport of 10-wheeler truck:	
Truck driver and crew wages and allowances	2,566/day
Truck fuel cost (1 liter of diesel per 2 km at 45Php per liter)	22.5/km
Toll fees	
Manila to Laguna South Luzon Expressway (SLEX)	496
Laguna to Batangas Southern Tagalog Arterial Road (STAR)	200
Port fees (Terminal fee, Weighing fee, PPA RoRo Terminal Fee)	611
Maintenance cost*	9.85/km

*Maintenance cost = (33 liters oil at 180Php/liter per 9,000km = 0.66Php/km)
+ (gear oil, automatic transmission fluid, brake fluid at total of 10,800Php per 30,000km=0.36Php/km)
+ (oil filter at 2,000Php/9,000km = 0.22Php/km) + (fuel filter at 1,800Php/9,000km = 0.20Php/km)
+ (air cleaner at 2,500Php/9000km = 0.28Php/km)
+ (tires at 19,000Php per tire x 10 tires / 55,000km = 3.09Php/km)
+ (RPS at 8,000Php/1,800km = 4.44Php/km)
+ (batteries at 6,500/piece x 2 pieces / 21,600km = 0.60Php/km)
= 9.85PhP/km

From the vessel tariffs and the other costs incurred, the total transport costs for both modes are estimated as shown in Table 3.10. Port-to-port distances and travel times data to aid the estimation, particularly for intermodal road-RoRo transport, were obtained from ADB (2010). The estimated total travel time range for intermodal transport mode indicates the shortest time when the truck does not have to wait in the port and the maximum time to include the maximum waiting time in the port in the case when the truck misses a vessel. This waiting time was made to equal to the maximum time interval between vessel arrivals.

Table 3.10: Estimates of total transport costs and travel times for inter-island shipping and intermodal road-RoRo transport

	20-Footer Container in Inter-island Sea Shipping		**10-Wheeler Truck in Intermodal Road-RoRo Transport**	
Destinations from Manila	**Estimated Total Transport Cost (PhP)**	**Port-to-Port Travel Time (hours)**	**Estimated Total Transport Cost (PhP)**	**Estimated Total Travel Time (hours)**
Iloilo	55,278.08	20 – 24	32,610.90	16 – 22.5
Bacolod	55,278.08	20 – 68	38,859.90	17.5 – 28
Dumaguete	63,098.34	25 – 44	50,690.65	23.5 – 34
Zamboanga	71,119.97	37 – 72	70,579.69	30 – 48.5
Cebu	52,075.24	22 – 27	43,525.15	22 – 60
Tacloban	53,252.16	~30	32,707.85	18 – 24
Davao	77,210.48	~60	65,200.66	31.5 – 45.5

Meanwhile, the port-to-port travel times for inter-island transport are the ranges gathered from shipping lines as posted in their websites. The variations and ranges are due to different vessel routes and port of calls. Total travel times for door-to-door transport for this mode will be longer than the port-to-port travel times shown since inevitably it takes time to transport from door to port (vice-versa), for the time leeway for the vessel loading cut-off time, and time in storage in container yards. A conservative estimate of 6 hours, in total, could be spent for these activities.

From Table 3.10, the transport cost estimates for 10-wheeler truck unit in intermodal transport are lower than the 20-footer container in inter-island shipping. The range of total travel times of intermodal transport is also lower than the port-to-port travel times of inter-island shipping, except for Cebu destination, which is due to less frequent RoRo trips from Cataingan, Masbate to Bogo, Cebu. Cebu being the second largest city in the Philippines has regular and frequent inter-island shipping vessels from Manila.

However, note that 10-wheeler truck and 20-footer container have different volumes and maximum payload limits, and interview with one of the largest freight forwarding company revealed that they take advantage of these characteristics to minimize cost. The maximum payload for 20-footer container (33 cbm) in container vessel is 18 tons and for 10-wheeler truck (45 cbm) is 13 tons. Thus, freight forwarders consolidate lighter cargoes with cargoes having shorter travel time demands and load them into 10-wheeler truck since intermodal transport arrives faster and the truck could carry bigger volume but lower weight. On the contrary, heavier cargoes are loaded into containers. Thus, if we calculate transport costs for both modes in per ton basis considering the maximum payload given, we can come up with the values in Table 3.11 for comparison.

Table 3.11: Cost per ton basis considering maximum payload of both modes

Destinations from Manila	**Cost per Ton Basis (PhP)**	
	20-Footer Container in Inter-island Sea Shipping	**10-Wheeler Truck in Intermodal Road-RoRo Transport**
Iloilo	3,071.00	2,508.53
Bacolod	3,071.00	2,989.22
Dumaguete	3,505.46	3,899.28
Zamboanga	3,951.11	5,429.21
Cebu	2,893.07	3,348.09
Tacloban	2,958.45	2,515.99
Davao	4,289.47	5,015.44

Intermodal transport to destinations in Panay island (Iloilo) and Negros island (Bacolod and Dumaguete) has shorter travel time and lower or comparable transport cost, thus intermodal transport has higher volume share than the other modes for these destinations as shown in Figure 3.3. Meanwhile, transport by container in inter-island shipping would cost less (per ton basis) for destinations such as Zamboanga, Cebu and Davao, which likely led to freight forwarders preferring this mode over the others as also indicated in Figure 5.3. In addition, Cebu has more regular and frequent inter-island vessel trips from Manila. Transport costs by both modes for Tacloban do not differ significantly, and indirect transport using inter-island shipping could be done through Manila-Cebu and Cebu-Tacloban. Both routes have regular and frequent trips, with Tacloban being near Cebu. Thus, this could be the reason why inter-island shipping dominates for Leyte island where Tacloban is located. Moreover, the road from Allen to Calbayog City, an intermediate link to be taken for Manila-Tacloban intermodal transport is categorized as having “bad” condition (ADB, 2010); and from Table 3.7, the “quality of road” has a low score on what makes intermodal transport attractive.

3.2.4 Summary: Mode Choice Condition

Transport cost and travel time are the top influential attributes for the choice for either of the two considered modes. Lower transport cost per unit container or per ton basis for relatively far destinations would lead freight forwarders to choose inter-island shipping over intermodal road-RoRo transport. This would be the case for transport to destinations such as Dumaguete, Zamboanga, Cebu and Davao, which are more than 600 km from Manila. Intermodal road-RoRo transport costs lesser and have shorter travel time for destinations along the western seaboard such as Mindoro, Panay and Negros islands, thus more cargoes are transported thru this mode according to the survey. In addition, the frequent RoRo trips along these destinations contribute to the preference for the intermodal mode. Frequent trips shorten the waiting time in ports and, consequently, lead to shorter travel times. On the other hand, inter-island shipping has daily regular trips to Cebu, adding to the preference for the said mode for this destination. Transport to Tacloban island is cheaper via intermodal road-RoRo but the choice for this mode could be discouraged by the bad condition of some roads.

3.3 Chapter Conclusion

This chapter details the developments of intermodal road-RoRo transport in the Philippines and provides an overview of its current state in the country. RoRo vessels have been in use in the country since the 1970s. However, increase use of RoRo transport as part of the intermodal transport system started when policies were enacted in 2003. The policies established the Road-RoRo Terminal System (RRTS), and provided policy changes that promote intermodal operations. The developments increased RoRo operations and heightened the competition in the shipping industry pushing some companies to remove or reduce inter-island shipping operations in some regions and venture into RoRo vessel operations. Positive impacts were realized since the operation of RRTS, namely, economic growth and area development in towns with RoRo ports, transport efficiency due to more frequent trips, opening of new markets especially for agricultural products, and enhancement of tourism.

The study contributes knowledge on the choice basis for intermodal road-RoRo transport over inter-island container transport and air transport for an archipelagic topology such as the Philippines, noting that this intermodal transport is distinct in that the vehicle traverses several land and sea legs in one shipment. The top five influential attributes for the choice of the intermodal modally with the findings of D'Este and Meyrick (1992), but relative importance is in the order of travel time, cost, frequency of vessels, reliability of delay and security in terms of losses and damages. The frequent trips of RoRo vessels in most legs compared to the inter-island shipping vessels give intermodal transport the advantage of shorter lead times leading to shorter travel times. Thus, from the survey, travel time, followed by transport cost, is the top attribute that influence freight forwarder on choosing intermodal transport. The result also indicates that even when transport using intermodal transport to a destination is cheaper, the choice for the mode could be countered by the poor condition of roads.

The results of the surveys conducted offer only an overview of the current situation of intermodal road-RoRo transport and the competition with inter-island shipping. The survey is limited in the number and classification of respondents. Since it is difficult to obtain actual transport costs information from freight forwarders, it is suggested to also interview frequent shippers such as individuals, farmers or companies of consumer goods. Moreover, for the transport costs comparison, the paper is limited in only considering 20-footer container and 10-footer truck for inter-island shipping and intermodal road-RoRo transport, respectively. Other transport units and vehicles are suggested to be looked upon in the next studies. For further study, a more comprehensive stated preference survey is suggested in order to develop a mode choice model for the alternative modes present in the Philippines; and thus, also be able to suggest concrete improvements for the freight transport operations of the country.

Chapter 4: Intermodal Freight Network Incorporating Hub-and-Spoke and Direct Calls for Archipelagic Geography

4.1 Introduction

In Chapter 3, the position of intermodal transport, as well as the other players in the shipping market in the Philippines has been detailed. This chapter then aims to achieve the second objective of this dissertation, which is to model a hub-and-spoke (HS) freight transport network that incorporates intermodality of transport modes existing in an archipelago such as the Philippines. From the data gathered in the Chapter 3 on the components of transport costs, namely, truck's and vessels' tariff and port fees as shown in Figure 4.8 and Table 4.4, respectively, we are able to pre-calculate the minimum link cost in Equation 4.20, which is input variable to the model. The location of ports and the distances between them are gathered from the field survey conducted in Chapter 3 study. These are plotted in Figure 4.8, and are used as input data to the model, particularly in the transport cost per link calculation.

4.2 The Characteristics of Archipelagic Philippines Considered in the Hub-and-Spoke Network Model

While we have established that intermodal transport has market share in the Philippines, previous studies also report as detailed in Section 2.3 that maritime industry and freight transportation companies could benefit from hub-and-spoke network concept. Compared to point-to-point (PTP) transport, a hub-and-spoke network benefits from consolidation of cargoes in hubs which results to lower average costs for inter-hub transport due to economies of density. Moreover, with hub-and-spoke, less resources are needed compared to the fully connected point-to-point network thus there is saving in investment (Farahani *et al.*, 2013). However, the archipelagic nature of the Philippines necessitates a unique HS network with certain deviations from the general model. The general model has the following the common assumptions as stated in Section 2.3, (1) the hub network is complete with a link between every hub pair; (2) there exists economies of scale when the inter-hub connections are used; (3) no direct service between two non-hub nodes is allowed

(Alumur and Kara, 2008). Moreover, there are two types of allocation of non-hub nodes to hub nodes: single allocation and multiple allocations.

The Philippine archipelago shown in Figure 4.1 is characterized by many islands, most of which are *small*, that are *spread in different directions* often in *chain formations* and are *only a short sea distant apart*. These four characteristics mentioned justifies the need for a unique HS formulation that incorporates the properties of general network configuration, multiple allocation, intermodal transport and, non-restrictive hubbing, respectively.

The following explains in detail the consequence of each of the characteristic:

a. Many islands are small in size – small islands are characterized by small trade volume; thus, a hub-and-spoke transport network that consolidates cargoes to achieve economies of density is fitting to be used. Moreover, what may also be a consequence of having small trade volume is that some islands conduct trade only with few regions. Thus, there are cases when even there are two hubs in the vicinity, it is not beneficial to route the cargo demands through these hubs because it would transport the cargoes farther from the regions the islands commonly do trade. Therefore, we relax the assumption that every hub is connected in a complete hub network. A hub pair is only created when transporting consolidated flows through it would improve the total transport cost of the network, and *therefore a general hub (or incomplete hub) network is employed*.

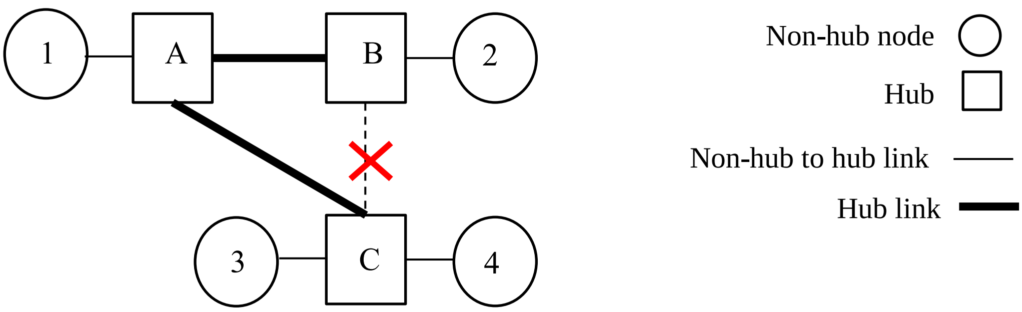


Figure 4.1: Simplified illustration of incomplete hub network

From Figure 4.1, hubs B and C are not connected. This probably exists because there are no cargoes from nodes 3 and 4 that are intended for node 2, or vice versa.

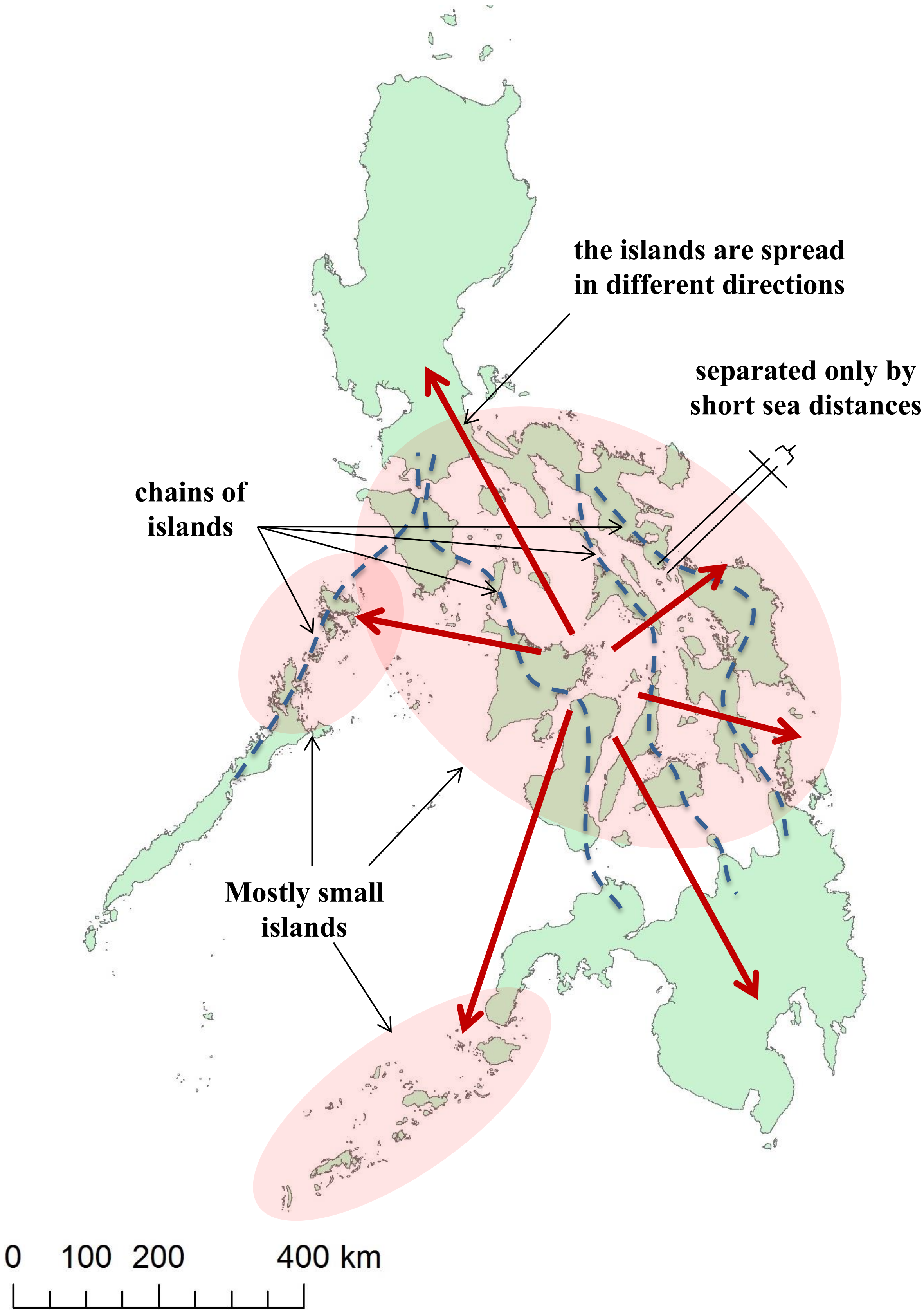


Figure 4.2: The characteristics of the Philippine archipelago

b. The islands are spread across different directions – the cargo flows of one region or island could be destined to (or originate from) locations of different (or opposite) directions. If all the cargoes of the region are allocated to only one hub, when the hub is in the opposite direction to the destination of the flow, shipping the cargoes via that hub would cost more. Li and Lindu (2011) state that adjacent demand ports have the tendency to ship a longer distance with single allocation case. Thus, the allocation of cargoes from a node is not restricted to only one hub (single allocation), but instead *allows multiple allocations*.

c. Chain of islands formations – In Chapter 3 we have established that intermodal transports along chains of islands (or along the Eastern and Western Nautical Highways) have mode share in the domestic shipping (it competes with the container vessel transport). The chain formation of islands makes it apt for intermodal land-sea-land-sea transport. Also in Chapter 3, we have established that road-RoRo intermodal transport is advantageous in the short distance thus could be utilized as feeder mode; while, for the inter-hub transport where travel could be of longer sea distance, container vessel could be used. Thus, *the HS model incorporates intermodal transport*.

d. Only a short sea distant separates the islands – a port in one island is only a short travel away from a port in an adjacent island. If we restrict that the cargo flows between all nodes are routed through hubs, the shipping cost for cargo flows between two adjacent ports could significant be greater. Thus, direct service shall be allowed between two non-hub nodes whenever it would is more cost efficient; in this case, *non-restrictive networking policy is employed*.

Therefore, the network is modeled to incorporate the properties of intermodality, non-restrictive networking policy, multiple allocations and general hub network topology.

4.3 Model Formulation

The mathematical model in this study is a total network transport costs minimization problem with the freight forwarder as decision maker as it tries to minimize the transport costs for the whole network it covers or serves. The model decides the location of a predetermined number of hubs *p* from a given node set *N*, and in the same time it also decides whether the flow from any origin to destination is transported directly or via a hub pair, while minimizing total network costs. The two hubs stop is considered since the goal is to realize economies of scale so that small islands with small trade volume could share in trade even for long distances. As stated in Section 4.2.1, the conventional model of hub-and-spoke usually assume that trips enable two stops as mass transport between hubs usually helps to reduce the transport cost Sasaki *et al.* (1999). The one-hub stop would be appropriate for short distances as also mentioned in the said study, but it is a limitation of this study that this case is not considered since it is presumed that it is in the inter-hub transport that significant consolidation, thus economies of density, is realized than in the one-hub stop.

The model is a formulation with $O(\underline{n}^4)$, which the developed heuristic algorithm solves in a reasonable time. Nodes are represented by notations *i*, *j*, *k* and *m*; with *i* and *j* corresponding to origin and destination nodes, respectively; and, *k* and *m* corresponding to 1st hub stop and 2nd hub stop, respectively. The input and decision variables are presented in Tables 4.1 and 4.2, respectively. The discount factor (α) represents the economies of density brought by cargo consolidation in inter-hub connections, and is fixed at values 0.9, 0.7 and 0.5. “Economies of density” is defined as the falling of average cost attributed to the increase of utilization of vehicle fleet (in this case container vessel) for a particular route (Jansson and Shneerson, 1985).

