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SHORT SEA SHIPPING STUDY: A REPORT ON SUCCESSFUL SSS MODELS THAT CAN IMPROVE PORTS' EFFICIENCY AND SECURITY WHILE REDUCING CONGESTION, FUEL COSTS, AND POLLUTION

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EXECUTIVE SUMMARY

Purpose and Methodology of the Project

The main objective of this Project has the specific aim of offsetting and lessening congestion at major hub ports which is expected to worsen substantially as larger ships call on these ports and trade doubles over the next two decade. It consists of three sub-objectives: to integrate underutilized ports to reduce congestion, to create a model in and to facilitate underutilized port development.

The Project's methodology by phase are as follows: Phase I - Identify and summarize existing coastal marine freight and passenger services flowing through ports (including ancillary services) along with legal and regulatory considerations between multiple economies in two specified APEC regions, namely America's Northwest and Yellow Sea; Phase II- Gather data from a case region and build a flow model in which to assess the marine transportation patterns that exist and could exist by the application of successful short sea shipping models and technologies and the use of underutilized ports, and then test the flow models; and Phase III - Run "what if scenarios" using the short sea shipping (SSS) model. Evaluation of model output, along with analysis and recommendation of successful models for short sea shipping in the APEC regions as well as the clustering of economic activities that promotes the inclusion of underutilized ports into the supply/demand chain.

Economic Growth in Asia and Significance of SSS

The accelerated growth of Asian economy, including high rate of Chinese economy, has both influenced and mirrored changes in the scope and operation of shipping connections within Asia and with the rest of the world, causing the repercussions on extra- and intra-Asian container shipping networks. As a result of that, in Europe, SSS has grown steadily over the last two decades. Asia needs an efficient logistics transport system combining the benefits of all modes to maintain and increase competitiveness and prosperity in line with the globalized economy in order to overcome less efficient rail and road transportation system and to make many of Asian main industrial centers get close to waterways. Thus, in many cases, SSS routes in Asia may provide the fastest and most reliable service between destinations. Fast growing trends of SSS has been also seen in Asia according to mega-hub port developments and China's high rate of economic growth. Recent years have brought an increasing focus on developing new SSS options that are better suited for moving container cargo, for example in Korea and China, that normally travels by truck and tends to include higher-value and time-sensitive goods.

Fast growth of heavy road transport and related congestion, accidents and pollution are the main economic, social and environmental problems so that the policy to promote SSS is worthwhile to address.

Benefits and obstacles of SSS and how to solve the obstacles

SSS may produce public and private benefits, by providing an additional and/or alternative option for transporting passenger and freight. SSS services are more fuel efficient than trucks so that they can contribute to improving air quality and reducing noise. SSS also plays a key role in reducing the road and terminal congestion as well as the number of trucks and trains traveling on crowded port access routes. As a result, SSS development may provide a more cost-effective alternative to building new roadways and rail lines. In particular, a new concept of "Motorway of the Sea" in Europe has contributed to reducing the amount of money spent on infrastructure projects, and maintenance costs. Despite of the benefits noted above, the potential obstacles can be identified in terms of legal, operational, and acceptance-related challenges. Legal requirements could present a barrier to SSS development by increasing the start-up or operating costs of operations. Operational challenges involve incompatible infrastructure and potential strains on port capacity. Furthermore, a general unwillingness among logistics providers to switch from well-established modes, such as trucking and rail - even if SSS can be shown to be a competitive option - can become a barrier to SSS development.

SSS Practices in Asia

COSCO Container Lines Company Ltd (Coscon), China's leading container carrier, plays a key role in intra- and extra-Asian shipping patterns closely parallel shifts in the country's economic geography, the accelerated growth of Chinese economy over the two decades, and the increasingly competitive global economic environment. In elaborating the maritime environment within China, Coscon operates the country's container ports that are allocated to one of three regions or port ranges: the northern range around the Bohai Rim, the central range focused on the Yangzi River Delta and southern range centered on the

Pearl River delta. Coscon has intensified traffic within a fully-fledged domestic cabotage maritime circuit between the above three port ranges. This process has confirmed Qingdao, Shanghai and Hong Kong, China as national hubs, the indisputable pivots within these ranges for a large number of domestic links and the bases for tangential services to secondary ports. Coscon's services have become a realistic choice in multimodal logistical transport chains in the intra-Asian market by building on the strengths of the short-sea liner trades and minimizing any weaknesses.