The number of hub arcs will not be an input variable as in other hub arc related papers (Campbell *et al*, 2005a; 2005b; Alumur *et al.*, 2009) but it will depend on the number of hubs *p*, and simply those which minimize total network costs. For *p* number of hubs, each hub could be paired to a maximum of *p-1* number of hubs. This is the concept used in formulating constraints (4.4) and (4.5). As a consequence of these constraints, the developed model falls under the general hub network category as classified by Karimi and Setak (2014) as in Figure 2.5(c). In addition, the model in this paper identifies hub arcs and ensures that more than one flow goes through each hub arc as compliant to assumption (2).

The following is the developed model:

MIXED-HUB:

Min $\sum_i \sum_j \sum_k \sum_m W_{ij}[c_{ik}^M + \alpha c_{km}^{CV,RV} + c_{mj}^M]X_{ijkm} + \sum_i \sum_j W_{ij} c_{ij}^M Y_{ij}$ (4.1)

s.t. $\sum_k \sum_m X_{ijkm} + Y_{ij} = 1 \quad \forall i, j \neq i$ (4.2)

$\sum_k h_k = p$ (4.3)

$\sum_m H_{km} \leq h_k(p-1) \quad \forall k \neq m$ (4.4)

$\sum_k H_{km} \leq h_m(p-1) \quad \forall m \neq k$ (4.5)

$X_{ijkm} \leq H_{km} \quad \forall i, j \neq i, k, m \neq k$ (4.6)

$\sum_\mathrm{i} \sum_\mathrm{j} X_{ijkm} \geq 2H_{km} \quad \forall k, m \neq k$ (4.7)

$X_{ijkm}, Y_{ij}, h_k, H_{km} \in \{0,1\}$ (4.8)

Table 4.1: Input variables

Symbol	Definition
W_{ij}	cargo flow volume from node *i* to node *j*
A	discount on the unit cost of flows for travel between hubs as consequence of economies of density
P	total number of hubs to be established
c_{ik}^M	cost of unit flow between nodes *i* and *j* using transport mode *M*, where *M* could be either truck, intermodal truck-RoRo, container vessel *(CV)* or RoRo vessel *(RV)* (when considering the two latter cases only, the cost of unit flow is given by $c_{km}^{CV,RV}$)

Table 4.2: Decision variables

Symbol	Definition
X_{ijkm}	1 if flow from node *i* to *j* goes through hubs *k* and *m*, 0 otherwise
Y_{ij}	1 if flow from node *i* goes directly to *j*, 0 otherwise
h_k	1 if a hub is installed at *k*, 0 otherwise
H_{km}	1 if a hub link (arc) is established between hubs *k* and *m*, 0 otherwise.

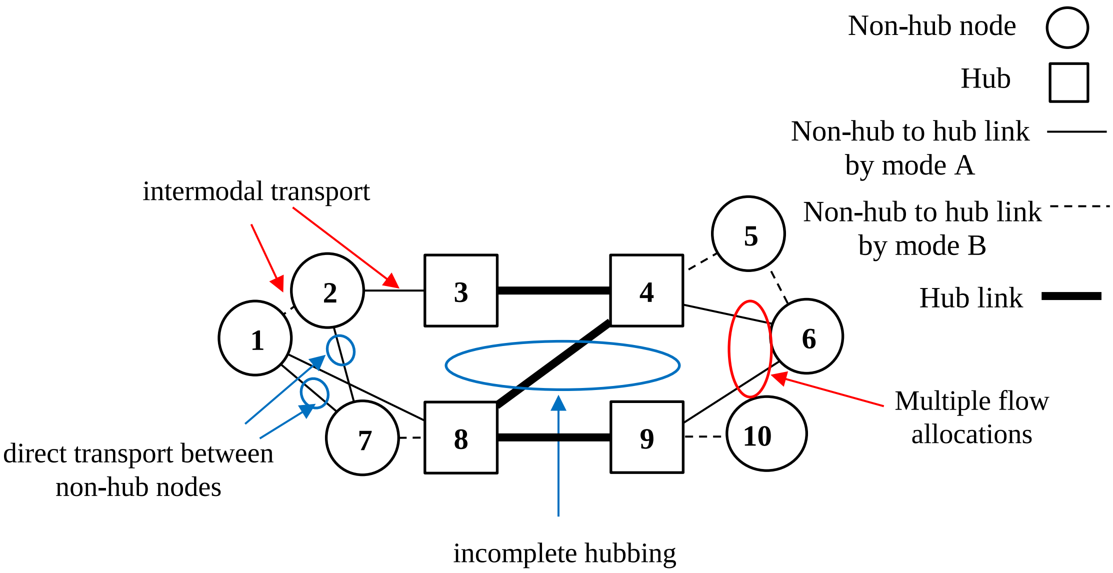


Figure 4.3: Example of the proposed Hub-and-Spoke model

The following decision variables would then have one as their value:

$$h_3 = h_4 = h_7 = h_9 = 1; \; H_{34} = H_{43} = H_{48} = H_{84} = H_{89} = H_{98} = 1$$

$$X_{1434} = X_{1534} = X_{1634} = X_{2434} = X_{2534} = X_{2634} = X_{3434} = X_{3534} = X_{3634} = 1$$

$$X_{4143} = X_{4243} = X_{4343} = X_{5143} = X_{5243} = X_{5343} = X_{6143} = X_{6243} = X_{6343} = 1$$

$$X_{4748} = X_{4848} = X_{5748} = X_{5848} = X_{6748} = X_{6848} = 1$$

$$X_{7844} = X_{7845} = X_{7846} = X_{8844} = X_{8845} = X_{8846} = 1$$

$$X_{1989} = X_{11089} = X_{7689} = X_{7989} = X_{71089} = X_{8989} = X_{81089} = 1$$

$$X_{6198} = X_{6798} = X_{6898} = X_{6198} = X_{9798} = X_{9898} = X_{10198} = X_{10798} = X_{10898} = 1$$

$$Y_{12} = Y_{13} = Y_{17} = Y_{18} = 1 \; ; \; Y_{21} = Y_{23} = Y_{27} = 1 \; ; \; Y_{31} = Y_{32} = 1$$

$$Y_{71} = Y_{72} = Y_{78} = 1 \; ; \; Y_{81} = Y_{87} = 1 \; ; \; Y_{910} = Y_{109} = 1$$

The resulting formulation has n^4+2n^2+n binary variables with n^4+2n^2+2n+1 linear constraints. The objective function (4.1) minimizes the total transportation cost for shipments via hub pairs and direct shipments. Note that hub-to-hub transport is restricted to use only container or RoRo vessels, the modes which are capable of consolidating containers. The superscript notations signify that different modes could be used per transport link, thus *intermodal transport is allowed*. Constraint (4.2) ensures that each pair of demand nodes has to be served either directly or via hubs. This constraint reflects the *non-restrictive networking policy*. Constraint (4.3) limits the number of hubs to p. Because of constraints (4.4) and (4.5), hub link can only be established if both ends of the link are hub nodes. When a node is a hub, the maximum number of possible hub links that can be created with it as a starting (or ending) hub is *p-1*. Constraint (4.6) ensures that a flow can only be routed through a hub link if the hub link is established. This constraint reflects the *general hub (or incomplete hub) network policy*, in that H_{km} could also be 0, meaning a connection between these 2 hubs do not exists. This constraint, in essence, show that *multiple allocation is allowed*. Flows from any *i* to *j*, could be allocated to any *k* and *m* only with the restriction than hub arc *k-m* is established. Constraint (4.7) restricts that every established hub link serves more than one origin-destination flow, or that at least 2 flows go through it. Lastly, constraint (4.8) represents the binary requirement. As earlier mentioned, the model does not require that all hubs are connected, as a consequence of the inequality used in constraints (4.4) and (4.5). Moreover, a more accurate constraint in lieu of (4.7) that would ensure only consolidated flows go through hub arcs is

$$\sum_i \sum_j X_{ijkm} \geq H_{km} V_{km}^{CV,RV}(\alpha) \qquad \forall k, m \neq k, W_{ij} \neq 0 \qquad (4.9)$$

where $V_{km}^{CV,RV}(\alpha)$ is the minimum consolidated cargo volume for hub arc *k-m* and given mode type (*CV* or *RV*) to merit a discount of factor α. However, with the current lack of knowledge of the relationship between discount and consolidated cargo volume, constraint (4.7) is instead employed.

For simplification, the transport cost of a flow from node *i* to *j* via hub pair *k* and *m* is denoted simply as *Fh* in equation (4.10), and the transport cost for direct shipment as *Fd* in equation (4.11).

$$Fh = W_{ij}\left[c_{ik}^{M} + \propto c_{km}^{CV,RV} + c_{mj}^{M}\right] \qquad (4.10)$$

$$Fd = W_{ij} c_{ij}^{M} \qquad (4.11)$$

Since the application of the HS model to the Philippines will generate a problem with large number of constraints, a heuristic with Lagrangian relaxation as a starting point is used for the solution.

The difference between the proposed formulation to the general hub-and-spoke model is particularly evident from constraints (4.2) and (4.6) which reflect the non-restrictive hubbing and incomplete hub network policies, respectively. The former constraint is deemed necessary because of the short sea distance separating the islands, and the latter because of the existence of small trade volume of the small islands, which are both characteristics of the archipelagic Philippines.

4.4 Solution Heuristic Development

The Lagrangian relaxation used in this study tackles the entire problem. A similar approach was undertaken by Pirkul and Schilling (1998). The constraints are selected to be relaxed in such a way that the problem is decomposed into two sub problems, making it easier to solve. Constraints (4.6) and (4.7) are chosen to be relaxed, which results in the following formulation:

MIXED-REL (Z_R):

$$\sum_i \sum_j \sum_k \sum_m \overline{Fh} X_{ijkm} + \sum_i \sum_j FdY_{ij} + \sum_k \sum_m A_{km} H_{km} \tag{4.12}$$

s.t. (4.2) – (4.5), (4.8)

where $\overline{Fh} = Fh + \beta_{ijkm} - \gamma_{km}$ and $A_{km} = 2\gamma_{km} - \sum_i \sum_j \beta_{ijkm}$ and β_{ijkm} and γ_{km} are the Lagrangian multipliers for constraints (4.6) and (4.7), respectively.

The problem now becomes completely separable, into two sub-problems (SUB-1 and SUB-2) without losing solution accuracy.

SUB-1: Min $\sum_i \sum_j \sum_k \sum_m \overline{Fh} X_{ijkm} + \sum_i \sum_j FdY_{ij}$ (4.13)

s.t. (4.2) and (4.8)

and

SUB-2: Min $\sum_k \sum_m A_{km} H_{km}$ (4.14)

s.t. (4.3)-(4.5) and (4.8)

SUB-1 is straightforward to solve, and SUB-2 has O($\underline{n}^2$) variables and can be solved by existing solvers in a reasonable time. Standard subgradient optimization is used to obtain a good, but not necessarily optimal, set of multipliers (β^*, γ^*) or bounds for the relaxed formulation MIXED-REL (Z_R),$Z_R(\beta^*, \gamma^*) = \text{Max}_{\beta,\gamma} Z_R(\beta, \gamma)$.

The heuristic procedure uses the Lagrangian relaxation as starting point and has the iterative procedure shown in Figure 4.4. The step size Δ is used in adjusting the Lagrangian multipliers. *No_improv* is the limit of number of consecutive iterations with no improvement (or increase) in the lower bound; after which the step size ∆ is divided by 2.

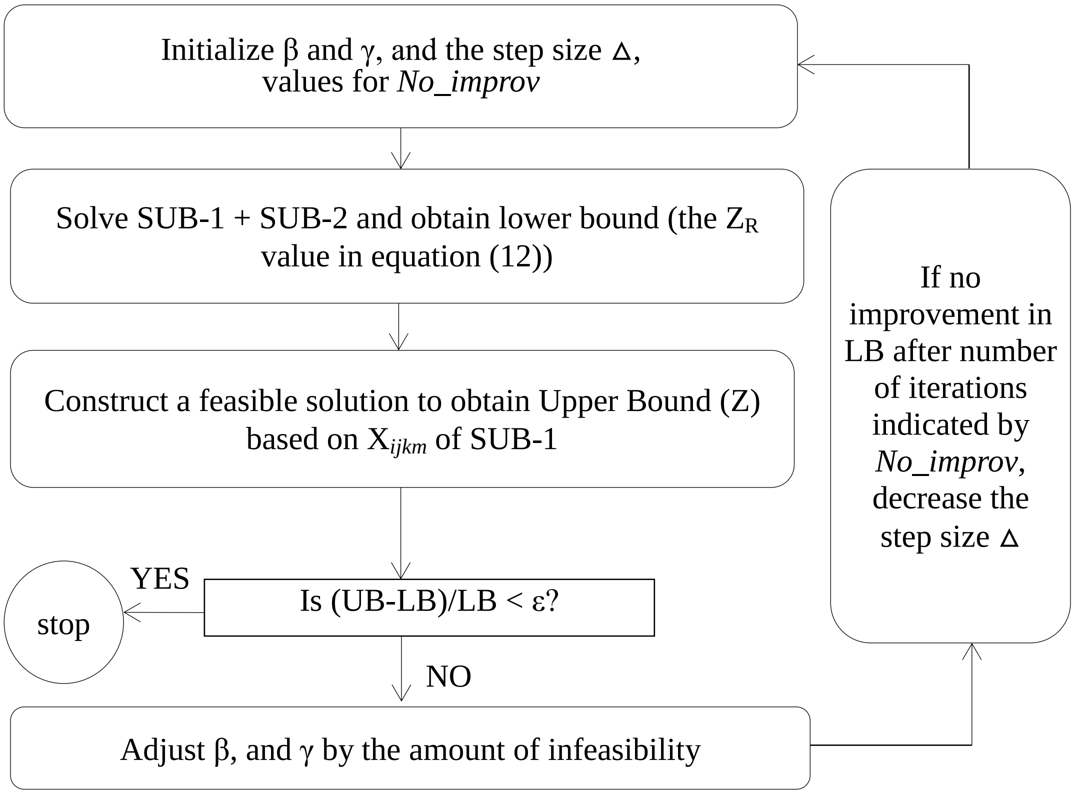


Figure 4.4: Iterative process of the Lagrangian relaxation heuristic

A feasible solution ($\bar{Z}$) is generated in every iteration, and the best feasible solution is retained as the Upper Bound. The approach to produce the feasible solution uses the X*ijkm* obtained from SUB-1. If $\sum_k h_k$, corresponding to all X*ijkm* equal to 1, is greater than p, the elements in set h_k selected to remain as 1 (so $\sum_k \mathrm{h}_k = p$) are those that would give the maximum cost savings when flows in the set {X*ijkm* = 1} are routed via hubs rather than directly, as shown below:

Feasible solution ($\bar{Z}$):

$$\text{Max } \sum_{\mathrm{i}}\sum_{\mathrm{j}} \mathrm{FdY_{ij}} - \sum_{\mathrm{i}}\sum_{\mathrm{j}}\sum_{\mathrm{k}}\sum_{\mathrm{m}} \mathrm{FhX_{ijkm}} \quad \forall i,j,k,m \in \{\mathrm{X_{ijkm}} = 1\} \quad (4.15)$$

s.t. (4.2), (4.3) and (4.8).

If the gap between the Upper Bound and Lower Bound is greater than ε, the Lagrangian multipliers are adjusted as follows:

$$\beta_{\mathrm{ijkm}}^{\mathrm{T+1}} = \beta_{\mathrm{ijkm}}^{\mathrm{T}} + \mathrm{t}^{\mathrm{T}}\left(\mathrm{X}_{\mathrm{ijkm}} - \mathrm{H}_{\mathrm{km}}\right) \qquad \forall\, i, j \neq i, k, m \neq k \tag{4.16}$$

$$\gamma_{\mathrm{km}}^{\mathrm{T+1}} = \gamma_{\mathrm{km}}^{\mathrm{T}} + \mathrm{t}^{\mathrm{T}}\left(2\mathrm{H}_{\mathrm{km}} - \sum_{\mathrm{i}}\sum_{\mathrm{j}}\mathrm{X}_{\mathrm{ijkm}}\right) \qquad \forall\, k, m \neq k \tag{4.17}$$

Where the computed Lagrangian multipliers should be non-negative such that, $\beta_{ijkm}^{T} = \max(0, \beta_{ijkm}^{T})$ and $\gamma_{km}^{T} = \max(0, \gamma_{km}^{T})$, and where,

$$t^{T} = \Delta^{T}\left[\frac{\bar{\mathrm{Z}} - \mathrm{Z}_{\mathrm{L}}^{\mathrm{T}}(\beta^{T}, \gamma^{T})}{\sum_{i}\sum_{j}\sum_{k}\sum_{m}\left(\mathrm{X}_{\mathrm{ijkm}} - \mathrm{H}_{\mathrm{km}}\right)^{2} + \sum_{k}\sum_{m}\left(2\mathrm{H}_{\mathrm{km}} - \sum_{\mathrm{i}}\sum_{\mathrm{j}}\mathrm{X}_{\mathrm{ijkm}}\right)^{2}}\right] \tag{4.18}$$

$\bar{\mathrm{Z}}$ is the best (smallest) feasible solution value, and $\mathrm{Z}_{\mathrm{L}}^{\mathrm{T}}$, the Lagrangian value from the current iteration *t*.

Moreover, the solution quality is evaluated as percent gap between the best feasible solution $\bar{\mathrm{Z}}$, or the Upper Bound, and the best Lagrangian value $\mathrm{Z}_{\mathrm{R}}(\beta^{*}, \gamma^{*})$, or the Lower Bound, calculated as:

$$Gap, \% = \frac{\bar{\mathrm{Z}} - \mathrm{Z}_{\mathrm{R}}(\beta^{*}, \gamma^{*})}{\mathrm{Z}_{\mathrm{R}}(\beta^{*}, \gamma^{*})} \mathrm{x}100. \tag{4.19}$$

4.5 Application to the Philippines

To reiterate, according to the Joint Foreign Chambers of Commerce of the Philippines, to increase the country's competitiveness among neighboring countries, a HS system should be in place, with highly developed ports for larger ships, and with cargoes delivered from smaller production centers by truck or small RoRo (JFC, 2010). This is among the recommended long-term actions to be undertaken by the Philippine Ports Authority (PPA) and Department of Transportation and Communication (DOTC). Moreover, according to Kobune (2008), it is understood that the advantage of RoRo ferry service for short distance transportation is fully utilized when a RoRo route provides a transverse service that complements a national HS network.

However, noting that certain cargoes are better transported directly without going through hubs, especially when the ports are adjacent to each other, the freight network model for the Philippines should give a leeway to allow direct transport between origin-destination demands and not only allocate demands to designated hubs. Thus, the proposed model of a mixed HS and PTP network where hub locations are determined to serve as consolidation and transshipment points of cargoes coming from feeder nodes (these could be sea ports in small islands with few throughputs catered by trucks and RoRo vessels). Then, transport within hubs (two-hub stop) would be by container vessels, or RoRo vessels, which are the modes deemed capable of delivering economies of density, or multiple containers in one shipment.

The University of the Philippines National Center for Transportation Studies conducted a survey of inter-regional freight flows for the whole country. This is the only available source of origin-destination (O-D) traffic data for all water, air and land modes (NCTS, 2004). Cargo volumes were allocated to the 25 ports shown in Figure 4.5. These ports are existing RoRo and/or container vessel ports. Each island was set to have at least two nodes (except for Palawan island in the far left) to capture the possible route when intermodal road-RoRo transport is used. Cebu was selected to have three nodes (Cebu port (12), Toledo port (13) and Argao port (14)) because it is often the intermediate island for east-west and north-south (vice-versa) intermodal transport in the mid-Philippine (Visayas) region.

The available cargo flows volume data, in metric tons, by water mode, for 2004 were projected to 2012, and not to the current year, due to data availability. Table 4.3 shows the total domestic trade data for 2004 and 2012 for rail, air and water, with the water mode being the dominant one. There is no rail trade data for 2012, as PNR Main Line South became non-operational in 2006 (Javier, 2008).

Inbound and outbound throughput data per port from the Philippines Ports Authority (2004, 2012) were used to project cargo volumes transported by water (Figure 4.6). Since road cargo volume data is only available for 2004, obtained through a roadside survey by University of the Philippines National Center for Figure 4.7. Linear extrapolation was used to obtain the vehicle quantities for 2012. Transportation Studies (UP NCTS, 2004), the increase in volumes for 2012 was estimated to be proportional to that of registered trailers and trucks shown in The O-D data is found in Appendix Table A.1. The transport costs per link for container and RoRo vessels, trucks and intermodal truck-RoRo/container modes were calculated from transport tariffs (Figure 4.8) and port fees (Table 4.4). These data were gathered from interviews with freight forwarders in Cebu City, the Cebu Ports Authority and the PPA in Surigao City in September 2013. Data for RoRo transport were obtained from interviews with seven shipping companies (for 61 origin-destinations), and that of container transport were obtained from seven shipping companies (for 20 origin-destinations). The shipping companies are tabulated in Table 4.5. Data for land transport were obtained from Alrey Cargo Forwarding, for 44 origin-destinations.

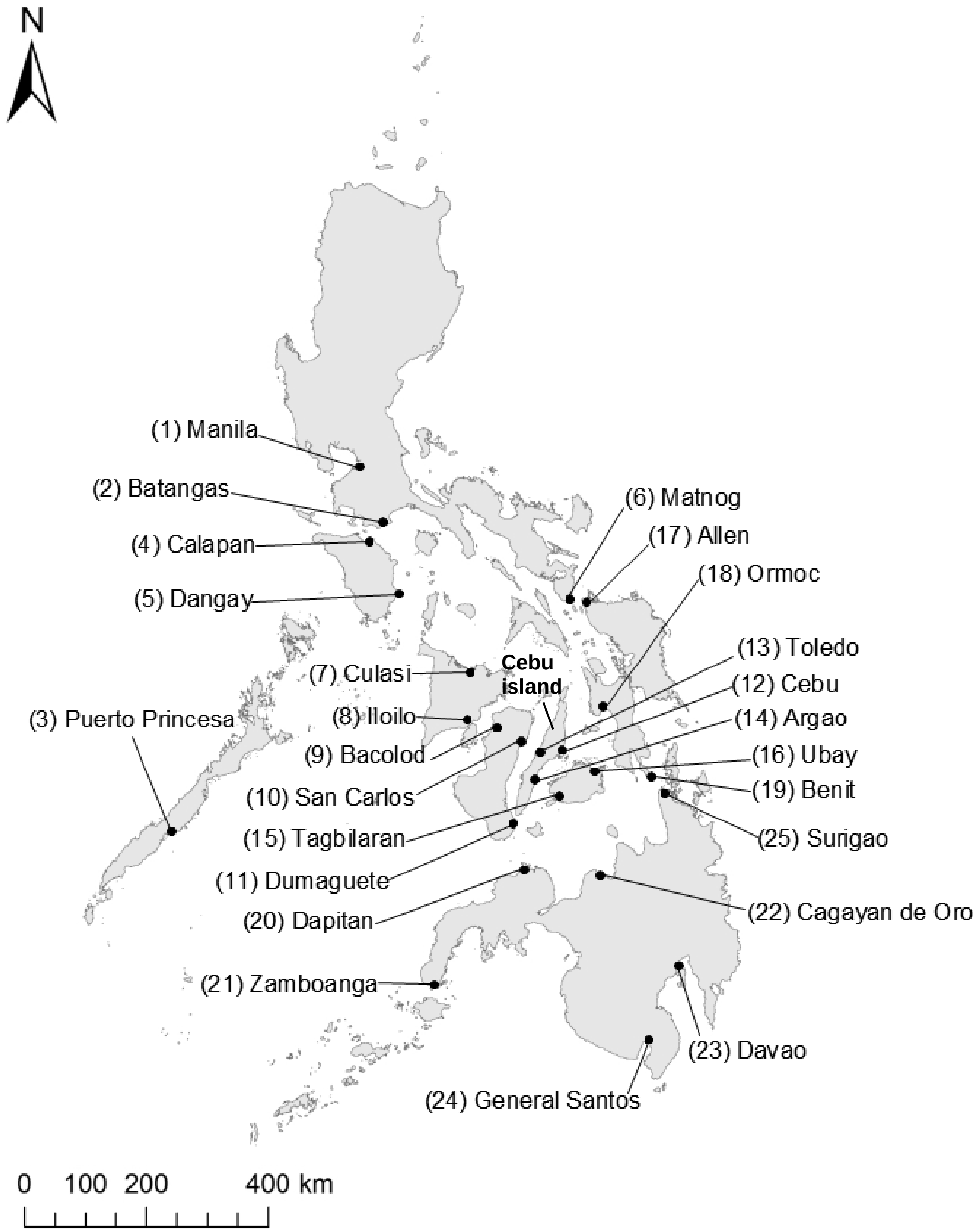


Figure 4.5: Location of 25 port nodes

Table 4.3: Quantity Domestic Trade data in Million Tons

Mode	Year	
	2004	2012
Water	24.57	20.31
Air	0.044621	0.033087
Rail	0.001751	---

Table 4.4: Port fees

Item	Tariff (PhP)*
Terminal Fee	516.00
Document stamp	10.00
Weighing fee	80.00
Arrastre	939.65

*1USD=44.5Php
Source: Field survey (Sept. 2013)

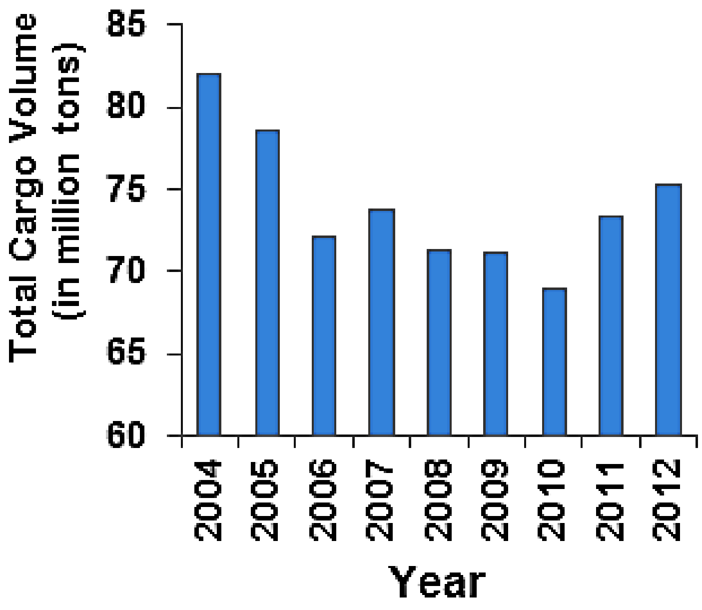


Figure 4.6: Total Domestic Inbound and Outbound Cargo Volumes
Source: Philippine Ports Authority

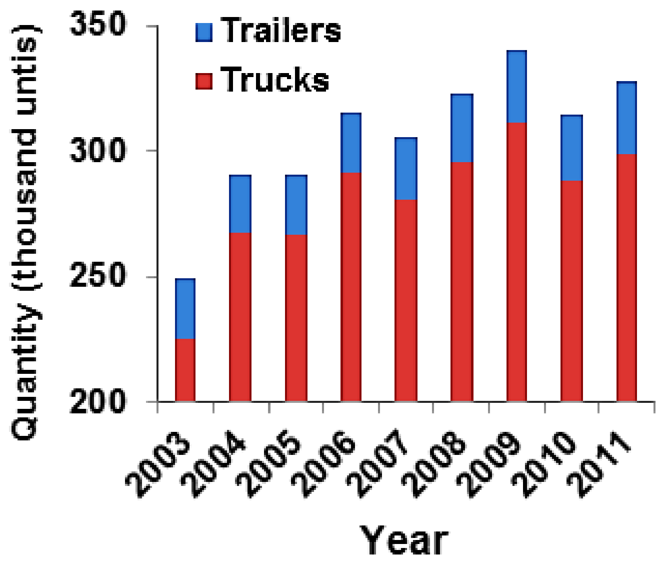


Figure 4.7: Number of Registered Freight Vehicles
Source: Philippine Statistics Authority, National Statistical Coordination Board

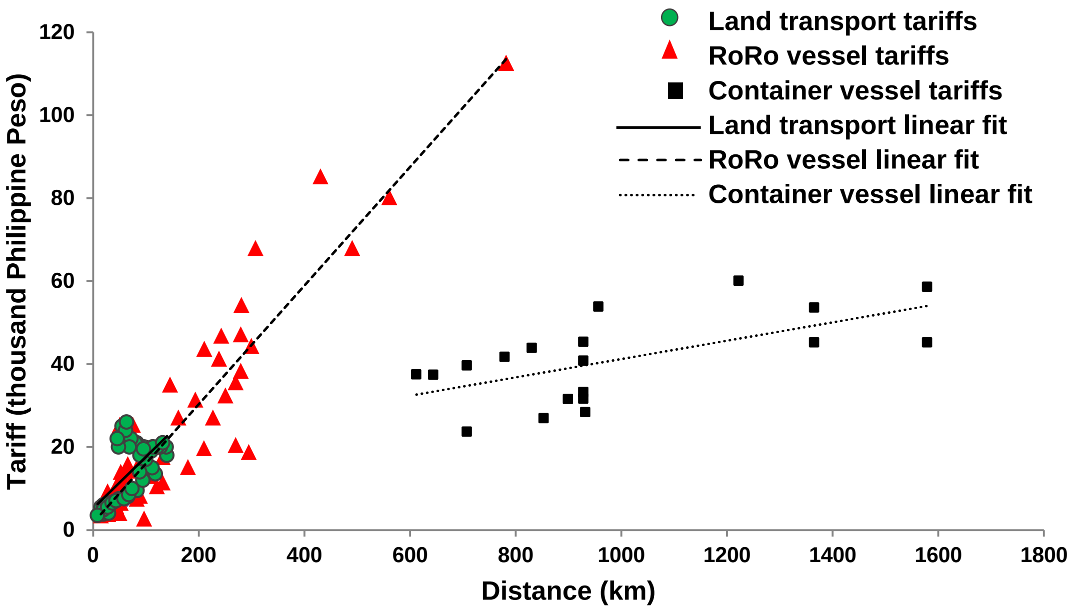


Figure 4.8: Tariff versus distance of the 3 modes of transport, namely land by container or truck, RoRo vessels and container vessels

Source: Field survey (Sept. 2013)

Table 4.5: Shipping Lines interviewed for RoRo and Container vessel tariff data

With RoRo vessels	With Container vessels
Asian Marine Transport Corporation	Aleson Shipping Lines
Lite Shipping	Cokaliong Shipping Lines
Medallion Shipping Lines	Escaño Lines Inc.
Montenegro Shipping Lines	Gothong Southern Shipping
Philharbor Ports And Ferries Services Inc.	Lorenzo Shipping Lines
Rapal Inter-Island Shipping	Solid Shipping Lines Corp.
Super Shuttle Roro	2go Travel

One TEU, the unit capacity of a twenty-foot container, is the basis for the tariffs. Weight carried by other container types and vehicle modes used in the Philippines are converted to 1 TEU based on Table 4.6.

Table 4.6: Common load-carrying capacity in cubic meters of containers and vehicles

Vehicle/ container type	20 foot container (1 TEU)	10 foot container	40 foot container	Wingvan (Isuzu)	Forward (Isuzu)	Canter (Mitsubishi)
Volume (cbm)	33	14	67	45	26	14

Source*:* Field survey (Sept. 2013)

Moreover, terminal handling charges, or "arrastre" as it is called in the Philippines, vary per port. The arrastre fee shown in Table 4.4 is the average of the arrastre fees in 11 ports namely, Manila, Bacolod, Cagayan de oro, Cebu, Cotabato, Davao, Dumaguete, General Santos, Iloilo, Zamboanga and Surigao. Note that road tolls are not considered because the present length of operational tolled expressways in the Philippines is roughly 345 km (Toll Regulatory Board, 2014), which is only around 0.16% of the total road length based on 2009 data from Department of Public Works and Highways (ASEAN-Japan Transport Partnership, 2014).

The transport mode used per link *i*-*k* is determined as the mode that gives the minimum transport cost, precalculated before input to the model as follows:

$$\text{Min } [c_{ik}^{M}, c_{ia}^{M} + l(a,k)] \qquad (4.20)$$

$$\text{s.t. } c_{ik}^{1} = t_{ik}^{1} d_{ik}^{1} \qquad (4.21)$$

$$c_{ik}^{2} = t_{ik}^{2} d_{ik}^{2} + TF + DS + WF \qquad (4.22)$$

$$\mathrm{c}_{\mathrm{ik}}^{3} = \mathrm{t}_{\mathrm{ik}}^{3} \mathrm{d}_{\mathrm{ik}}^{3} + TF + DS + WF + A \qquad (4.23)$$

where the terms used are defined in Table 4.7. Equation (4.20) is the shortest path formula which finds the route with the minimum transport cost between two nodes in the network. The route could consist of links catered by modes M being container truck, RoRo and container vessels, in combination (intermodal) or unimodal, whichever path/route would provide the minimum transport cost between two nodes *i*-*k*. Equations (4.21) to (4.23) are the formulas for transport cost for container truck, RoRo, and container vessel, respectively. As mentioned, RoRo cargo will not pay for terminal handling charges (arrastre) because vehicles are simply rolled-in and out of the vessel, as stated in Section 2 of the Presidential Executive Order 170-B (Basilio, 2008) . Intermodality in the case where both RoRo and containership are used with one cargo shipment could be realized with the use of container on chassis.

Table 4.7: Definitions of symbols used

Symbol	Definition
I	Originating node
K	Ending node
C	Cost in Philippine peso
M	Mode, designated with
	1 for container truck
	2 for RoRo vessel
	3 for container vessel
T	Tariff fee per kilometer per TEU
D	Distance per kilometer
TF	Terminal fee
DS	Documentation stamp fee
WF	Weighing fee
A	Arrastre fee
A	The last node travelled to being a closed state
l(a,k)	Minimum cost among modes in set *M* for the link joining node *a* to *k*

The discount given by shipping companies is subject to the type of client, i.e. special clients with regular shipments or ordinary clients. Thus, three different discount factors (α) are tested in the model, namely, 0.5, 0.7 and 0.9, each uniformly applied to the whole network.

4.6 Results and Discussion

The proposed algorithm was coded in MATLAB and ran using 31 GB memory/node capacity of a supercomputing facility that enables running several problem scenarios simultaneously. Three network sizes are considered, *N*=8, 15, and 25, for 3 types of hub-to-hub discount factors (∝), 0.5, 0.7 and 0.9. The nodes in the subset used for the *N*=8 case are ports (9) to (16), while in the *N*=15 case are ports (1)-(2), (4)-(14) and (17)-(18). The number of hubs per network size is also varied, *p*=2 to 6 for *N*=8 and *p*=2 to 4 for *N*=15 and 25. Larger memory and longer solving times are required for larger networks with more hubs.

The *N*=8 cases are solved using an exact solution branch and bound algorithm to compare the solving time with the Lagrangian heuristic given a 0.001 gap, as calculated in equation (4.19). MATLAB bintprog solver is used for the branch and bound method; however, this is inefficient in solving the problem with larger networks.

Lagrangian multipliers are initially set to 0 and *Max_iter* to 10,000. The step sizes used are 1 for *N*=8, 2 for *N*=15 and 4 for *N*=25; *No_improv* is set to 100.

4.5.1 Location of hubs, total network costs and validity of the heuristic method

The results are shown in Table 4.8. Total network costs are in billions of Philippine Pesos, and exact and heuristic solution algorithm running times are in seconds.

Table 4.8: Results of the mixed network problem

Nodes, N	Pure PTP total network cost (in Trillion Pesos)	Hubs p	Data	Hub discount factor, α		
				0.5	0.7	0.9
8	9,565	2	Mixed network total cost (billion PhP)	7,041,339	8,126,312	9,119,743*
			Saving %	26.39	15.05	4.66
			Exact time (seconds)	0.95	0.98	0.83
			Heur. time (seconds)	5.20	1.84	4.90
			Iterations	118	44	117
			Hub ports	(9),(12)	(9),(12)	(9),(12)
		3	Mixed network cost	6,116,038	7,608,933	8,989,952
			Saving %	36.06	20.45	6.02

			Exact time (seconds)	104.45	276.89	175.42
			Heur. time (seconds)	7.39	4.91	0.72
			Iterations	85	60	15
			Hub ports	(9),(11),(12)	(9), (11), (12)	(9), (11),(12)
		4	Mixed network cost	5,641,793	7,428,911	8,940,934
			Saving %	41.02	22.34	6.53
			Exact time (seconds)	1481.77	2570.23	757.77
			Heur. time (seconds)	14.99	20.67	2.39
			Iterations	118	203	29
			Hub ports	(9), (10), (11), (12)	(9), (10), (11), (12)	(9), (10), (11), (12)
		5	Mixed network cost	5,485,224	7,270,727	8,906,122
			Saving %	42.66	23.99	6.89
			Exact time (seconds)	13831.41	1475.29	781.85
			Heur. time (seconds)	3.06	7.24	6.16
			Iterations	48	105	50
			Hub ports	(9), (10),(11) (12), (13)	(9), (10),(11) (12), (13)	(9), (10),(11) (12),(13)
		6	Mixed network cost	5,351,804	7,156,137	8,892,066*
			Saving %	44.05	25.19	7.04
			Exact time (seconds)	7593.27	1735.64	1156.25
			Heur. time (seconds)	3.06	4.60	5.76
			Iterations	58	93	64
			Hub ports	(9), (10),(11) (12),(13),(14)	(9), (10),(11) (12),(13),(14)	(9), (10),(11) (12),(13),(14)
15	454,657	2	Mixed network cost	365,706,788	404,227,748	437,336,243
			Saving %	19.56	11.09	3.81
			Heur. time (seconds)	5.49	3.22	2.22
			Iterations	50	27	19
			Gap %	0.723	0.005	0.118
			Hub ports	(1),(9)	(1),(9)	(1),(9)
		3	Mixed network cost	333,074,983	391,451,502	437,322,172
			Saving %	26.74	13.90	3.81
			Heur. time (seconds)	102.33	49.76	347.67
			Iterations	216	119	667
			Gap %	0.851	0.612	0.824
			Hub ports	(1),(2),(9)	(1),(2),(9)	(1),(5),(9)
		4	Mixed network cost	307,561,891	381,100,732	433,230,301
			Saving %	32.35	16.18	4.71
			Heur. time (seconds)	875.76	287.17	8778.78
			Iterations	348	187	1012
			Gap %	0.966	0.939	0.926
			Hub ports	(1),(2),(8),(9)	(1),(2),(8),(9)	(1),(8),(9),(12)
25	615,159	2	Mixed network cost	525,053,786	563,162,330	602,892,382
			Saving %	14.65	8.45	1.99
			Heur. time (seconds)	47.20	259.80	1065.81
			Iterations	43	436	1092
			Gap %	0.271	0.951	0.973
			Hub ports	(1),(9)	(1),(9)	(1),(9)
		3	Mixed network cost	496,597,299	552,846,862	597,948,003
			Saving %	19.27	10.13	2.80
			Heur. time (seconds)	387.87	605.11	296.55
			Iterations	152	153	96

		Gap %	0.947	0.659	0.785
		Hub ports	(1),(2),(9)	(1),(9),(23)	(1),(9),(23)
	4	Mixed network cost	466,915,999	541,700,926	597,858,503
		Saving %	24.10	11.94	2.81
		Heur. time (seconds)	26095.06	7601.69	1387.27
		Iterations	440	335	417
		Gap %	0.758	0.976	0.006
		Hub ports	(1),(2),(8),(9)	(1),(2),(8),(9)	(1),(2),(8),(9)

*the solution of the heuristic algorithm is the optimal solution

Pure PTP total network costs is the sum of all direct shipment costs for all cargo flows when the transport mode with the minimum cost is used per link, as calculated in equation (4.24). Mixed network total cost per case results as the solution of equation (4.1). Percentage savings for mixed network compared to a purely PTP network are calculated by equation (4.25). The definition of iterations is illustrated in Figure 4.4. The Lagrangian heuristic gap is calculated in equation (4.19), and the identified hub ports for each case are also shown.

$$\mathrm{Min}\ \sum_i \sum_j \mathrm{W}_{ij} \mathrm{c}_{ij}^{\mathrm{M}} \mathrm{Y}_{ij} \tag{4.24}$$

$$Saving, \% = \frac{\text{PTP total network cost} - \text{Mixed Network Total Cost}}{\text{PTP total network cost}} \mathrm{x}100 \tag{4.25}$$

For N=8 and p=3 to 7, the heuristic algorithm within a 0.001% gap is able to provide the optimum solutions in shorter time durations than the branch and bound algorithm. This proves that the heuristic is valid, in that it is able to come up with the same optimal solution obtained with the exact branch and bound solution method. We, therefore, are able to prove that the Lagrangian relaxation heuristic is able to solve hub-and-spoke model that incorporates at once the properties of intermodality, non-restrictive networking policy, multiple allocations and general hub network topology, which application has not been done before.