Hong Kong, China is expected to have the ability to respond to the growing competition through its innovative ingenuity thanks to two aspects: the increased use of river barges to lower transport cost between Hong Kong, China and its PRD hinterland, and the penetration to mainland ports by Hong Kong port operators. In addition, because of Hong Kong's established trading networks, legal system, ease of communications, and efficient support services and with China's accession to the WTO, China's international trade and investment would further expand and Hong Kong, China would be playing a key role in providing trading services. In this regard, so long as Hong Kong, China is able to continue to attract international logistics operators to base its regional or international operations in Hong Kong, China, the seaport of Hong Kong, China should be able to continue to maintain a competitive edge over the growing seaports in Southern China. In doing so, SSS development in association with the efficiency of entire shipping chain - barging, trucking, consolidating, and other logistics - is critical to attract transshipment cargo for ports in this region.

The Japanese short sea shipping network comprehensively covers all around the country from the north to the south in 3000 km range. The network involves 23 routes, 48 operators, 101 ships, 112 ports and 196 sailings per week. The majority of ships operated by the SSS in Japan are RORO, ferry and conventional boats. The size and the capacity of them are moderate and handy to accommodate local niche cargo demand. Therefore, most of the ports called by the SSS are relatively smaller ports in local areas even though some routes call bigger ones like the Port of Tokyo. In contrast, most of the container ports are intensively located in the proximity to the greater metropolitan areas. The reality that the Japanese SSS has been well developed suggests the evidence of great possibilities to create the international SSS network in the Northeast Asia.

In recent years, Korean government has initiated a strategy to build a logistic hub of the Northeast Asia in Korea and a great deal of efforts have been made to implement the strategy. In spite of these efforts, many people argue that there is great inefficiency in transporting international trade cargoes, in particular in the capital region of Korea. Although thirty three per cent of cargoes of national container export and import were generated in this region as of year 2001, most of these cargoes had to be handled in farthest seaports such as the Port of Busan and the Port of Gwangyang rather than its vicinity ports like the Port of Incheon and the Port of Pyeongtaek. This phenomenon causes many problems including road congestion on and damage to major highways between Seoul and Busan, environmental degradation, inefficient infrastructure investment and notably truck drivers' illegal and intentional strike on major highways to block major cargo flows for their bargaining power (the strike started on April 28, 2003 and ended on September 5, 2003.). Under these circumstances, Korean government and industries as well as general public have begun to explore more diverse transportation network for the capital region's cargoes among coastal shipping, railway , truck and also air transportation. SSS in Korea has not attracted sufficient attention of government. Government seem to be more concerned about developing coastal shipping rather than developing SSS, plausibly due to unawareness of the characteristics and importance of SSS. It is not until recent year that public stakes have been expressed in favor of coastal shipping to resolve inland congestion along major highways and reduce air pollution and other environmental degradation,

SSS network model design and its major findings

The research team has employed two quantitative models in building cargo flow network in the case region. One model is a kind of heuristic approach, particularly using Genetic Algorithms focusing on the capital region of Korea, and the other is traditional mathematical program - linear programming covering up the whole nation's international trade. The objective of both models is to find the minimum logistics cost to handle international trade cargoes in the capital region and the whole Korea, respectively.

Prior to building the cargo flow network models, our research team first analyzed the data of Korea's coastal shipping and predicted future demand for the shipping using origin-destination matrix of cargoes.

Our research team attempted to analyze container cargo flows generated in capital region of Korea and estimated the logistics cost and time. Based on integer goal programming model, we tried to find optimal solutions for international freight routing problems taking into account the three factors of cost, time and risk of handling cargoes. Genetic Algorithms were used to tackle huge number of variables and cases and also considering its flexibility of handling other qualitative variables when our model is extended later on. The most important finding is that the Port of Incheon should be utilized in handling the international cargoes of the capital region in both aspects of logistics and time. Under various scenarios such as major liners' calling Incheon or not calling Incheon (as is the case today), using the Port of Incheon shows that we can reduce a great deal of logistics costs and time. This observation can be more vividly reflected more in coming years like year 2008 and 2011 when more increased containers are expected to be generated in the region.