The case of N=25, $\propto$=0.5 and p=4 took the longest solving time (26,095.06 seconds or 7.25 hours), which is reasonable for a network size of such complexity. All other scenarios were solved in a reasonable number of iterations.

Within an 1% gap, all mixed networks can provide cost savings compared to purely PTP. However, total network cost savings are less than 10% in all cases where $\propto$=0.9, which may not compensate the possible added costs to the port operators for running a hub. For all network sizes, total network costs decline as the number of hubs increases, and the discount factor decreases. For the N=25 network cases, significant savings of 8.45% and higher are possible when discount factors are either 0.5 or 0.7.

The combination of hubs identified by the heuristic algorithm is not always the same across the different discount factors used in the cases of N=15, p=3 and N=25, p=3. Moreover, the same ports are not always retained as hubs with the increase of the number of hubs. Such is Davao port (23), which is a hub for the cases of N=25, p=3, discount factors of 0.7 and 0.9, but no longer among the hubs for the N=25, p=4 cases. Nevertheless, these hub combinations provide good solutions (total network costs savings) when solved by the heuristic algorithm.

4.5.2 The Resulting Intermodality and Incomplete Hub Network Topology

To examine the mixed network in more detail, the routes taken for N=25, p=4 and α=0.7 are tabulated in Table 4.9 and shown in Figure 4.9. Since there are a total of 471 cargo flows between the 25 ports, Table 4.9 only shows the 48 cargo demands that go through hubs. All other cargo demands are transported directly. The hub ports identified are Manila (1), Batangas (2), Iloilo (8) and Bacolod (9). Eight out of the 48 O-D flows that are routed through hubs use a combination of road and sea vessel intermodal transport, as shaded in Table 4.9. The cargo flow from Toledo (13) to Iloilo (8) uses two sea links and one land leg. This route intermodally connects Cebu Island to Panay Island while traversing the Negros Island, and shows that intermodal transport through chain of islands could be utilized in the HS network. Several other routes with spoke to hub, and vice versa, use RoRo and container vessel in complement to each other. Notice that although ports (1), (2), (8) and (9) are identified as hub ports, there are no hub-to-hub links between ports (1) and (2), (1) and (8), (2) and (8), and (8) and (1). The resulting network therefore has an incomplete network configuration. The hub-to-hub links created are those that could provide good solution (total network cost saving), and a hub is not restricted to be connected to all other hubs (of quantity p-1) if the creation of a hub-to-hub link will not increase the total network cost saving.

Table 4.9: Flows routed through hubs for the case of N=25, p=4 and α=0.7

Origin node, i	1st hub node, k	2nd hub node, m	End node, j	Mode per link: i to k	Mode per link: k to m	Mode per link: m to j
1	1	9	9	---	Container v.	---
1	1	9	16	---	Container v.	Container v.
5	1	9	7	Container v.	Container v.	Container v.
5	1	9	8	Container v.	Container v.	Roro v.
5	1	9	12	Container v.	Container v.	Container v.
6	1	9	10	Container v.	Container v.	Truck/trailer
6	1	9	15	Container v.	Container v.	Container v.
6	1	9	21	Container v.	Container v.	Container v.
6	1	9	22	Container v.	Container v.	Container v.
7	1	9	23	Container v.	Container v.	Container v.
17	1	9	13	Container v.	Container v.	Intermodal transport
18	1	9	9	Container v.	Container v.	---
20	1	9	9	Container v.	Container v.	---
22	1	9	10	Container v.	Container v.	Truck/trailer
23	1	9	10	Container v.	Container v.	Truck/trailer
24	1	9	10	Container v.	Container v.	Truck/trailer
24	1	9	17	Container v.	Container v.	Container v.
2	2	1	1	---	Roro v.	---
3	2	1	1	Roro v.	Roro v.	---
2	2	9	9	---	Container v.	---
2	2	9	10	---	Container v.	Truck/trailer
3	2	9	4	Roro v.	Container v.	Container v.
3	2	9	5	Roro v.	Container v.	Container v.
3	2	9	8	Roro v.	Container v.	Roro v.
14	2	9	9	Container v.	Container v.	---
8	8	2	2	---	Container v.	---
8	8	2	3	---	Container v.	Roro v.
8	8	2	5	---	Container v.	Container v.
8	8	2	6	---	Container v.	Container v.
8	8	2	14	---	Container v.	Container v.
11	8	2	2	Container v.	Container v.	---
23	8	2	3	Container v.	Container v.	Roro v.
24	8	2	2	Container v.	Container v.	---
25	8	2	2	Container v.	Container v.	---
8	8	9	9	---	Roro v.	---
8	8	9	10	---	Roro v.	Truck/trailer
8	8	9	18	---	Roro v.	Container v.
8	8	9	20	---	Roro v.	Container v.
8	8	9	22	---	Roro v.	Container v.
8	8	9	23	---	Roro v.	Container v.
9	9	1	1	---	Container v.	---
15	9	1	1	Container v.	Container v.	---
19	9	1	1	Container v.	Container v.	---
9	9	2	2	---	Container v.	---
9	9	2	3	---	Container v.	Roro v.
9	9	8	8	---	Roro v.	---
13	9	8	8	Intermodal transport	Roro v.	---
20	9	8	8	Container v.	Roro v.	---
Total network cost					PhP 466,915,999	
Total saving compare to purely PTP					PhP 148,242,660	

Moreover, the current model is able to restrict more than one flow going through a hub pair (or a hub pair serving more than one origin-destination flow), given that a hub is defined as a consolidation port. This constraint is overlooked in previous mixed network models.

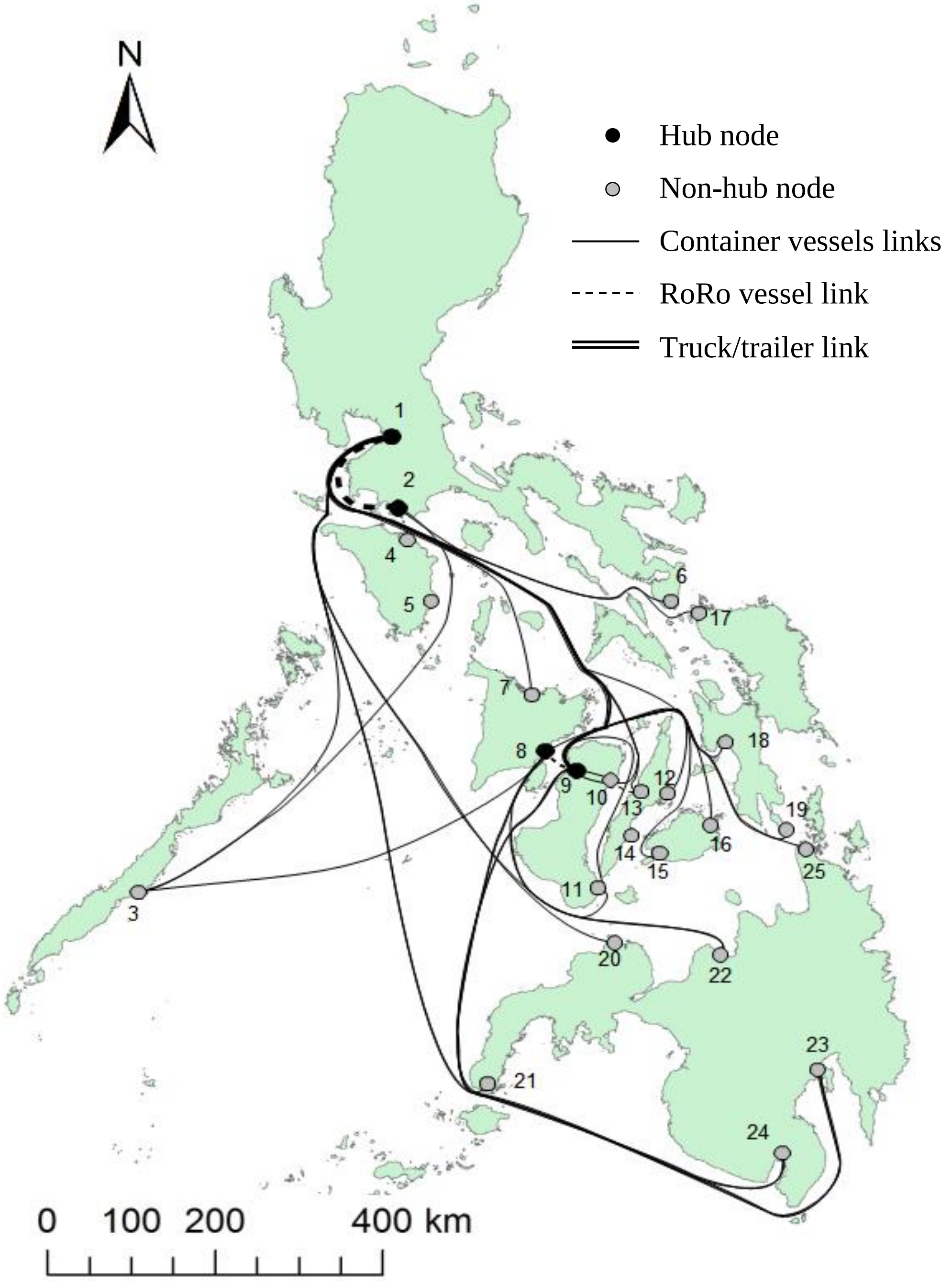


Figure 4.9: Cargo flows that are routed through hubs for the case of N=25, p=4 and α=0.7, direct flows are not included. Weight of the lines is indicative of the relative volume of flow

4.6 Chapter Conclusion

The application of the intermodal mixed network model to an archipelagic setting resulted to considerable cost savings compared when only direct transport is applied. This chapter presented a suitable HS freight network model that integrates intermodal transport across the said modes and which allows non-stop direct services, incorporates multiple flow allocations, non-restrictive networking policy and general hub network topology. These properties have not been tackled at once by other HS network models. We are also able to show that the Lagrangian relaxation heuristic is able to solve a hub-and-spoke network problem that incorporates such properties at once.

Being of such geography, the Philippines necessitates a seamless multimodal system that incorporates the use of road transport, RoRo vessel, and container vessel in complement with each other. The model therefore could be used as a tool for the strategic planning level such as in the Philippines in identifying the ports that need upgrade to cater hub quality, hub capacity, and facilities capable of modal complementarity.

Chapter 5

The Cost Effects of Shifting Cargoes and Port Call from Manila to Batangas Port as Hub

5.1 Introduction

Thus far, we have shown from Chapter 4 that the HS freight network could provide a more cost efficient transport network than the purely point-to-point network. In this chapter, we attempt at using the same concept and properties of the HS freight network model of Chapter 4 in maximizing the number of trucks that could be shifted from Manila port to Batangas port, taking it as one of the hub ports, with the intention of minimizing the presence of trucks in the adjacent congested roads of the Manila ports, and in the Metro Manila in general.

To give a background, the Ports of Manila shown in Figure 5.1 is located very close to the oldest part of the town and Tondo, the most densely populated district of Manila. As can be seen in Volume-Capacity ratio (V/C) of Metro Manila in Figure 5.1, the road section of Roxas Boulevard that is adjacent to the ports is already at or above its capacity the same as most of the roads in the capital. Most roads are operating at saturation level where for the study area of 805 km road length, the average V/C is 1.25 and 62% of the section operates at less than 10kph.

Table 5.1 shows that trucks amount to only 3.80% of the vehicles registered in the Greater Capital Regions (GCR), comprising of the National Capital Region (NCR), and adjacent Central Luzon and Southern Tagalog regions. Nevertheless, from the study of Castro (2003), one of the most popular alternatives in improving operational efficiency of urban streets is to restrict the presence of large trucks, as perceived by the motoring public. Trucks are often viewed as slow moving and occupy a large amount of road space thus hampers the smooth flow of traffic. Given that the ports are located in the densest district of Manila, restricting the port activity would limit the truck traffic in the metropolitan areas close to the ports and thus contribute to the improvement of local traffic (Boquet, 2013).

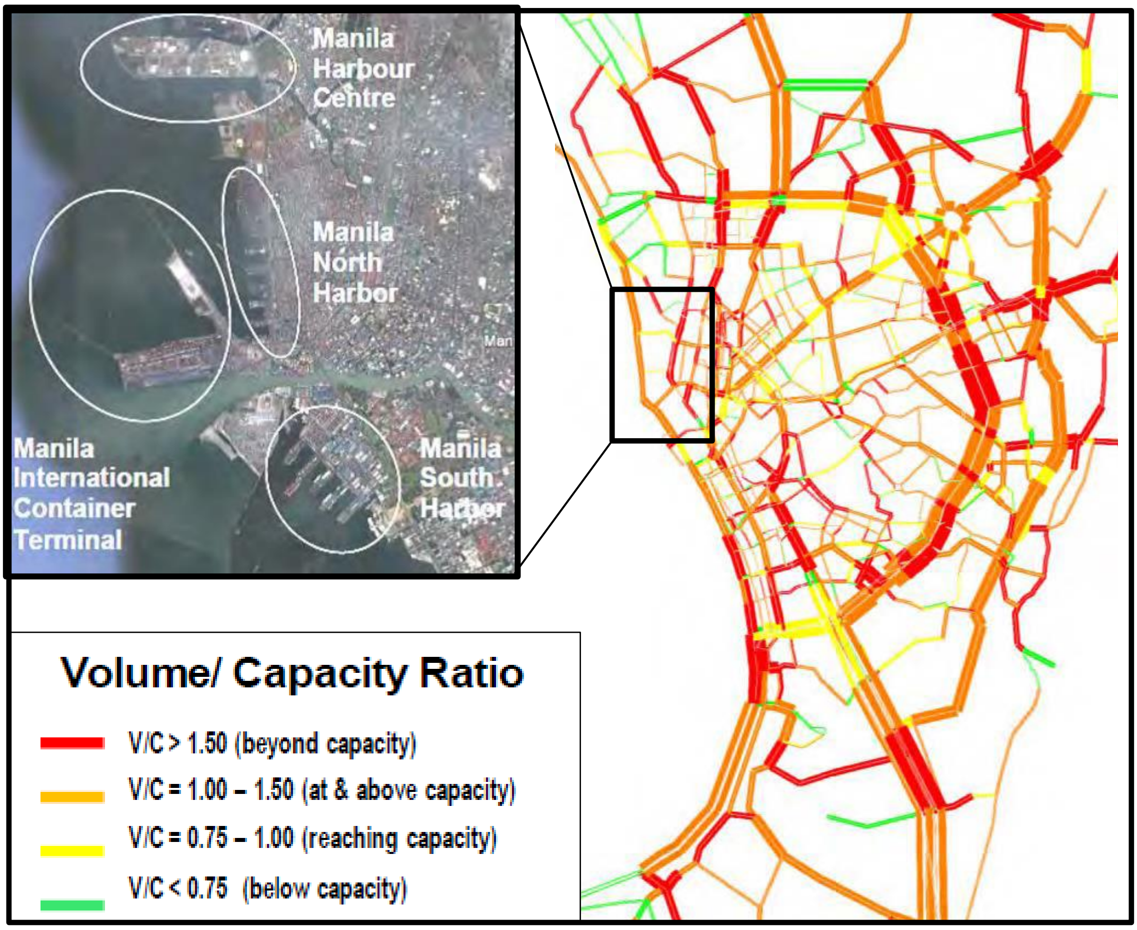


Figure 5.1: Road traffic volume and v/c ratio based on traffic assignment model in 2012, Source: JICA, NEDA (2014)

Since the presence of trucks was often cited as a cause of traffic congestion, truck bans that had been in effect for more than 3 decades, were adopted in the major thoroughfares in Metro Manila by the Metro Manila Development Authority (MMDA). However, the recent truck ban issued by the City of Manila (Ordinance No. 8366) brought congestion problem in the ports and made quite a steer. The ban was Manila's answer to the internal traffic jam of the city. It was implemented from February 24 to September 13, 2014 and restricted eight- wheeler and up whose gross vehicle weight exceeds 4,500 kilograms to enter the City of Manila from 5am to 9pm daily. The severe congestion caused to the port of Manila had a domino effect even up to the national level. The domino effect progressed as follows: delay in the unloading of international vessels increased container inventory resulted to slower yard production and higher dwell time and caused undue strain on

Table 5.1: Number of Registered Vehicles in GCR from 2007 to 2013

Vehicle Type	2007	2008	2009	2010	2011	2012	2013	Vehicle Type to GCR Total for 2013 (%)
Cars	575,925	591,070	593,775	619,970	639,039	652,753	661,661	15.78%
UV	1,019,740	1,004,479	1,015,616	1,051,241	1,063,456	1,060,031	1,065,361	25.41%
SUV	143,255	146,827	160,930	190,648	207,762	227,478	252,612	6.03%
Buses	16,649	16,984	19,960	23,092	23,330	22,402	20,998	0.50%
Trucks	**125,226**	**135,412**	**144,745**	**144,575**	**148,095**	**150,913**	**159,514**	**3.80%**
MC/TC	1,224,365	1,425,905	1,559,836	1,679,571	1,876,486	1,958,798	2,007,585	47.88%
Trailers	15,863	16,781	19,518	19,996	22,490	24,216	24,877	0.59%
Total GCR	3121023	3337458	3514380	3729093	3980658	4,096,591	4,192,608	
Philippines	5,530,052	5,891,272	6,220,433	6,634,855	7,138,942	7,463,393	7,689,898	
GCR % to Phil.	56%	57%	56%	56%	56%	55%	55%	

Note: UV–Utility Vehicle; SUV–Service Utility Vehicle; MC/TC – Motorcycle/Tricycle
Source: Department of Transportation and Communication (DOTC) – Motor Vehicle Registered by District and Type, 2007 - 2013

port resources. Truck turnaround worsened and affected the normal delivery of supplies and aggravated traffic along major roads. The road logistic cycle of supply chains was disrupted especially that in Metro Manila area (Perez, 2015; Mira, 2015). The economic loss to businesses and citizens amounted to P30-billion-a day (Cruz, 2014).

The negative effects of the truck ban are emphasized on international cargoes as it comprises 72% of the cargoes serviced by the Manila Ports as shown in Table 5.2. Nevertheless, to be able to divert a portion of the domestic cargoes, which throughput has continuously increased as shown in Figure 5.2, would contribute in alleviating the road traffic of Metro Manila.

Table 5.2: Foreign and domestic container throughput and capacity of selected ports

Port	Capacity (TEU)	Volume (TEU)				Volume/ Capacity (%)
		Foreign	Share (%)	Domestic	Share (%)	
M.I.C.T.	2,800,000	1,842,183	54.93	35,085	1.62	67.05
Manila - South Harbor	850,000	889,464	26.52	-	-	104.64
Manila – North Harbor	1,500,000	-	-	1,043,705	48.07	69.58
Total for Manila Ports		2,731,647	81.45	1,078,790	49.69	
Subic	600,000	76,652	2.29	-	-	12.78
Batangas	400,000	97,614	2.91	37,428	1.72	33.76
Other ports		448,045	13.36	1,054,945	48.59	

Source: PPA, 2014

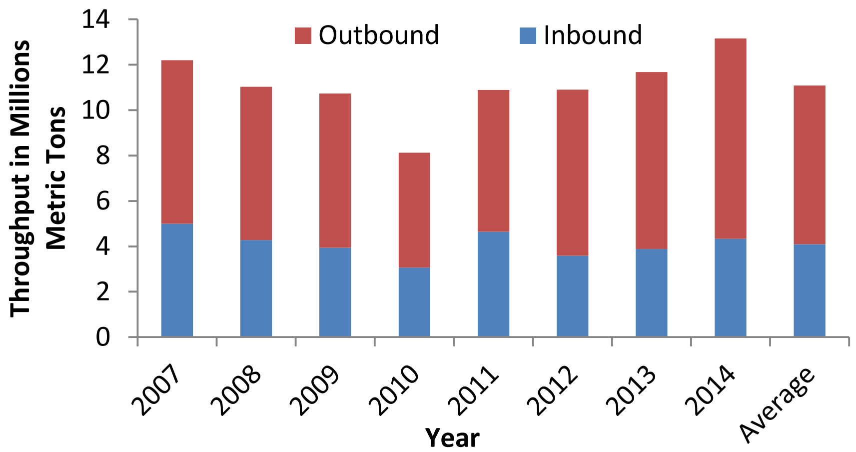


Figure 5.2: Containerized domestic cargo throughput for Manila North Harbor in Metric Tons

Moreover, cited as among the Medium-term Transportation Investment Program studies to be conducted is the feasibility of redeveloping the North Harbor into a mixed-used waterfront property while shifting the cargo movement to Batangas Port that is 100 km south of Manila ports as shown in Figure 5.3 (JICA, NEDA, 2014). Batangas port is accessible from Manila through three expressways: Southern Luzon Express Way (SLEX), Southern Tagalog Arterial Road (STAR) Express Way and the SLEX-STAR Interlink. Domestic shipping is primarily from the south of Manila, thus there would be saving in ship operating cost if they dock at the Batangas port rather in than in the North Harbor. This move would also provide a volume of exportable TEUs that may entice foreign vessels to call at Batangas Port (JICA, NEDA, 2014). This chapter's aim relates with the said program in that we study the shifting of cargo to Batangas Port but also in conjunction with the usage of the HS transport concept.

Figure 5.3: Location of Batangas Port relative to Manila;

Source: JICA, NEDA (2014)

With the country being archipelagic and having scattered small markets, the challenge is in finding a way to build infrastructures that are conducive to efficiently distribute goods using economies of density. The largest percentages of people are scattered and difficult to reach, thus to have access to their needs, these people have to pay more. It has therefore been a recommendation by groups of business companies to develop economies of density by building HS network where cargoes from smaller towns is transported quickly and efficiently to hubs via road or smaller ships (JFC, 2010; The Report, 2012). Hubs will be developed with cranes and equipment for greater efficiency.

The HS network is a viable approach, as also been shown in Chapter 4. While the Manila ports account around 50% share of total domestic container throughput as seen in Table 5.2, it may not be the best choice to be a hub. From the previous premise that container traffic has contributed to the street traffic congestion in Manila Metropolitan area, assigning Manila ports as hub will increase the container throughput and thus the traffic congestion.

This chapter therefore explores the feasibility of a HS network with Batangas port as a designated hub as opposed to the Manila ports. The study will look into the incentive/disincentive of this strategy to (i) shippers and (ii) shipping companies.

For the shipper's perspective, transport using HS could lower transport cost due to the discount in inter-hub transport cost brought by economies of density. However, when cargoes intended for Manila would use Batangas hub port instead, the shipper will incur additional land transport cost. For the shipping company's perspective, calling in Batangas port instead of Manila port would shorten the distance to the source and destination of cargoes (since cargoes inbound and outbound of Metro Manila comes from the south of the capital). Shorter distance and direct transport to other hubs (and not calling in multiple ports since consolidated cargoes of inter-hub transport would then be sufficient to fill the vessel's capacity) would lead to faster turnaround time. This would allow the vessel to have more round voyages than the multi-ports calling case given the same time interval. More round voyages could lead to greater revenues.

The shift of vessel calling from Manila to Batangas port would likely be either prompted or encouraged exogenously such as by a governmental order or policy. This would only be welcomed by the shipping stakeholders (shipper and shipping companies company) if the shift of operations from Manila to Batangas port would not increase their transport costs and lower their profit, respectively.

The succeeding sections attempt to estimate both the effects to shippers' transport costs and carriers' profit of implementing the HS network wherein one of the hubs is Batangas port. Table 5.3 summarizes this strategy's effect to the stakeholders involved. But since the move is not intended to increase the carrier's profit, should they only maintain their profit as to the multi-ports calling case, what would be an increase in their profit would be the tariff discount the carrier would provide to the shipper for using the inter-hub route.

5.2 Selection of Hub Ports

The hub ports for this chapter will be predetermined. From Table 5.3, Batangas port is under-utilized even with the foreign and domestic throughput combined. A study by JICA and National Economic Development Authority (NEDA) (2014) recommends that the foreign cargoes be shifted to the adjacent ports of Batangas and Subic. However, for the purpose of this research, we explore the transport cost feasibility of shifting also the domestic cargoes. Domestic cargoes provide exportable cargoes to international vessels.

From Chapter 4, result of the model designated Bacolod port as hub port. Moreover, Table 5.4 shows that that top 2 destinations of commodities from NCR are Central and Western Visayas, which leads us to select Cebu and Bacolod located. The hub port locations, Batangas, Bacolod and Cebu are shown in Figure 5.4.

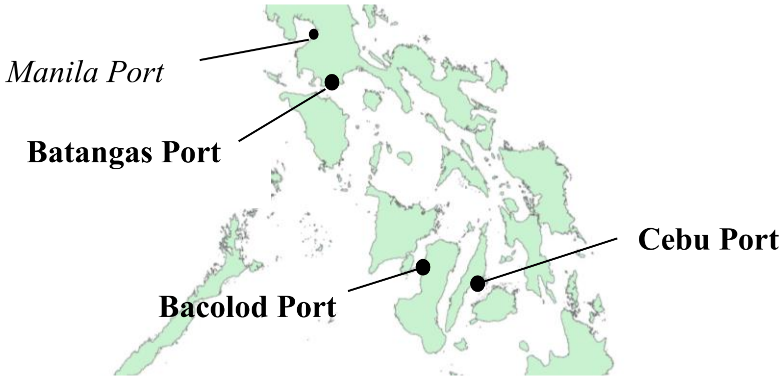


Figure 5.4: Locations of the Selected Hub Ports

Table 5.3: Summary of the possible effects of the strategy to the stakeholder

	Shipper	Carrier
Possible effects of HS network and the use of Batangas port as hub instead of Manila ports to the following stakeholders	Lower transport cost when routing cargoes via hubs due to economies of density. The possible drawback would be the additional land transport cost of cargoes intended for Manila but shifted to Batangas port.	For carriers serving inter-hub route, lowered shipping cost is due to the shorter distance taken with Batangas as hub, as opposed to Manila, since Batangas is nearer to the sources and destinations of cargo demands (which are mostly south of Manila) The vessel serving inter-hub routes would then have sufficient consolidated cargoes to fill its capacity. The vessel would then call directly between hubs and not in multiple ports. The possible drawback would be the saving in shipping cost, when translated to the tariff discount they would give the shippers should they maintain their profit at the same level, would not be enough to attract shippers to use Batangas port.
Method to estimate the possible positive effects	Compare the total network transport cost for HS and PTP with the aid of the maximization problem of equation 5.1.	Estimate the increase in profit due to the decrease in shipping costs. The increase in profit would translate to the discount in tariff the carrier could provide to the shipping line.

Table 5.4: Value of commodities that flow from the National Capital Region in thousand Pesos; Source: National Statistics Office (2012)

REGIONS	Food and Live Animals	Beverages and Tobacco	Crude Materials, Inedible, Except Fuels	Mineral Fuels, Lubricants and Related Materials	Animal and Vegetable Oils, Fats and Waxes	Chemical and Related Products	Manufactured Goods Classified Chiefly by Material	Machinery and Transport Equipment	Other Manufactured Articles	Others
N C R	9,856	0	15051	1408805	0	145671	26636	501	8672	0
C A R	0	0	0	0	0	0	0	0	0	0
Ilocos Region	949	39	18	0	0	278	45	633	1822	100942
Cagayan Valley	0	0	0	0	0	0	0	0	10	0
Central Luzon	3,526	0	0	1160	0	376	12311	5130	848	50
CALABARZON	502	0	0	7639	0	2530	537435	41588	1244	10508
IMAROPA	3,025,328	1,186,931	53371	139683	8549	703311	2323019	1618670	965004	150174
Bicol Region	53,669	8	3021	5707	0	138259	165119	51718	15106	2402
Western Visayas	***10,423,147***	***5,840,884***	***187998***	***263629***	***11410***	***4425659***	***6988376***	***3530693***	***4539424***	***472498***
Central Visayas	***13,396,247***	***3,352,719***	***295166***	***313220***	***10627***	***4154930***	***8543064***	***7250750***	***5190162***	***944627***
Eastern Visayas	1,406,456	1,093,509	14804	171079	1171	483060	926727	456272	370093	139656
Zamboanga Peninsula	2,805,188	1,174,834	41666	109318	6464	681540	1865338	729197	1075383	161102
Northern Mindanao	6,974,786	2,440,128	108797	184228	5105	2681758	5810618	5479111	4022978	408616
Davao Region	4,500,481	1,392,842	43808	146476	4373	1658591	6746452	3356369	2374545	335740
SOCCSKSARGEN	1,954,007	1,18,09	58723	29431	2125	897658	2678646	932081	833104	98657
Caraga	904,984	722,429	13316	4228	1767	740941	1014470	1112625	536991	35917
ARMM	64,256	4,427	188	4	0	3448	3738	12484	54467	238924
Total value	45,523,382	17,248,581	835,927	2,784,607	51,591	16,718,010	37,641,994	24,577,822	19,989,853	3,099,813
Total Quantity in Tons	**5,719,116**	**615,063**	**1,349,961**	**5,488,285**	**236,411**	**1,574,194**	**3,699,195**	**1,382,921**	**793,618**	**709,008**

From the Philippine Ports Authority and Cebu Ports Authority, the shipping companies plying Manila-Cebu and Manila-Bacolod are shown in Table 5.5 and 5.6.

Table 5.5: Shipping companies serving Manila-Cebu (vice-versa) route and their vessel frequencies for the month of August

SHIPPING LINES	VESSEL	NRT	TRIP FREQUENCY both ways (August)
Escaño Lines Inc.	Foxbat	878.65	2
Fortune Sea Carrier Inc.	Fortune Express	295.50	1
	Fortune Harvest	348.00	1
Gothong Southern Shipping Lines, Inc.	Don Alberto Sr.	1,094.00	4
	Don Albino Sr.	1,532.00	4
	Don Alfredo Sr. 2	1,532.00	3
	Don Daniel	1,532.00	4
	Don Carlos Sr. 2	1,532.00	4
	Don Daxton	1,532.00	4
	Don Alfonso Sr.	1,532.00	1
Lorenzo Shipping Lines	Lorcon CDO	300*	3
	Lorcon GenSan	2724.00	3
	Lorcon Visayas	300*	2
	Lorcon Dumaguete	3513.00	2
Oceanic Container Inc.	Ocean Greatness	1,516.00	2
	Ocean Hope	986.00	4
	Ocean Mighty	2,437.00	3
	Ocean Serenity	1,038.00	2
	Ocean Wisdom	1,516.00	3
Philippine Span Asia Carrier Corporation	Princess Of The South	3,452.01	9
	Span Asia 12	1,575.00	2
	Span Asia 16	3,255.41	6
	LCT Brizu	368	1
	LCT Cratus	289	1
	LCT Daichi	289	1
Seaford Shipping Lines	SF Horizon	303.80	1
	SF Mariner	348.00	2
	SF Navigator	401.39	1

*in the absence of NRT data, TEU is provided;
Source: Interview with Cebu Ports Authority, vesselfinder.com, Lorenzo Shipping Lines website, Manila North Harbor Vessel Schedule (http://www.mnhport.com.ph)

Table 5.6: Shipping lines serving Manila-Bacolod (vice-versa) route and their vessel frequencies for the month of August

SHIPPING LINES	VESSEL	NRT	MANILA-BACOLOD / BACOLOD-MANILA TRIP FREQUENCY (AUGUST 2014)	Port of Calls
Aleson Shipping Lines Inc.	MV Aleson Con Carrier 12	1,340	4x / 4x	Manila, Bacolod, Zamboanga
	MV Aleson Con Carrier 14	1,826	4x / -	Manila, Bacolod, Zamboanga
	MV Aleson Con Carrier 15	1,383	- / 4x	Manila, Bacolod, Zamboanga
Lorenzo Shipping Lines	MV Lorcon Iloilo	1988	4x / 4x	Manila, Tagoloan, Iloilo, Bacolod
	MV Lorcon Manila	2196	4x / 4x	Manila, Bacolod, Iloilo
Moreta Shipping Lines Inc.	MV Moreta Cargo 5	2,055	4x / 4x	Manila,Iloilo, Bacolod
	MV Moreta Venture	1,839	3x / 3x	Manila,Bacolod, Iloilo
	MC Hunter	2,982	1x / 1x	Manila,Bacolod, Iloilo
Oceanic Container Lines Inc.	MV Ocean Abundance	3,149	2x / 2x	Manila,Iloilo, Bacolod
	MV Ocean Blessing	2,428	3x / 3x	Manila,Iloilo, Bacolod
	MV Ocean Serenity	1,038	1x / 1x	Manila,Bacolod, Iloilo
Philippine Span Asia Carrier Corp.	MV Span Asia 2	1,733	4x / 4x	Manila,Bacolod, Ozamiz
	MV Span Asia 22	1578	4x / 4x	Manila, Bacolod, Cagayan de Oro
Agro Marine Corp.	Agro Marine 1	137.96	1x / 1x	Manila, Bacolod
	Agro Marine Ii	384.74	2x / 2x	Manila, Bacolod
	Agro Marine 3	99.5	1x / 1x	Manila, Bacolod
Philippine Span Asia Carrier Corp.	LCT Brizu	368	1x / 1x	Manila, Bacolod , CDO, Cebu
	LCT Cratus	289	1x / 1x	Manila, Bacolod, Cebu
	LCT Daichi	289	1x / 1x	Manila, Bacolod, Cebu
	LCT Mazu	289	3x / 3x	Manila, Iloilo, Bacolod
Seaford Shipping Lines	Seaford 9	336	1x / 1x	Manila,Bacolod, Iloilo
	SF Mariner	348	2x / 2x	Manila,Bacolod, Iloilo

Source: Interview with Philippine Ports Authority PMO Pulupandan

Almost all of these vessels have several ports of calls other than Manila, Cebu and Bacolod. For instance, MV Lorcon General Santos and MV Lorcon Manila (Figure 5.5) of the Lorenzo Shipping Lines call at ports Manila-Iloilo-Batangas and Manila-Cebu-Dumaguete-Zamboanga respectively. The Lorenzo Shipping Company vessels ply at speeds of 11 knots to 15 knots (SEC Lorenzo Shipping Company

Annual Report 2013), with the other vessel characteristics for MV Lorcon Manila summarized in Tables 5.7. The execution of the HS network would prompt changes in structure of the existing shipping lines. One is the transfer of port of calls from Manila port to Batangas port. Second is the change from multiple ports calling to just direct calls from two hub ports as it would be given that the consolidated cargoes would increase or maximize the vessels' capacity to just cater the two hub ports, thus the economies of density. Figures 5.6 shows the case of the corresponding direct call.

5.3 Estimation of the Effect to Carrier's Profit

Here we estimate the difference in the shipping company's profit when multi-ports calling is altered to direct calls between hub ports as illustrated in Figures 5.6 to 5.7 for MV Lorenzo Manila, a vessel of Lorenzo Shipping Lines, with properties shown in Table 5.7.

Figure 5.5: Existing multi-port calling route of Lorcon Manila

Figure 5.6: Hypothetical inter-hub direct transport route from Batangas to Bacolod

Table 5.7: Lorenzo Shipping Lines Company Vessel Information

Detail	MV Lorcon Manila
DWT (tons)	5,998.30
GT (tons)	4,328.00
NRT (tons)	2,196.00
Capacity (TEU)	426
Design Service Speed (knots)	15
Average Recorded Speed (knots)	11.6
Engine Type and Power in bhp	*4,843.74bhp
Year Built	1996

*in the absence of searchable data for Lorcon Manila engine power, value is estimated from the regression model found in Cullinane and Khanna (2000) as ln(bhp)=2.6308+0.967ln(TEU) which has r^2 of 0.94.
Sources: http://www.alphaliner.com/

As we attempt to estimate the differences in profit between the two calling cases, which would translate to the tariff discount in inter-hub transport, the formulations are simplified by designating notations. The following notations (Table 5.8) are used to differentiate the route and ports, as well as the cost variables, as will be used in the formulas. Since we only consider one vessel, MV Lorcon Manila, we will not denote any notation for *t* and simply ignore it.

Table 5.8: Notations for routes, ports and vessels and cost variables

Detail	Notation	Detail	Notation
Multi-port calls case	*1*	Vessel Capacity	*Cap*
Inter-hub port calls case	*2*	Variable Cost	*VC*
Manila port	*MNL*	Profit	*P*
Batangas port	*BAT*	Revenue	*Rev*
Bacolod port	*BCD*	Load Factor	*LF*
Iloilo port	*ILO*	Tariff	*T*

The estimation of the difference in profit for the two calling scenarios will be based on Equation (5.1).

$$\Delta P = \Delta Rev - \Delta C_t^{2-1} \quad (5.1)$$

Where from Equation (2.9), total shipping cost based on Cullinane and Khanna (2000) is

$$C_t^m = f\sum_i \left[\delta_{it} + O_t W_i^m + F_{it}^m + D_i \ \left(\frac{O_t}{V_t} + F_t^m\right)\right] + \sum_i \sum_j \left[\left(G_i + \frac{\beta_{it}}{R_i} + \frac{O_t}{R_i}\right)\left(Q_{ij}^m + Q_{ji}^m\right)\right]$$

(2.9)

From Figure 2.9, the daily capital and daily operating costs, or the expenses paid for using the ship each day, O_t, are fixed costs and are the same for the same vessel. So for the same duration or season, O_t would be the same for the same vessel. Thus, the difference in shipping costs for the two scenarios of multi-port calling and inter-hub direct transport for the same season or time duration is only with the variable costs (assuming there are no additional crew expenses).

$$\Delta C_t^{2-1} = VC_t^2 - VC_t^1 \quad (5.2)$$

Where the shipping variable costs are expressed as follows

$$VC_t^m = f\sum_i [\delta_{it} + F_{it}^m + D_t F_t^m] + \sum_i \sum_j \left[\left(G_i + \frac{\beta_{it}}{R_i}\right)\left(Q_{ij}^m + Q_{ji}^m\right)\right] \quad (5.3)$$

Therefore the difference in profit of the two calling cases could be expressed as

$$\Delta P = \Delta Rev - (VC_t^2 - VC_t^1) \quad (5.1a)$$

From Figure 5.7, the cost components considered for the variable costs, Equation (5.3), are the highlighted ones.

5.3.1 MV Lorcon Manila Existing Multi-ports Calling Voyage

The existing route of MV Lorcon Manila is multi-ports calling as can be seen in Figures 5.5. Table 5.9 shows the existing schedule and duration of one round voyage. MV Lorcon Manila can make one round voyage in 7 days.