Despite that our findings are temporary ones, we can derive very important implications from them as follows: First, we have to maximize using the regional ports of the capital region, namely the Ports of Incheon and Pyeongtaek replacing currently road-and-Busan-port dominant transportation system. Second, we should, therefore, develop container ports in Incheon/Pyeongtaek much earlier that current plan. Third, we need to think about designing the ports in Incheon/Pyeongtaek to accommodate major ocean going shipping lines. Our findings in scenario I and II show that we can reduce hundreds of billion Wons (hundreds of million dollars) solely for the capital regional cargoes even excluding the possibility inducing more international cargoes when attracting major lines. Recent movement of major shipping lines' calling Northeastern Chinese ports in the vicinity of the Port of Incheon and increasing foreign direct investment in container terminals in Incheon are likely to justify this argument. This argument has to be tested asking various stakeholders of the ports whether they would use the ports or not. This remains to be our next step study.

Next problem considered in this Project is the intermodal routing problem of international container cargoes in Korea, which can be defined as the problem of determining the cargo flow quantity and the transportation mode in each trade route while satisfying the demand. The objective is to minimize the sum of shipping and inland transportation costs. There are two major constraints: maximum cargo volumes capacitated at each seaport and maximum cargo volumes that can be carried by available vehicles of each transportation mode. In order to solve optimally and represent the problem, our research team employed a linear programming model, which is an operations research technique. The problem is formulated by extending the well-known network design problem by considering the two major constraints. The model is solved using CPLEX, a commercial linear programming software. The test results using a real cargo flow data in Korea show that the model represents closely the real situation.

After validation of our model, we tested what would happen if we relax current capacity of port and availability of vehicle constraints. The results show that the port of Busan and Incheon will be less used and other ports will be more used. One of the reasons for this change may be caused by pricing structure, but this time our research team could not incorporate the price change into the model. Further the model output showed that coastal shipping will be enormously increased by over twelve times. This means if we further develop ports and SSS capacity in terms of available number of ships, SSS will develop at rapid speed in the region. Again, we tested what would happen if we only release the vehicle availability constraint. The result showed that all underutilized ports will be more used if we only provide more SSS vessel services although we do not change current port capacity. This is very meaningful finding and as we expected from our proposal, this shows important policy implications toward further developing SSS system in the region in the near future.

Concluding remark

Short Sea Shipping has been supported by European Union in the past decade and similar advocacy can be observable in North American continent. On the basis of our findings, it seems to be high time that Asia-Pacific region should develop SSS as early as possible in view of expected benefits ranging from reduced logistics costs, and environmental protection to further utilization of underutilized seaports in the region. The research team attempted to capture current practices of SSS in major maritime regions and to build cargo flow network model. Our findings from the models are clear: SSS will provide more transportation and logistics routing choices for various stakeholders; reduce logistics costs; encourage currently underdeveloped or less-used seaports to be further developed and/or used in the future. To do this, new technology such as faster ship and turnaround in major intermodal nodes and policy formulation to expedite cargo movements need be incorporated into the SSS system in the near future.

Recommendation and necessity of further research

Some caveats should be taken in interpreting the results since the results of this study are intermediate ones constrained by lack of data like more detailed level of cost, time and in particular time variances. These lacking data will be further sampled and investigated in the near future in our study if the Phase III-work is approved by APEC as proposed in the original proposal. Even if we attempted to build up the cargo flow network model to test how SSS can affect the total logistics and transportation network in terms of cost and time in the case study, a great deal of factors need to be further considered in the future to analyze more detailed impacts of the SSS in the APEC region by providing APEC economywise specific data and evaluate the validity of our model in these numerous cases. This can be done by WHAT-IF type analysis as described in our proposal.

PROJECT OVERVIEW

Project Objectives

This Project meets objectives of the Intermodal Experts Group, as noted in the mission statement which is to contribute to and facilitate the implementation of an efficient, integrated intermodal transportation system and to promote and facilitate the uptake of electronic commerce among businesses, including SMEs in transportation and related trading activities in the Asia Pacific Region.