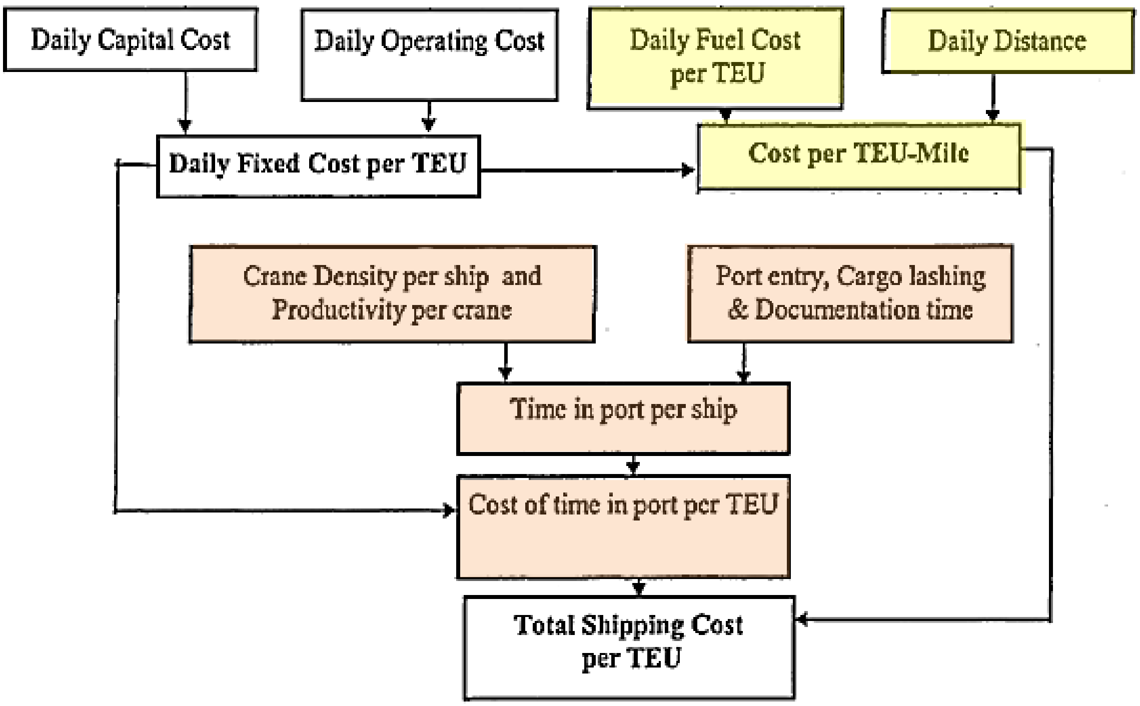


Figure 5.7: Conceptualization of Total Shipping Cost (Cullinane and Khanna, 2000)

Table 5.9: Existing Vessel Route and Schedule
(Source: Lorenzo Shipping Lines website)

PORT	ETD	PORT	ETA
Manila	Mon 19:00H	Bacolod	Wed 01:00H
Bacolod	Thu 04:00H	Iloilo	Thu 10:00H
Iloilo	Fri 04:00H	Manila	Sat 10:00H
Manila	Mon 19:00H		

For the estimation of flow between ports, Q_{ij}^{1}, it could be rational to assume that the vessel is not likely to carry cargoes loaded from Iloilo intended for Bacolod since the distance from the two location is 100km and it is shown from Figure 4.8 that container transport tariff for this distance is cheaper for RoRo vessel than container vessel. Moreover, RoRo transport between Bacolod and Iloilo is frequent at 19 tips per day as can be seen in Chapter 3 Table 3.1. From this, it is assumed that

$$Q^1_{BCD-ILO} = 0. \tag{5.4}$$

Different vessel capacity utilizations will be considered in the estimation where their values will be set the same for the all port-to-port flows of a voyage. Then, the flow between the ports is:

$$Q^1_{MLA-ILO} + Q^1_{MLA-BCD} = Q^1_{ILO-MLA} + Q^1_{BCD-MLA} = LF \cdot Cap \tag{5.5}$$

Moreover, the distances between ports are as follows:

$D_{MLA-BCD} = 330\ nm$; $D_{BCD-ILO} = 54$ nm; $D_{ILO-MLA} = 347$nm

5.3.2 MV Lorcon Manila Hypothetical Direct Inter-Hub Voyage

We try to create a hypothetical schedule for the vessel following the route in Figures 5.7, which shall also be in accordance to the vessels' characteristics (e.g. vessel maximum speed). The estimation of the time of the vessel at port is estimated taking the data from Cebu Daily News (2013) where the average gross productivity in container per hour of vessels (or average gross handling rate, R_i) of 7 shipping lines docking at Cebu ports is 10.18 containers per hour. Note that the distance between Batangas and Bacolod is 251.

From Table 5.10, for the hypothetical inter-hub direct calling case, MV Lorcon Manila could complete one round voyage in 5 days when it is operating at sea at speed of 14 knots. The same as the multi-ports calling case, different capacity utilizations scenarios will be considered, thus the flows will be taken as:

$$Q^2_{BAT-BCD} = Q^2_{BCD-BAT} = LF \cdot Cap \tag{5.6}$$

Table 5.10: Hypothetical Vessel Routes and Schedule for Inter-hub Voyages

PORT	ETD	PORT	ETA
Batangas	Mon 19:00H	Bacolod	Tue 13:00H
Bacolod	Thu 07:00H	Batangas	Fri 01:00H
Batangas	Sun 19:00H		

5.3.3 Estimations of Variable Costs Components for the Two Case Scenarios

From the formula of variable cost in Equation (5.1), the following are the components and their values considering the two vessels and the two calling types.

a. Charge at Port for a Type of Ship for Certain Route, δ_{it}^{m}

From PPA website, vessels engaged in domestic trade that berth or drop anchor at any government port shall be charged a Domestic Dockage Fee (Usage Fee) as shown in Table 5.11. Domestic vessels calling at officially registered private ports shall be charged at one-half (1/2) of the Domestic Dockage Fee at a government port but shall not be less than PhP82.00 nor greater than PhP 413.00.

Table 5.11: Domestic Vessel Dockage Fee in Government Ports

Gross Registered Tonnage (GRT)	Charge in PhP
6 to 100 GRT per calendar day or fraction thereof	82.00
Over 100 GRT per GRT per calendar day or fraction thereof	0.80

From this information, we can formulate the charge at government port for a type of vessel t as $\delta_{it}^{m} = [0.80(GT - 100) + 82]W_{it}^{m}$ where we would know from Table 5.9 the days the vessel spends in the ports for the existing multi-port calling case. (Note that Bacolod port (or BREDCO port) is a private port thus will have half the charge.) From this formula, the calculated values are as follows:

Table 5.12: Calculated charge at port for MV Lorcon Manila

Detail	Charge at Port (PhP)	Detail	Charge at Port (PhP)
δ_{MLA}^{1}	8,227.95	δ_{ILO}^{1}	2,598.30
δ_{BCD}^{1}	1,948.73	δ_{BAT}^{2}, δ_{BCD}^{2}	6,062.70

b. Fuel Cost at Port i by a Ship of Type t on Route m, F_{it}^{m}

Fuel cost at port is the product of the metric ton fuel consumed in port per hour, time at port and the cost of fuel per ton,

$$F_{it}^{m} = F_w \cdot (W_i^m \cdot 24) \cdot F_c^b \quad (5.7)$$

Where from the report of Clean North Sea Shipping (2014, March), the approximation of total hourly fuel consumption of container ships in metric ton per hour as a function of ship volume is $F_w = 0.000041(GT)^{0.83}$. Moreover, from shipadbunker.com, Marine Gas Oil (MGO) which is used by vessel at berth is priced at 550usd/metric ton or, taking 1 usd = 47.89 PhP, fuel cost for MGO per metric ton, F_c^{MGO}, is PhP26,213.85. Thus the calculated costs are:

Table 5.13: Calculated fuel cost at port *i* by the MC Lorcon Manila

Detail	Cost (PhP)	Detail	Cost (PhP)
F_{MLA}^1	63,871.62	F_{ILO}^1	20,169.99
F_{BCD}^1	30,254.98	F_{BAT}^2, F_{BCD}^2	47,063.30

c. *Fuel cost at sea per nautical mile for a ship of type t on route m,* F_t^m *(PhP per nautical mile)*

Fuel cost at sea (F_t) can be calculated from fuel oil consumption per hour *(FO)* in metric tons which can be ascertained from the installed engine power in bhp and the specific fuel oil consumption (SFOC) (Cullinane and Khanna, 2000) through the formula:

$$F_{t(designed)}^m = \frac{FO}{V_t^m(designed)} \cdot f_c^{IFO} \qquad (5.8)$$

The paper moreover presented that SFOC information could be derived from the Institute of Marine Engineers (1994) and The Motor Ship (1995 and 1996) to be on average equal to 125 gms/bhphr.

$$FO = {Installed\ bhp\ [\ SFOC]\ [Utilisation\ (80\%)]}/{1{,}000{,}000} \qquad (5.9)$$

From shipadbunker.com, Intermediate Fuel Gas Oil 180 (IFO180) used by vessel at sea is priced at 280usd/metric ton, or taking 1usd=47.89PhP, fuel cost for MGO per metric ton is $f_c^{IFO180} = \frac{PhP13{,}407.66}{m.t.}$. Therefore, $F_{t(AVE)}$ values are:

$$F_{t(designed)}^m == \frac{0.4843\ \text{m.t.}/\text{hr}}{15\ \text{n.m.}/\text{hr}} \cdot \frac{\text{PhP13,407.66}}{\text{m.t.}} = \text{PhP }432.89/\text{n.m.}$$

Operations of vessel at lower than the designed speed results in fuel savings because of the reduced water resistance. From Stopford (2003), actual fuel consumption will be calculated based on 'cube rule'.

$$F_t^m = F_{t(\text{designed})}^m \left(\frac{V_{(\text{actual})}^m}{V_{(\text{designed})}^m}\right)^a \tag{5.10}$$

where a is about 3 for diesel engines. Thus,

$$F^1 = \text{PhP } 432.89/_{\text{n. m.}} \left(\frac{11.6}{15}\right)^3 = \text{PhP } 200.21/_{\text{n. m.}}$$

$$F^2 = \text{PhP } 432.89/_{\text{n. m.}} \left(\frac{14}{15}\right)^3 = \text{PhP } 351.96/_{\text{n. m.}}$$

d. *Average Handling Rate in Port, G_i, Variable Portion of Port Charge β_{it}, and Average Gross Handling Rate, R_i*

Here, the average handling rate in port (G_i) is what we would refer as the wharfage fee or the charge that the owner of the port charges for the movement of cargo through the facility. While the port charge per average gross handling rate ($\frac{\beta_{it}}{R_i}$) would be the stevedoring fee. These are the only known fees incurred in the port for the cargoes from the PPA website, which the PPA regulates. In Table 5.14 are the charges on cargoes for all ports. The cargo charges are independent of the handling rate.

Table 5.14: Wharfage and Stevedoring Charges for 1 TEU Container (Source, PPA website)

	Charge in PhP
Wharfage fee	126.00
Stevedoring fee	301.00

$$G_i = PhP\ 126.00/TEU\ ; \quad \frac{\beta_{it}}{R_i} = PhP\ 301.00/TEU$$

5.3.4 Estimation of the Difference in Profit as Indicator of Inter-hub Tariff Discount

The difference in profit can be calculated from Equation (5.1a) from variable costs and revenues.

a. Variable Costs

These are estimated from Equation (5.3) with the components of the formula already calculated in the preceding Section 5.2.3. Considering one round voyage, we arrived at the following formulation based on load factor. The full process in arriving at these formulations could be found in the Appendix B.

Table 5.15: Variable costs of vessel and calling types as function of load factor

Detail	Formulation for 1 round voyage based on Load Factor
VC^1	$PhP\ 273{,}425.08 + PhP\ 620{,}256 \cdot LF^1$
VC^2	$PhP\ 282{,}935.92 + PhP\ 620{,}256 \cdot LF^2$

b. Tariff

Tariff in thousand PhP for 1 TEU container can be estimated from the linear fit of container vessel case of Figure 4.8, which is

$$Y = 22.122\,X + 19{,}119 \qquad (5.11)$$

where X is kilometer travelled by the container vessel. Moreover, we have stated in Sections 5.2.1 and 5.2.2 the distances between ports. Thus, in Table 5.16 are the calculated tariff for 1 TEU container transport between the ports.

Table 5.16: Tariff for 1 TEU container for transport between ports

Detail	Tariff (PhP/TEU)
$T_{(MLA-ILO)}$; $T_{(ILO-MLA)}$	32,633.542
$T_{(MLA-BCD)}$; $T_{(BCD-MLA)}$	33,341.446
$T_{(BAT-BCD)}$; $T_{(BCD-BAT)}$	29,403.73

c. Percent Difference in Profits as Percent Tariff Discount in Inter-hub Flow

From Section 5.2.1 and 5.2.1, it has been established that MV Lorcon Manila could complete one round voyage for the multi-ports calling and the inter-hub direct calling cases in 7 and 5 days, respectively. If considering one season to be 35 days, using Equation (5.1a) and the preceding information, the difference in profit for the two calling scenarios can be estimated from the following formulas:

$$\Delta P = \Delta Rev - (VC_t^2 - VC_t^1) \tag{5.1a}$$

While the percent difference of profit compared to the original (existing) multi-ports calling case is:
Calculating, we will have:

$$\Delta P^{2-1} = \begin{bmatrix} 7\left\{(2)\left(\dfrac{\text{PhP}29{,}403.73}{\text{TEU}}\right)(426\text{TEU})\left(LF^2\right)\right\} \\ -5\left\{(2)\left(\dfrac{\text{PhP}32{,}633.542 + \text{PhP}33{,}341.446}{\text{TEU}}\right)(426\text{TEU})\left(LF^1\right)\right\}\end{bmatrix}$$
$$- [7\{\text{PhP } 282{,}935.92 + \text{PhP } 620{,}256(LF^2)\}$$
$$- 5\{\text{PhP } 282{,}935.92 + \text{PhP } 620{,}256(LF^1)\}]$$
$$\Delta P^{2-1} = \text{PhP}171{,}022{,}053.7LF^2 - \text{PhP}137{,}425{,}444.4LF^1 - \text{PhP}613{,}426.04$$

As mentioned earlier in the introduction of this chapter, the shift in port of call from Manila to Batangas by shipping company is not intended to maximize their profit but to comply with a regulation or policy imposed by the government. Thus, if the profit level will be maintained, the would be increase in profit as a consequence of increased revenue and decrease in total shipping costs shall be the tariff discount the carrier would give to the shipper for using the inter-hub link. Mathematically, the rationale is as follows:

$$\Delta P = \Delta Rev - \Delta VC \tag{5.1a}$$

$$\Delta P = \left[\left(T^2 f \textstyle\sum_i \sum_j Q_{ij}^2\right) - Rev^1\right] - \Delta VC \tag{5.12}$$

If ΔP is set to zero, but is instead used to decrease T^2, the new tariff for the direct inter-hub calls case is expressed as shown:

$$T^2 - \overline{T^2} = \frac{\Delta P}{f \sum_i \sum_j Q_{ij}^2} \tag{5.13}$$

Thus, the tariff discount in percent is

$$\%T\ discount = 100\left(\frac{T^2 - \overline{\overline{T^2}}}{T^2}\right) \tag{5.14}$$

For the scenario considered,

$$\%T\ discount = 100\ x\ \frac{\dfrac{\begin{array}{c}\text{PhP}171{,}022{,}053.7LF^2\\ -\text{PhP}137{,}425{,}444.4LF^1\\ -\text{PhP}613{,}426.04\end{array}}{7(2)(426\text{TEU})\left(LF^2\right)}}{\dfrac{\text{PhP}29{,}403.73}{\text{TEU}}}$$

$$= \frac{\begin{array}{c}\text{PhP } 171{,}022{,}053.7LF^2 - \text{PhP}137{,}425{,}444.4LF^1\\ -\text{PhP}613{,}426.04\end{array}}{\text{PhP } 1{,}753{,}638.457LF^2}$$

A JICA and MARINA (2005) study shows that a sample container vessel with 5,589GT plying Manila-Cebu-Iloilo-Bacolod-Manila has an annual container load factor of only 13.9% in 2003. This is very low compared to the common load factor of 70% for vehicles. Figure 5.8 shows the graph of %tariff discount with varying load factors of vessels in the two calling cases.

Load factors of 0.1 to 1.0 are provided for the multi-ports calling case. Considering 0.2 and 0.4 load factor for multi-ports and inter-hub direct calling cases, respectively, more than 60% tariff discount could be provided to the shipper. The case of inter-hub direct calling is assumed to have higher load factor since consolidation is expected with inter-hub transport. Even if we consider the common load factor of 0.7 for the multi-ports calling case and 0.8 for the inter-hub direct calling case, the tariff discount is at approximately 30%.

Therefore, we can consider different discount factors, α, in the HS model since, from what we have shown, the existing load factor is very low. The effect of consolidation and increase in load factor could facilitate tariff discount of even as high as 60%. This justifies the use of α=0.5, 0.7 and 0.9 in the Chapter 4.

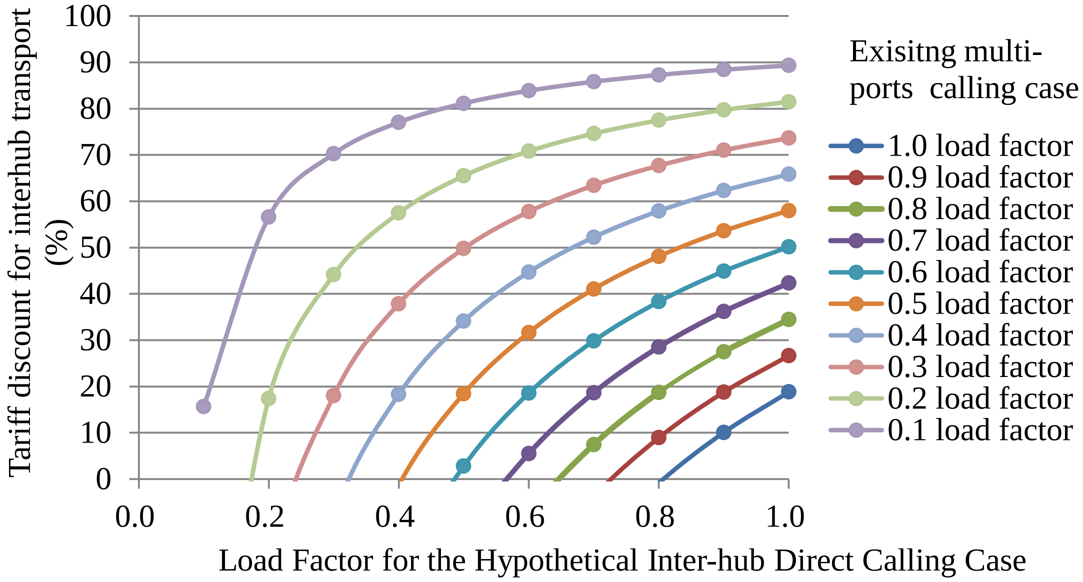


Figure 5.8: Percent tariff discount for inter-hub transport

For the succeeding section, we consider αvalues of 0.6, 0.7, 0.8 and 0.9.

5.4 Transport Costs Savings for Shippers

5.4.1 Model Formulation

The model in this chapter is based on that of Chapter 4 and incorporates the same properties of intermodality, multiple allocations of flows, non-restrictive networking policy and general hub network topology. The decision maker is a freight forwarder who aims to minimize the total transport cost for the network it covers.

In this model, the volume of cargoes intended for Manila ports but shifted to the Batangas port, which is a predetermined hub, is maximized as the objective function. Concurrently, the route taken (whether via hubs or directly), modes, allocation to hubs and the total transport cost savings are determined. In Tables 5.17 and 5.18 are the input and decision variables used in the model, respectively.

Table 5.17: Input variables

Symbol	Definition
W_{ij}	cargo flow volume from node *i* to node *j*. In this study, the origin-destination data considered is the total national domestic cargo data for the year 2012 as shown in Table 5.10
α	discount on the unit cost of flows for travel between hubs as consequence of economies of density
c_{ij}^{M}	Total transport cost of TEU unit between nodes *i* and *j* using transport mode *M*, where *M* could be either truck, intermodal truck-RoRo, container vessel *(CV)* or RoRo vessel *(RV)* (when considering the two latter cases only, cost of unit flow is given the symbol $c_{ij}^{CV,RV}$)
F	Increase in volume to be satisfied in the link for it to be a hub arc

Table 5.18: Decision variables

Symbol	Definition
X_{ijK}	1 if flow from node *i* to *j* goes through hub arc K, 0 otherwise
Y_{ij}	1 if flow from node *i* goes directly to *j*, 0 otherwise
H_K	1 if a transport arc K is utilized as hub arc, 0 otherwise

Transport costs per link for container vessel and, RoRo vessels, trucks and intermodal truck-RoRo/container modes were calculated from port fees and transport tariffs as can be found in Table 4.4 and Figure 4.8 of Chapter 4. The transport mode used per link i-k is determined as the mode that gives the minimum transport cost, which is precalculated before input to the model as shown in Equations 4.20 to 4.23 of Chapter 4 with the definition of the symbols in Table 4.7. The discount factor (α) represents the economies of density brought by cargo consolidation in inter-hub connections, and is fixed at values 0.9, 0.7 and 0.5. "Economies of density" is defined as the falling of average cost attributed to the increase of utilization of vehicle fleet (in this case container vessel) for a particular route (Jansson and Shneerson, 1985).

$$\text{Max} \;\; \sum_{i=2}\sum_{j=2} W_{ij}X_{ijK} \qquad \forall\, K \qquad (5.15)$$

$$\text{s.t.} \;\; \sum_{K} X_{ijK} + Y_{ij} = 1 \qquad \forall i, j \neq i, K \qquad (5.16)$$

$$X_{ijK} \leq H_K \qquad \forall i, j \neq i, K \qquad (5.17)$$

$$\sum_i \sum_j W_{ij} X_{ijK} \geq F(W_K) H_K \qquad \forall i, j \neq i,\ K \qquad (5.18)$$

$$\sum_i \sum_j \left[\left(c^M_{iK_1} + \alpha c^{CV,RV}_K + c^M_{K_2 j} \right) - c^M_{ij} \right] W_{ij} X_{ijK} < 0 \quad \forall i, j \neq i,\ K \qquad (5.19)$$

$$X_{ijK}, Y_{ij}, H_K \in \{0,1\} \qquad (5.20)$$

The objective function (5.15) maximizes the volume to be shifted from Manila harbour to Batangas port. These include both incoming and outgoing cargoes. Constraint (5.16) regulates that each pair of demand nodes has to be either transported directly or via hubs. Constraint (5.17) ensures that a flow can only be routed through a hub arc if the arc or link is established as a hub arc. Constraint (5.18) restricts that there is an increase of volume for the route serviced by the hub arc by a factor *F*. Constraint (5.19) ensures that the sum of transport costs when HS network is used is less than when cargoes are simply transported directly. Lastly, constraint (5.20) represents the binary requirement.

The problem is coded in MATLab and run using its solver *intlinprog* for linear integer programming. It is the limitation of this study that the actual discount benefit due to density economies is not calculated as part of the research, since shipping companies do not divulge their financial information such as operating, capital, bunker cost, etc. The discount factor αis varied at values 0.9, 0.8, 0.7 and 0.6. The consolidated volume is designated by the increase in the hub link volume by a factor of "*F*".

5.4.2 Results

a. Consolidated Volumes and Transport Costs Savings

The hub arcs *K* considered are (1) Batangas-Bacolod, (2) Batangas-Cebu, (3) Bacolod-Batangas, and (4) Cebu-Batangas. Since transport cost discounts for hub-to-hub transport is brought by economies of density, we restrict that the increase in consolidated volumes in hub-to-hub links be at least 30%, thus we examine the cases of "F" equal to 30%, 50%, 100% and 150% increases in hub link volumes. Table 5.19 shows what would be the shifted volume intended for Manila to Batangas ports that satisfy our objective function in equations in 5.1 to 5.6. These are for the cases of discount factors 0.9, 0.8, 0.7 and 0.6 with the said increase in consolidated volumes.

Table 5.19: Shifted Cargo Volume Intended for Manila Ports (Metric Ton)

Discount Factor (α)	Increase in Link Volume, *F*			
	30%	**50%**	**100%**	**150%**
0.9	101,190	-	-	-
0.8	215,985	152,451	76,185	-
0.7	2,076,362	2,060,821	2,039,088	1,960,000
0.6	205,863	4,193,992	4,193,992	1,960,000

From Figure 5.2, the average total containerized volume domestic throughput is 12,206,481 metric tons. Discount factors for hub-to-hub transport costs of 0.9 and 0.8 would not yield substantial shift in cargo volume, while discount factors 0.7 and 0.6 for F=100% case could yield shifts of 17% and 34% of Manila port cargoes, respectively.

The objective function represented in equations 5.1 to 5.6 maximizes the volume of cargoes intended for Manila port given that a HS system is in place which hub arcs are Batangas-Bacolod, Batangas-Cebu and vice-versa, and which total transport cost for the resulting network provides costs saving relative to when purely PTP network is used. The transport costs saving are ensured by equation 5.5, but are not determinate as of how much.

The optimal volume of cargo flows routed through hubs given at least 100% increase in link volume and 0.7 transport cost discount factor for hub-to-hub transport is shown in Table 5.20.

Only the Batangas-Cebu link satisfies the constraint that to be a hub arc given, there shall be 100% increase in link volume. Thus, the results show nine flows intended for Manila as origin are routed through the Batangas-Cebu hub link. The negative values in parenthesis in column 8 entails that more is paid to transport 1 TEU of these cargoes through this route. These cargo flows are included in the results because even when the per TEU transport cost via hubs is more expensive than direct transport, the total transport cost when the consolidated volumes and discount factor are considered, there is transport cost saving of 0.18%.

Table 5.20: Case 0.7 discount factor in hub-to-hub transport (F=100%)

Cargo Flow	Ports			Volume (Metric Tons)	Flow Cost of Direct Transport[1] (PhP)	Flow Cost of Transport via Hubs[2] (PhP)	Transport Cost Saving due to Discount Factor (PhP/TEU)
	i	***K***	***j***				
1	Batangas	Batangas-Cebu	Cebu	676,212	1,258,355,812	880,849,068	10,049
2	Batangas	Batangas-Cebu	Toledo	98,973	193,301,162	176,459,889	3,063
3	Calapan	Batangas-Cebu	Cebu	665	1,200,234	1,192,173	218
4	Manila	Batangas-Cebu	Cebu	1,960,000	4,042,395,689	4,355,245,304	(-2,873)
5	*Manila*	*Batangas-Cebu*	*Ubay*	*76,185*	160,218,185	226,773,855	*(-15,725)*
6	*Manila*	*Batangas-Cebu*	*Benit*	*103*	*224,034*	*370,079*	*(-25,485)*
7	*Manila*	*Batangas-Cebu*	*Allen*	*144*	*266,670*	*530,595*	*(-33,024)*
8	*Manila*	*Batangas-Cebu*	*Dangay*	*2,655*	*4,061,348*	*10,408,878*	*(-43,037)*
9	*Manila*	*Batangas-Cebu*	*Calapan*	*2,260*	*3,132,406*	*9,101,921*	*(-47,537)*
							Total Cost Saving via Hubs (PhP)
Considering Cargo Flows 1 to 9				2,817,198	5,663,155,540	5,660,931,762	2,223,778 (0.18%)
Considering Cargo Flows 1 to 4				2,735,850	5,495,252,897	5,413,746,434	81,506,463 (6.48%)

1 $W_{ij}c_{ij}^{M}$

2 $W_{ij}\left(c_{iK_1}^{M} + \propto c_{K}^{CV,RV} + c_{K_2 j}^{M}\right)$

The total consolidated volume when considering cargo flows 1 to 9 is 2,817,198 metric tons. However, if only cargo flows 1 to 4 are considered, the consolidated volume is 2,735,850 metric tons which is still 316.61% higher than the original cargo volume of Batangas-Cebu, and greater than our 100% restriction and thus would merit density economies. Nonetheless, the transport costs saving even increase to 6.48% when only cargo flows 1 to 4 are routed through the hubs.

The minimization optimization described by the objective function suggests a strategy to be taken by a freight forward given a certain O-D matrix of cargo flows. However, in this case the cargo volume O-D flows are taken to be that of the whole domestic cargo flows of the Philippines for year 2012. The full transport cost saving would be realized and achieved by the freight forwarder if there is only one freight forwarding company player that services all the cargo flows; but to assume that is a fallacy. It is therefore not realistic for a small freight forwarding company to route 1 TEU of cargo with Manila-Calapan as OD through the hubs even though he has other cargoes that could be routed in the same route (e.g. for Batangas-Cebu) that would give him transport costs saving. However, the 2,873 PhP increase in per TEU cost for Manila-Cebu when routing through hubs is minimal and could be eliminated if policies will be implemented favoring shifting of cargoes to Batangas port (e.g. discount in port fees, improvement of access road, etc.); thus, this route is retained. The problem with Manila port congestion in 2015 prompted the government to encourage shippers to shift cargoes to Batangas and Subic ports by giving 50-90% discount to the total port fees. If the total port fees amount to PhP 606 per TEU for domestic cargoes (not including arrastre) as shown in Table 4.4, discount of PhP 545 would be given.

The consolidated volume of 2,735,850 metric tons is 316.61% increase in the Batangas-Cebu volume and 39.58% increase in the Manila-Cebu volume. The liner vessels listed in Table 5.5 with total NRT of 1,361,754 tons, and having other ports of calls aside from Manila and Cebu, could be re-routed to cater Batangas-Cebu solely. No container liner vessel is currently plying the Batangas-Cebu route.

Meanwhile, Tables 5.21 and 5.22 show the results that satisfy the case of at least 100% increase in link volume for 0.6 discount factor for hub-to-hub links.

Table 5.21: 0.6 discount factor in hub-to-hub transport (*F*=100%)

Cargo Flow	Ports			Volume (Metric Tons)	Flow Cost of Direct Transport[1] (PhP)	Flow Cost of Transport via Hubs[2] (PhP)	Transport Cost Saving due to Discount Factor (PhP/TEU)
	i	***K***	***j***				
1	Batangas	Batangas-Bacolod	Bacolod	96,641	166,908,368	100,145,021	12,435
2	Calapan	Batangas-Bacolod	Bacolod	794	1,332,146	1,212,310	2,716
3	Batangas	Batangas-Bacolod	San Carlos	12,808	24,565,856	23,105,997	2,052
4	Manila	Batangas-Bacolod	Bacolod	1,168,021	2,227,940,693	2,284,291,859	(-868)
5	*Manila*	*Batangas-Bacolod*	*Dangay*	*2,655*	4,061,348	9,372,147	*(-36,008)*
6	*Calapan*	*Batangas-Bacolod*	*Manila*	*733*	1,015,112	2,515,187	*(-36,862)*
7	*Manila*	*Batangas-Bacolod*	*Calapan*	*2,260*	3,132,406	8,211,361	*(-40,446)*
8	Batangas	Batangas-Cebu	Cebu	676,212	1,258,355,812	755,013,487	13,398
9	Batangas	Batangas-Cebu	Toledo	98,973	193,301,162	158,042,058	6,412
10	Calapan	Batangas-Cebu	Cebu	665	1,200,234	1,068,413	3,568
11	Batangas	Batangas-Cebu	Argao	255,553	455,769,982	442,350,322	945
12	Batangas	Batangas-Cebu	Tagbilaran	116,981	226,879,335	223,529,012	516
13	Batangas	Batangas-Cebu	Ubay	116,981	222,001,963	218,880,316	480
14	Manila	Batangas-Cebu	Cebu	1,960,000	4,042,395,689	3,990,510,718	476
15	*Manila*	*Batangas-Cebu*	*Argao*	*740,237*	1,584,922,548	1,961,917,002	*(-9,167)*
16	*Manila*	*Batangas-Cebu*	*Toledo*	*286,873*	564,864,341	721,845,135	*(-9,850)*
17	*Manila*	*Batangas-Cebu*	*Tagbilaran*	*76,266*	161,669,429	215,851,876	*(-12,788)*
18	*Dapitan*	*Batangas-Cebu*	*Manila*	*7,101*	15,452,902	36,744,710	*(-53,975)*
19	Bacolod	Bacolod-Batangas	Batangas	254,688	439,869,171	263,921,502	12,435

20	Bacolod	Bacolod-Batangas	Calapan	1,725	2,892,552	2,632,347	2,716
21	San Carlos	Bacolod-Batangas	Batangas	33,754	64,740,688	60,893,385	2,052
22	Bacolod	Bacolod-Batangas	Manila	753,795	1,437,826,827	1,474,193,692	(-868)
23	*San Carlos*	*Bacolod-Batangas*	*Manila*	*99,900*	193,207,998	272,077,089	*(-14,211)*
24	*Iloilo*	*Bacolod-Batangas*	*Manila*	*48,205*	93,829,386	138,809,252	*(-16,796)*
25	*Ubay*	*Bacolod-Batangas*	*Manila*	*10,670*	22,438,742	37,326,080	*(-25,115)*
26	Cebu	Cebu-Batangas	Batangas	7,276	13,540,591	8,124,354	13,398
27	Cebu	Cebu-Batangas	Manila	312,176	643,845,317	635,581,432	476
28	*Tagbilaran*	*Cebu-Batangas*	*Manila*	*10,670*	22,618,099	30,198,406	*(-12,788)*
29	*Benit*	*Cebu-Batangas*	*Manila*	*44*	95,925	150,238	*(-22,135)*
30	*Dangay*	*Cebu-Batangas*	*Manila*	*2,289*	3,502,172	8,549,744	*(-39,687)*
31	*Manila*	*Cebu-Batangas*	*Benit*	*103*	224,034	533,351	*(-53,975)*
32	*Manila*	*Cebu-Batangas*	*Allen*	*144*	266,670	698,032	*(-53,975)*

1 $W_{ij}c_{ij}^{M}$

2 $W_{ij}\left(c_{iK_1}^{M} + \propto c_{K}^{CV,RV} + c_{K_2 j}^{M}\right)$

With the given discount factor, all the four arcs can have consolidated volumes of more than 100% of the original volumes the link service. The same case as with the 0.7 discount factor results of Table 5.21, if cargoes would enjoy 0.6 discount factor in hub-to-hub transport costs, hub arcs Batangas-Cebu and Bacolod-Batangas would have significant increase volume. The liner shipping vessels intended for Manila (i.e. Manila-Cebu and Bacolod-Manila) in Tables 5.5 and 5.6 could be shifted to Batangas Port. The significant increases in volume could merit the 0.6 discount factor.

Table 5.22: Additional details for the case of 0.6 discount factor (F=100%)

Cargo Flows being Considered	Total Transport Costs Savings		Consolidated Volume (Metric Ton)	Increase in Volume	
	PhP	%		Reference Flow	%
1 to 4	11,991,876	0.50	1,278,264	Batangas-Bacolod[1]	1222.69
				Manila-Bacolod	9.44
8 to 14	610,509,850	9.54	3,225,366	Batangas-Cebu[1]	376.98
				Manila-Cebu	64.56
19 to 23	143,688,312	7.39	1,043,962	Bacolod-Batangas[1]	309.90
				Bacolod-Manila	38.49
26 to 27	13,680,122	2.08	319,452	Cebu-Batangas[1]	4,290.24
				Cebu-Manila	2.33

Notes: [1] Hub arcs;

*the table does not include the cargo flows in italics in Table 5.14

b. Mode Per Link

Table 5.23 and 5.24 show that should the cargo flows be routed to the hub arc, transport intermodality shall be taken by the cargoes. Thus, the hub ports should be equipped with facilities that would cater fast servicing of intermodal transport.

Table 5.23: Transport modes taken per link for the resulting cargo flows of the case of 0.7 discount factor in hub-to-hub transport (F=100%)

Ports			**Mode**		
i	***K***	***j***	***i***	***K***	***j***
Batangas	Batangas-Cebu	Cebu	-	Container Vessel	-
Batangas	Batangas-Cebu	Toledo	-	Container Vessel	Truck
Calapan	Batangas-Cebu	Cebu	RoRo Vessel	Container Vessel	-
Manila	Batangas-Cebu	Cebu	Truck	Container Vessel	-

Table 5.24: Transport modes taken per link for the resulting cargo flows of the case of 0.6 discount factor in hub-to-hub transport (F = 100%)

Ports			**Mode**		
i	***K***	***j***	***i***	***K***	***j***
Batangas	Batangas-Bacolod	Bacolod	-	Container Vessel	-
Calapan	Batangas-Bacolod	Bacolod	RoRo Vessel	Container Vessel	-
Batangas	Batangas-Bacolod	San Carlos	-	Container Vessel	Truck
Manila	Batangas-Bacolod	Bacolod	Truck	Container Vessel	-
Batangas	Batangas-Cebu	Cebu	-	Container Vessel	-
Batangas	Batangas-Cebu	Toledo	-	Container Vessel	Truck
Calapan	Batangas-Cebu	Cebu	RoRo Vessel	Container Vessel	-
Batangas	Batangas-Cebu	Argao	-	Container Vessel	Truck
Batangas	Batangas-Cebu	Tagbilaran	-	Container Vessel	RoRo Vessel
Batangas	Batangas-Cebu	Ubay	-	Container Vessel	RoRo Vessel
Manila	Batangas-Cebu	Cebu	Truck	Container Vessel	-
Bacolod	Bacolod-Batangas	Batangas	-	Container Vessel	-
Bacolod	Bacolod-Batangas	Calapan	-	Container Vessel	RoRo Vessel
San Carlos	Bacolod-Batangas	Batangas	Truck	Container Vessel	
Bacolod	Bacolod-Batangas	Manila	-	Container Vessel	Truck
Cebu	Cebu-Batangas	Batangas	-	Container Vessel	-
Cebu	Cebu-Batangas	Manila	-	Container Vessel	Truck

5.5 Chapter Conclusion

The study reveals that significant volume of cargoes intended for Manila port (1,960,000 Metric Tons of cargoes for Manila to Bacolod) could be shifted to ply through Batangas to Bacolod if the latter link be created as hub ports to consolidated increased volumes thus could prompt shipping lines to offer 30 to 40% transport cost discount per TEU. In the same way, Bacolod to Manila cargo of volume of 753,795 Metric Tons could be shifted to Bacolod-Batangas link if the arc Bacolod-Batangas were designated as hub arc which within hubs transport could give 0.6 discount in transport costs. This would yield a total of 2,713,795 metric tons of cargoes to be shifted to Batangas port or 22.23% of the average annual throughput of Manila ports.

This chapter shows that there could be transport cost saving benefits for the shippers in shifting cargoes intended for Manila ports to the adjacent Batangas ports when the latter port is a hub port that consolidates other domestic volume flows, and shipping cost savings benefits for the shipping in restructuring from multiple port calls to direct hub-to-hub transport. These benefits could only be realized with government interventions to create policies to encourage shippers to route through Batangas port as hub port. The following interventions could be taken:

i. Equip Batangas, Bacolod and Cebu ports with facilities that could cater quick operations and transshipment of multimodal transport
ii. Improve access to Batangas port to shorten travel time and lower land transport costs from Manila to Batangas. Rail transport infrastructure is suggested to be created for this link.
iii. Provide incentive by discounting or eliminating port fees at Batangas port. This has been done for the case of international cargoes.
iv. Initiative to discourage or restrict shipping companies (i.e. those that service Manila-Bacolod and Bacolod-Manila) to call in Manila port and instead in Batangas port. Item iii is an encouragement to the shipping lines to follow this initiative.
v. Promote industrial development in Region III and Region IV-A for products to be more proximate to Batangas port thus encouraging vessels to call in this port.