In order to explore and develop successful business models for short sea shipping in the APEC Region, the project will extend over three phases and will look at two major APEC regions which include America's Northwest inland-waterways, encompassing Washington State (USA) and British Columbia (Canada), and the Yellow Sea region, which encompasses China's northeast coastal ports and Korea's coastal ports. The three phases are as follows:

Phase I: Identify and summarize existing coastal marine freight and passenger services flowing through ports (including ancillary services) along with legal and regulatory considerations between multiple economies in two specified APEC regions. This study will identify existing coastal and inland water freight and passenger services in the two regions as well as compiling and summarizing laws and regulations that pertain to trade, labor, and transportation between the economies identified in the two regions. This includes the import and export processing requirements that are specific to marine transportation as well as evolving security considerations. Also included is an assessment of the legal, regulatory, and institutional barriers to short sea shipping in the two APEC regions. Phase I is currently being conducted in several ways: 1) In cooperation with the USA and Canada, information on the PNW region (Washington State and British Columbia) will be available from a study by the International Mobility and Trade Corridor Project (IMTC) that is funded by the U.S. and Canada. 2) In cooperation with Korea, information will be provided on the Pentaport[1] Project that is being funded by the Korean Government. And 3) Inha University in Korea has funded a workshop that took place in October 2004 to

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[1] Pentaport is a concept developed at Inha University in Incheon Korea for regional economic development that brings together a cluster of various services in the context of 5 ports – a business port, a techno port, leisure port, airports and sea port (2003).

assess current short sea shipping operations and methods in the APEC regions as well as identify and summarize the information required for completion of Phase 1. (Note: The IMTC has no formal role in this project. IMTC representatives have been briefed on this proposal and are supportive of ongoing communication and information sharing between the two projects.)

Phase II: Gather data from each of the two regions and build a flow model in which to assess the marine transportation patterns that exist and could exist by application of successful short sea shipping models and technologies. Part of this data will come from the U.S. (self funded) and part from Korea (self funded). Addition funds will be needed for building the flow model (APEC Operational Account).

Phase III: Evaluation of model output, along with analysis and recommendation of successful short sea shipping alternatives to surface transportation in the APEC region. The results of the work will be included in a final report, which will contain an executive summary and conclusion section. This final phase is contingent upon funding from the U.S. and in the event that funding is not available in a timely manner, a request for additional APEC funding could be submitted later on at APEC TPT. Working Group.

The three main objectives of this Project has the specific aim of offsetting and lessening congestion at major hub ports which is expected to worsen substantially as larger ships call on these ports and trade doubles over the next two decade.

The first objective is specifically the integration of underutilized ports to reduce congestion: This study will determine which underutilized ports in the APEC region could become better integrated into the region's transportation system and supply chain by employing emerging successful short sea shipping models and technologies. Part of the data for this portion of the project has been collected in Phase I, which is almost complete.

The second objective is to create a model in which to demonstrate the integration of underutilized ports: This modelling will help demonstrate how an underutilized port might become part of a short sea shipping network while at the same time acting as a direct shipping port and as a feeder port for transhipment of cargos in the APEC region in order to reduce congestion as noted in the first objective. This work will be accomplished in Phase II and III of the project.

The third objective is to facilitate underutilized port development: This effort will look at clusters of multipurpose commercial activities such as free trade zones, business parks, techno-parks, leisure-parks that might facilitate a port's development and economic growth enabling it to become more integrated into the larger system. This information will be collected over the three phases and will be summarized in the final report.

METHODOLOGY

Description of Project's Methodology

The project's methodology consists of three phases:

Phase I: Identify and summarize existing coastal marine freight and passenger services flowing through ports (including ancillary services) along with legal and regulatory considerations between multiple economies in two specified APEC regions. This Project will identify existing coastal and inland water freight and passenger services in the two regions as well as compiling and summarizing laws and regulations that pertain to trade, labor, and transportation between the economies identified in the two regions. This includes the import and export processing requirements that are specific to marine transportation as well as evolving security considerations. Also included is an assessment of the legal, regulatory, and institutional barriers to short sea shipping in the two APEC regions. The study will also look at clusters of multipurpose commercial activities such as free trade zones, business parks, techno-parks, and leisure-parks that might facilitate a port's development and economic growth enabling it to become more integrated into the larger system.

Phase I will be conducted in three stages:

1. In cooperation with the USA and Canada, information will be made available for the PNW region from the International Mobility and Trade Corridor Project (IMTC) SSS study that is being funded by the U.S. and Canada.

2. In cooperation with Korea, information will be provided on the Pentaport Project that is being funded by the Korean Government.

3. Information from Inha University's (Korea) workshop in October 2004 will be made available to assess current successful short sea shipping models in the APEC regions as well as identify and summarize the information required for completion of phase 1 with regard to clustering and underutilized ports.

Phase II: Gather data from a case study regions and build a flow model in which to assess the marine transportation patterns that exist and could exist by application of successful short sea shipping models and technologies and the use of underutilized ports. Test the flow models.

Phase III: Run "what if scenarios" using the short sea shipping model. Evaluation of model output, along with analysis and recommendation of successful models for short sea shipping in the APEC regions as well as the clustering of economic activities that promotes the inclusion of underutilized ports into the supply/demand chain.

Timetable for Accomplishment

The originally proposed short sea shipping project involves three phases with components, dates, and tasks shown in the following table:

TIMELINE	COMPONENT	COMPLETION DATES	OUTPUT
Phase I	1. IMTC SSS ongoing.	Late 2005	Information from the IMTC study on existing coastal marine freight flowing though ports.
	2. Korea provides data on Pentaport project	August 2005	Information on developments in Incheon and Yellow Sea Region regarding SSS and port development.
	3. Inha University Conference & Workshop	October 2004	Assess current short sea shipping practices in the APEC regions as well as identify and summarize the information required for completion of Phase 1.
Phase II	1. Gather data	March 2006	Short sea shipping models and the clustering of port related activities
	2. Build model	September 2006	Assessment of marine

			transportation patterns that exist and could exist by application of successful short sea shipping models and technologies
	3. Test model	October 2006	Evaluation Report
Phase III	1. Run model	March 2007	"What if" Scenarios
	2. Model output	June 2007	Evaluation
	3.Analysis of Model Output	August 2007	Recommend successful models for short sea shipping in the APEC regions
	4. Final report to TPT	October 2007	Finalization of work results including an executive summary and conclusion and presentation to APEC of assessment criteria.

It is noteworthy that due to protracted approval of this project by APEC Secretariat and ensuing delay of the payment to the consultants from APEC Operational Account, the conducting of this research in particular regarding the Phase II was delayed and finally agreed between the Secretariat and the consultant to finish the Phase II work by the end of August, 2007.

The remaining parts of this report summarize the works of Phase I and describes detailed work of Phase II. The Phase III will work depend upon the availability of further financial support of APEC Transportation Working Group as proposed in the proposal.

PART I

REPORT ON THE PHASE I: SHORT SEA SHIPPING WORKSHOP AND PENTAPORT APPROACH

Summary of Short Sea Shipping Workshop and Practices in SSS

Korea's Strategic Plan to be Northeast Asia's Logistics Hub: Towards the Pentaport Approach

REPORT ON THE PHASE I: SHORT SEA SHIPPING WORKSHOP AND PENTAPORT APPROACH

SUMMARY OF SHORT SEA SHIPPING WORKSHOP AND PRACTICES IN SSS

I. Introduction

The short sea shipping (SSS) of freight has a strong presence in Europe because of its geography, where European Union policies have encouraged its use. In Europe, SSS grew steadily over the last three decades. Europe needs an efficient logistics transport system combining the benefits of all modes to maintain and increase European competitiveness and prosperity in line with the mid-term review of the White Paper on European Transport Policy in order to overcome less efficient rail system and to make many of Europe's main industrial centers get close to waterways. Thus, in many cases, SSS routes in Europe have provided the fastest and most reliable service between destinations.

Fast growing trends of SSS has been also seen in Asia according to mega-hub port developments and China's high rate of economic growth. Recent years have brought an increasing focus on developing new SSS options that are better suited for moving container cargo, for example in Korea and China, that normally travels by truck and tends to include higher-value and time-sensitive goods.

Fast growth of heavy road transport and related congestion, accidents and pollution are the main economic, social and environmental problems so that the policy to promote SSS is worthwhile to address. A number of obstacles, however, are slowing down its development in Asia, which will be further discussed later on.