Chapter 6

Conclusions

6.1 Summary of Findings

As a whole, this study aimed at developing an intermodal hub-and-spoke network that is suitable for an archipelagic country such as the Philippines that would enable goods to be moved efficiently (lower cost and in a seamless manner) while not aggravating the existing problem of road congestion.

This section summarizes how the study has addressed its objectives:

Chapter 3: One of the characteristics of the HS network model for the Philippines is the use of intermodality. However, there is a lack of studies about the intermodal transport that exists in the country. Thus, the first objective was to clarify the development of the intermodal road-RoRo transport in the Philippines and its current position in the domestic shipping market against the inter-island shipping mode. We were able to address this objective in Chapter 3 by showing that the road-RoRo intermodal transport in the country has been brought to its current position by the regulatory changes made in 2003. Positive impacts have been realized since the operation of RRTS, and the road-RoRo intermodal transport has established its share in the domestic cargo shipping market. Its market dominance compared with the conventional container vessel shipping is primarily influenced by transport cost and travel time attributes of the shipment. The elimination of cargo handling charges reduces the transport cost, while frequent trips of RoRo vessels in most legs compared to the inter-island shipping vessels give intermodal transport the advantage of shorter lead times leading to shorter travel times. For example, the intermodal transport has higher market share for transport from Manila to destination along the western seaboard, except for destinations 600 km away, because of lesser transport costs and shorter travel time than the container vessel mode.

Chapter 4: An intermodal mixed HS network model suitable for archipelagic setting was developed in Chapter 4 that could provide considerable total transport costs savings compared to direct transport. The model incorporates properties of HS that has not been tackled at once in the model development of the previous studies. The Chapter also provided a step-by-step procedure, with Lagrangian as starting point, in solving the problem as it is applied to the large Philippines scope. The model is able to identify hub locations as well as cargo flow allocation to hubs, thus would be useful tool in the domestic transport strategic planning level in identifying the ports that need upgrade to cater hub quality, hub capacity, and facilities capable of modal complementarity.

Chapter 5: In Chapter 5, we were able to show that the strategy of shifting cargo from Manila to Batangas port with the latter port designated as a hub in a hub-and-spoke transport network would reduce the trucks that uses Manila ports, thus also reduce the presence of trucks in the Manila City and Metro Manila, by 11 to 23% of its current number. We are also able to show that both shipper and shipping company could benefit from the strategy, with the aid of some government regulatory interventions.

6.2 Scope of Future Works

The scope for future works is geared toward addressing the limitation encountered in the conduct of this study. Though the findings in this paper contribute to the body of knowledge in the field and are useful baseline information for actual implementation in the Philippines, the following are interesting areas that could still be explored further:

a. Mode Choice Model for the cargo transport modes - The current questionnaire survey in Chapter 3 tackles the attributes that influence the choice of mode between intermodal transport, container transport and air transport. The number of respondents in the questionnaire survey is limited thus a mode choice model is beyond the scope of the methodology. Thus, modelling of mode choice based on utility function gathered from a shippers' behavior survey would be interesting to explore.

b. Consideration of various loading units in the Hub-and-Spoke Network modelling – One TEU is taken as the loading unit to simplify the model. Considerations of other loading units would make the analysis and results more realistic.

c. Consideration of time constraints – because we encountered complexity in estimating travel times especially during that of transshipment in hub ports, time constraints have not been considered in the modelling. Results would be reflective of reality when time constraints are taken into account.

d. Consideration of link capacity constraint – this is a limitation of the current study but could be considered in the future. Future study could incorporate vessel capacity and frequency per route to determine the exact capacity of links.

e. Flow dependent tariff discount for the HS model – various fixed-valued discount factors are considered in the HS model instead of the actual tariff discounts that the inter-hub volumes merit. Equation (4.9) in Chapter 4 is provided to give a more accurate constraint that takes the minimum consolidated volume corresponding to discount factor ($V_{km}^{CV,RV}(\alpha)$). This would entail further research, data gathering of vessel capacities and details, and estimations related to the shipping economics. Moreover, the volume flow dependent discount could also be applied to non-hub node to hub node transport if the consolidated volume is sufficient to merit economies of density.

f. Minimization of transport costs components (e.g. tariff, port fees) as higher order optimization as initial optimization or concurrent optimization with the hub-and-spoke transport network minimization would be a challenging but more realistic approach which could be considered for future research.

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APPENDIX A: OD Tables

Table A.1: Estimated Origin to Destination Cargo Volume Flow in TEU

O \ D	Manila	Batangas	Calapan	Dangay	Puerto Princesa	Matnog	Culasi	Iloilo	Bacolod	San Carlos	Dumaguete	Cebu
Manila	0.00	356.22	13.06	3.72	25.64	243.83	42.67	69.80	112.64	14.93	7.20	182.63
Batangas	3081.14	0.00	133.13	62.37	62.37	125.62	50.46	381.96	30.48	4.04	5.42	386.14
Calapan	15.49	0.89	0.00	0.75	0.54	0.00	0.10	0.79	0.00	0.00	0.00	0.14
Dangay	0.26	6.14	0.25	0.00	0.45	0.05	0.01	0.04	0.03	0.00	0.00	0.05
Puerto Princesa	86.75	6.14	0.04	0.45	0.00	0.05	1.18	1.22	0.14	0.02	0.00	1.21
Matnog	132.58	10.43	4.53	2.94	2.94	0.00	0.38	2.46	11.27	1.49	4.08	11.94
Culasi	96.16	0.23	0.27	0.01	0.47	0.16	0.00	0.50	3.43	0.45	0.00	3.04
Iloilo	105.78	0.88	1.03	0.05	0.50	0.54	0.28	0.00	13.07	1.73	0.00	10.56
Bacolod	5054.93	646.51	37.16	66.88	66.99	319.58	282.67	2139.89	0.00	0.00	51.08	179.48
San Carlos	669.93	85.68	4.92	8.86	8.88	42.35	37.46	283.60	0.00	0.00	38.18	23.79
Dumaguete	32.31	1.29	0.00	0.00	0.00	3.51	0.00	0.00	13.15	13.15	0.00	6.53
Cebu	247.31	0.05	0.00	0.02	0.21	0.73	0.76	4.71	1.71	0.23	2.98	0.00
Toledo	36.20	0.01	0.00	0.00	0.03	0.11	0.11	0.69	0.25	0.03	0.44	0.29
Argao	61.92	0.02	0.00	0.01	0.06	0.27	0.27	1.76	0.53	0.07	1.13	0.64
Tagbilaran	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	8.98
Ubay	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	2.52
Allen	17.80	1.89	0.00	0.24	0.24	0.00	0.00	0.00	0.00	0.00	0.00	4.55
Ormoc	14.23	2.36	0.00	1.65	1.65	2.83	0.22	1.67	0.83	0.11	2.83	39.85
Benit	2.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dapitan	54.08	0.00	0.11	0.00	0.02	0.00	0.19	0.53	0.53	0.07	0.78	3.38
Zamboanga	50.49	0.00	0.04	0.00	0.02	0.00	0.15	0.27	0.20	0.03	0.27	1.20
Cagayan de Oro	181.42	5.73	0.00	0.00	0.00	0.46	0.60	4.57	6.94	0.92	1.76	61.37
Davao	566.29	0.36	0.95	0.00	0.49	1.52	1.77	5.42	3.96	0.52	32.45	40.01
General Santos	7.60	2.22	2.48	0.64	0.64	7.68	2.49	18.85	10.93	1.45	4.01	10.70
Surigao	86.73	0.57	0.00	1.89	1.89	0.19	0.02	0.17	0.50	0.07	0.75	16.97

Table A.1: Estimated Origin to Destination Cargo Volume Flow in TEU (Continuation)

O \ D	Toledo	Argao	Tagbilaran	Ubay	Allen	Ormoc	Benit	Dapitan	Zamboanga	Cagayan de Oro	Davao	General Santos	Surigao
Manila	26.59	18.15	11.18	1.32	7.99	45.09	5.73	26.87	26.87	77.71	201.67	23.71	25.71
Batangas	56.21	38.38	148.44	17.73	21.20	5.92	0.00	30.86	14.99	26.13	75.44	38.46	70.51
Calapan	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.21	0.00	0.00
Dangay	0.01	0.00	0.01	0.00	0.05	0.06	0.00	0.01	0.00	0.00	0.00	0.01	0.16
Puerto Princesa	0.18	0.12	0.01	0.00	0.05	0.06	0.00	0.07	0.07	0.00	0.74	0.26	0.16
Matnog	1.74	1.19	0.81	0.10	4.98	3.62	0.00	3.05	1.48	0.91	2.35	14.49	0.00
Culasi	0.44	0.30	0.02	0.00	0.04	0.31	0.01	0.23	0.12	0.41	0.61	0.07	0.04
Iloilo	1.54	1.05	0.09	0.01	0.15	1.15	0.01	0.82	0.41	1.43	1.41	0.26	0.04
Bacolod	26.13	17.84	0.00	0.00	0.00	37.38	0.07	25.10	12.24	223.04	7.87	37.16	7.50
San Carlos	3.46	2.36	0.00	0.00	0.00	4.95	0.01	3.33	1.62	29.56	1.04	4.92	0.99
Dumaguete	0.95	0.65	0.16	0.02	0.00	0.00	0.00	1.37	0.66	2.40	0.00	0.37	0.18
Cebu	0.29	0.22	9.41	1.12	2.21	10.96	0.01	4.40	2.19	15.27	4.14	1.76	5.58
Toledo	0.00	0.09	1.38	0.16	0.32	1.60	0.00	0.64	0.32	2.24	0.61	0.26	0.82
Argao	0.15	0.00	3.56	0.42	0.84	4.14	0.00	1.65	0.81	5.77	1.39	0.66	2.11
Tagbilaran	1.31	0.89	0.00	0.12	0.00	0.00	0.00	0.00	0.00	1.36	0.00	0.27	0.55
Ubay	0.37	0.25	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.00	0.08	0.15
Allen	0.66	0.45	0.00	0.00	0.00	1.01	0.07	0.00	0.00	1.42	3.31	23.15	0.00
Ormoc	5.80	3.96	0.84	0.10	3.37	0.00	0.07	0.00	0.00	40.63	3.78	26.93	0.00
Benit	0.00	0.00	0.00	0.00	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00	66.62
Dapitan	0.49	0.34	0.80	0.10	0.00	0.02	0.01	0.00	4.42	7.39	2.68	7.83	0.07
Zamboanga	0.17	0.12	0.27	0.03	0.00	0.02	0.01	3.10	0.00	7.02	1.58	2.75	0.07
Cagayan de Oro	8.93	6.10	1.32	0.16	1.11	1.11	0.00	28.09	27.73	0.00	64.22	22.21	80.44
Davao	5.82	3.98	0.11	0.01	0.00	1.22	0.20	10.83	6.01	128.60	0.00	203.68	37.55
General Santos	1.56	1.06	2.29	0.27	0.94	15.62	0.00	10.44	3.60	22.28	114.34	0.00	2.24
Surigao	2.47	1.69	1.35	0.16	0.19	0.00	25.27	1.84	0.93	247.48	118.14	19.48	0.00

Table A.2: Estimated Origin-Destination Cargo Volume Flows in Thousand Metric Tons for the Year 2012

D \ O	Subic	Manila	Batangas	Puerto Princesa	Calapan	Dangay	Matnog	Culasi	Iloilo	Bacolod	San Carlos	Dumaguete	Cebu
Subic	0	30603.81	4271.62	66.32	3.14	3.14	649.69	33.21	33.21	135.41	17.95	0.94	426.03
Manila	46146.92	0	5640.64	472.10	2.26	2.65	4118.12	315.79	315.79	1168.02	154.80	220.98	1960.0
Batangas	9270.47	40700.15	0	322.70	9.19	9.19	943.37	237.59	237.59	96.64	12.81	8.01	676.21
Puerto Princesa	0	88.82	13.55	0	4.41	0.53	0.00	3.31	3.31	0.00	0.00	0.00	1.69
Calapan	0.05	0.73	111.08	4.56	0	0.54	0.68	0.21	0.21	0.79	0.11	0.00	0.67
Dangay	0.05	2.29	111.08	0.69	0.54	0	0.68	0.23	0.23	0.80	0.11	0.00	0.69
Matnog	341.77	2142.95	164.98	26.72	1.06	1.06	0	3.63	3.63	86.42	11.45	14.65	44.99
Culasi	0.12	48.20	8.24	10.44	0.03	0.04	3.88	0	5.45	173.03	22.93	0.00	74.51
Iloilo	0.12	48.20	8.24	10.44	0.03	0.04	3.88	5.45	0	173.03	22.93	0.00	74.51
Bacolod	0	753.80	254.69	15.77	1.72	1.73	100.79	233.01	233.01	0	0	655.69	54.90
San Carlos	0	99.90	33.75	2.09	0.23	0.23	13.36	30.88	30.88	0	0	652.36	7.28
Dumaguete	0	188.50	46.08	0	0	0	100.15	0	0	236.77	236.77	0	181.05
Cebu	0	312.18	7.28	0	0.24	0.24	81.57	190.10	190.10	172.03	22.80	295.97	0
Toledo	0	45.45	1.06	0	0.03	0.04	11.87	27.67	27.67	25.04	3.32	43.09	27.01
Argao	0	31.67	0.72	0	0.02	0.02	8.11	18.89	18.89	17.10	2.27	29.42	18.82
Tagbilaran	0	10.67	0	0	0	0	0	0	0	0	0	9.18	358.73
Ubay	0	10.67	0	0	0	0	0	0	0	0	0	9.18	358.73
Allen	0	84.24	27.61	0	0.23	0.23	0	0	0	0	0	0.00	51.78
Ormoc	0	17.77	12.20	0	0.56	0.56	11.72	2.38	2.38	6.07	0.80	9.61	160
Benit	0	0.04	0	0	0	0	0	0	0	0	0	0	0
Dapitan	4.73	7.10	0	0.60	0	0	0	0.55	0.55	3.46	0.46	2.56	12.87
Zamboanga	45.56	61.06	0	3.93	0	0	0	3.57	3.57	22.70	3.01	16.76	84.39
Cagayan de Oro	0	681.10	299.92	0	0	0	19.37	66.14	66.14	511.60	67.80	60.30	2497.51
Davao	2.28	411.32	2.00	5.75	0	0.01	4.82	6.54	6.54	15.81	2.10	119.50	138.19
General Santos	18.44	21.98	17.23	20.71	0.33	0.33	47.77	40.46	40.46	119.59	15.85	20.44	64.63
Surigao	0	45.31	1.46	0	0.32	0.32	0.39	0.12	0.12	1.81	0.24	1.27	33.97

Table A.2: Estimated Origin-Destination Cargo Volume Flows in Thousand Metric Tons for the Year 2012 (Continuation)

O / D	Toledo	Argao	Tagbilaran	Ubay	Allen	Ormoc	Benit	Dapitan	Zamboanga	Cagayan de Oro	Davao	General Santos	Surigao
D	62.36	161.01	8.96	8.96	0	62.44	0	29.24	171.40	266.38	294.90	67.28	19.09
Manila	286.87	740.24	76.27	76.19	0.14	187.56	0.10	83.60	488.97	2199.80	1955.02	179.10	111.02
Batangas	98.97	255.55	116.98	116.98	77.26	3.75	0	17.30	49.25	79.28	152.68	50.21	34.13
Puerto Princesa	0.25	0.64	0	0	0	0	0	0	0	0	43.87	0	0
Calapan	0.10	0.25	0.07	0.07	1.38	0.30	0	0.04	0.10	0	0	0.12	0.64
Dangay	0.10	0.25	0.07	0.07	1.38	0.30	0	0.04	0.10	0	0.01	0.13	0.64
Matnog	6.58	16.99	1.55	1.55	44.18	5.58	0	4.16	11.84	6.69	11.16	46.04	0
Culasi	10.91	28.16	0.30	0.30	2.35	3.00	0	1.87	5.32	17.64	9.16	1.41	0
Iloilo	10.91	28.16	0.30	0.30	2.35	3.00	0	1.87	5.32	17.64	9.16	1.41	0
Bacolod	8.04	20.75	0	0	0	4.12	0	2.46	6.99	118.39	2.64	8.49	0.63
San Carlos	1.06	2.75	0	0	0	0.55	0	0.33	0.93	15.69	0.35	1.13	0.08
Dumaguete	26.50	68.42	2.06	2.06	0	0.00	0	12.14	34.56	115.37	0	7.64	1.42
Cebu	27.15	68.23	498.52	498.52	541.99	464.68	0	162.21	461.87	3109.47	379.57	151.96	181.54
Toledo	0	10.95	72.57	72.57	78.90	67.65	0	23.61	67.24	452.67	55.26	22.12	26.43
Argao	3.77	0	49.55	49.55	53.87	46.19	0	16.12	45.91	309.06	37.73	15.10	18.04
Tagbilaran	52.51	135.57	0	9.95	0	0	0	0	0	94.35	0	8.12	6.02
Ubay	52.51	135.57	9.95	0	0	0	0	0	0	94.35	0	8.12	6.02
Allen	7.58	19.57	0	0	0	5.08	1.19	0	0	27.92	43.46	196.23	0
Ormoc	23.44	60.53	1.53	1.53	28.85	0	1.19	0	0	282.92	17.56	80.69	0
Benit	0	0	0	0	1.19	1.19	0	0	0	0	0	0	164.81
Dapitan	1.88	4.86	1.39	1.39	0	0	0	0	32.14	126.01	24.21	23.47	1.19
Zamboanga	12.35	31.89	9.13	9.13	0	0	0	74.00	0	146.86	65.92	147.25	1.19
Cagayan de Oro	365.55	943.86	24.21	24.21	94.00	16.33	0	502.13	518.61	0	1204.29	406.04	1432.29
Davao	20.23	52.18	0.21	0.21	0	0.95	0	30.98	55.16	2305.95	0	3647.00	644.01
General Santos	9.46	24.43	6.22	6.22	11.81	34.13	0	21.26	41.26	375.98	2046.80	0	31.87
Surigao	4.97	12.84	1.21	1.21	0.79	0	109.17	2.33	4.44	4092.89	2102.78	229.26	0

APPENDIX B: Variable Cost Estimation

The variable costs are calculated based on Equation (5.3):

$$VC_t^m = f\sum_i [\delta_{it} + F_{it}^m + D_t F_t^m] + \sum_i \sum_j \left[\left(G_i + \frac{\beta_{it}}{R_i}\right)\left(Q_{ij}^m + Q_{ji}^m\right)\right]$$

For MV Lorcon Manila existing multi-ports calling case:

$$\begin{aligned} VC_M^1 = {} & (PhP\ 8{,}227.95 + PhP\ 1{,}948.73 + PhP\ 2{,}598.30) \\ & + (PhP\ 63{,}871.62 + PhP\ 30{,}254.98 + PhP\ 20{,}169.99) \\ & + (330\ nm + 54\ nm + 347 nm)\left({PhP\ 200.21}/{nm}\right) \end{aligned}$$

$$\begin{aligned} & + PhP\ 126.00/TEU[(2\ x\ 426 TEU) * load\ factor_M^1] + \\ & 2\left({PhP\ 301.00}/{TEU}\right)[(2\ x\ 426 TEU) * load\ factor_M^1] \end{aligned}$$

$$VC_M^1 = PhP\ 273{,}425.08 + PhP\ 620{,}256 * load\ factor_M^1$$

For MV hypothetical inter-hub direct calling case:

$$\begin{aligned} VC_M^2 = {} & 2(PhP\ 6{,}062.70) + 2(PhP\ 47{,}063.30) + 2(251\ nm)\left({PhP 351.96}/{nm}\right) \\ & + PhP\ 126.00/TEU[(2\ x\ 426 TEU) * load\ factor_M^2] \\ & + 2\left({PhP\ 301.00}/{TEU}\right)[(2\ x\ 426 TEU) * load\ factor_M^2] \end{aligned}$$

$$VC_M^2 = PhP\ 282{,}935.92 + PhP\ 620{,}256 * load\ factor_M^2$$