This section aims to review how SSS is being operated as an option for addressing freight mobility concerns and the factors that affect its viability as an approach in Asia. In doing so, we conducted a literature review of academic papers, reports, and studies related to freight mobility issues and the waterborne transport of goods, and discussed with SSS experts both from Japan, China and Korea and from the public and private sectors at SSS workshop held at Incheon in Korea in 2004, organized by our research team at Inha University.

II. Benefits and Challenges of SSS

The development of SSS operations may produce a number of public and private benefits. By providing an additional option for transporting freight and moving cargo out of busy ports to less congested ports, such services would increase the capacity of certain freight routes, thus alleviating many of the capacity stresses and external costs that currently affect the land transportation system. In addition, they could help reduce the road and terminal congestion and the number of trucks and trains traveling on crowded port access routes. Stakeholders of SSS services contend that since SSS services are more fuel efficient than trucks, SSS operations can help not only improve air quality but also reduce noise and road accidents. Finally, they maintain that SSS services may provide a more cost-effective alternative to building new roadways and rail lines, thus reducing the amount of money spent on infrastructure projects as well as maintenance costs(See Table 1)[2].

Table 1: Benefits of Short Sea Shipping Cited by Stakeholders

Benefits	Explanation
Improved freight mobility (increased freight capacity and availability of modal choice)	At a basic level, incorporating SSS into the intermodal transportation system may add capacity to certain cargo routes because it increases modal alternatives. SSS operations may also help increase capacity in other ways, such as helping remove containers from busy ports.
Improved freight mobility (less congestion)	By taking trucks off the road, SSS may help alleviate congestion along key corridors.
Improved air quality	Coastal ship services may be more fuel efficient than

[2] United States Government Accountability Office (2005), Short Sea Shipping Option Shows Importance of Systematic Approach to Public Investment Decisions. Gao-05-768.

and reduced noise	trucking, and one coastal ship may be able to carry as much freight (for example one barge carrier's capacity equivalent to 58 trucks.). Removing these trucks from the road and using a more fuel-efficient option may reduce emissions, improve air quality and, in addition, reduce noise and road accidents.
Reduced need to build roadways and rail lines and maintenance costs	By reducing the pressure on existing transportation infrastructure, SSS can reduce the need to build new infrastructure and maintenance costs. Large infrastructure projects, such as new roadways and rail lines, are expensive, time consuming, and in some cases may be limited because of population density or land costs.

**Source*: Based on GAO Report (2005) on Freight Transportation with authors' revision.

Despite of the benefits noted above, the potential obstacles can be also identified in terms of legal, operational, fear of changes, and acceptance-related challenges. Legal requirements could become a barrier to SSS development by increasing the start-up or operating costs of operations. Operational challenges involve incompatible infrastructure and potential strains on integration of intermodal transportation system. Finally, a general unwillingness among logistics providers to switch from well-established modes, such as trucking and rail - even if SSS can be shown to be a competitive option - can produce a barrier to SSS development. Leaving aside legal and technical aspects, acceptance-related challenges of SSS will be further discussed.

Development and enhancement of SSS services require a prerequisite. It is to offer economic advantages before shippers would be willing to use such services. In other words, for shippers to be willing to try SSS, its operations need to provide service that is cost-competitive with other modes and is as consistent and reliable. In addition, shippers' needs are to identify some advantages to shifting to SSS services, such as faster, more reliable, seamless, or cheaper service than other transportation modes.

Despite of the potential benefits, a general reluctance among shippers, freight forwarders, and others involved in SSS system poses an additional challenge, according to many users of SSS services. According to a Korean case, shippers are unwilling to shift business to SSS operations regardless of perceived benefits owing to unfavorable administrative and inefficient procedures between the point of origin and the point of destination. To make matters worse, they pointed out that coastal ship operations are too slow to compete with trucking along certain cargo routes and that legal and operational aspects hinder seamless service of container cargo movements.

One necessary action to promote the use of SSS is to convert its misconception from that of an old-fashioned and slow mode to modern reality: that of a dynamic and seamless link in the door-to-door supply chain. Thanks to shipbuilding and informational technology, SSS ships can generally offer speed, reliability, flexibility, regularity, frequency, security, and cargo safety to a high degree. The users of SSS services should be better aware of this when making decisions on the choice of the mode.

Having identified the obstacles to SSS developments, a further necessary step is to show how central governments in collaboration with stakeholders of SSS need to thoroughly assess and tackle key issues, such as[3]:

- the potential impact of central government involvement in developing SSS on the competitive balance among all transportation modes;
- lessons learned from new SSS services, such as the Europe and Gulf Coast;
- the way to make SSS viable as a cost- efficient and effective approach; and
- obstacles and mitigating actions necessary to developing SSS, particularly with respect to the reluctance by shippers and logistics providers to using this option.

In-depth insight into those is an important prerequisite in order to establish the extent of central government involvement needed, if any, in the development of SSS in Asia.

III. Identification and elimination of obstacles to making SSS more successful

As from December 1999 the EU Commission has been collecting a list of obstacles that hamper the development of SSS. This “bottleneck exercise” also contains ideas towards possible solutions to the obstacles as well as best practices. Lessons from them may be

[3] Commission of the European Communities (2006), Impact Assessment, Commission Staff Working Document

useful to develop SSS in Asia. The identified obstacles can be classified into seven categories, referring to European and Korean cases[4]:

- SSS has not yet fully converted its negative image of an old-fashioned industry;
- It has not yet developed full integration in the intermodal supply chain;
- It involves complex administrative, legal procedures and documentary procedure to ensure seamless service in the process of cargo flow;
- It needs governments' as well as service users' understanding of importance of SSS;
- It requires higher port efficiency and good hinterland accessibility;
- Application of the rules and procedures differs between countries; and
- Central governments do not recognize the benefits of SSS;

EU members have taken many actions to overcome the obstacles and reinforce SSS in Europe. Among them one can mention[5]:

- Adoption of a Directive standardizing certain reporting formalities for ships to arrive in and/or depart from ports in the Member States;
- Proposal for a new support programme "Marco Polo";
- Proposal for a Directive on intermodal loading units;
- Introduction of the "Motorways of the Sea" approach in the Commission White Paper on European Transport Policy for 2010;
- Proposal for a Directive on market access to port services;
- Publication of a Guide to Customs Procedures for Short Sea Shipping;
- Introduction of the New Computerized Transit System (NCTS) in Customs transit; and
- Further development of telematics networks for ports and SSS.

As a result of the above measures, original list of bottlenecks (161) has been reduced to 35 today. Unlike Europe, in Asia full integration of SSS into intermodal door-to-door supply chains still remains to be achieved. This is primarily for the industries to accomplish, but

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[4] Commission of the European Communities (2003), Programme for the Promotion of Short Sea Shipping. Proposal for a Directive of the European parliament and of the Council on Intermodal Loading Units. Korea Shipping Association (2005), Vision and Development Strategy for Innovation of Coastal Shipping. Seoul, Korea.

[5] Commission of the European Communities (2003), op. cit.

efforts at other levels can help the process and alleviate the framework obstacles that hinder SSS from developing faster.

To fully utilize SSS in Asia likewise Europe, a governance system is required to help successfully integrated SSS into logistics chains and offer seamless door-to-door operations. Such system may enable to make logistics chains commercialize by single commercial entities, so-called “one-stop shops”. The system should be designed to offer customers a single contact point that takes responsibility for the whole intermodal chain. Furthermore, the notion of competition between modes should be replaced by complementarities because co-operation between modes is vital in chains involving more than one mode.

IV. SSS Practices by Region and Country

1. Europe

In September 2001 the European Commission presented its “White Paper on European Transport Policy for 2010: time to decide”, which sets a number of ambitious targets to ensure competitiveness and sustainability of mobility.[6] SSS contributes to playing a key role in achieving these targets. The political conviction that Short Sea Shipping is a priority for the European Union was also reconfirmed in the informal meeting of the European Union Transport Ministers in June 2002. The political and business momentum has been maintained.

SSS is currently the only mode that has growth rates comparable to those of road transport. Between 1995 and 2004, the tonne kilometer performance of SSS in the EU-25 grew by 32%, while road performance grew by 35%.

The total volume of SSS of containers declared by EU-25 main ports amounted to 22.2 million TEUs in 2005. In the same year, the SSS of the United Kingdom represented 354 million tonnes of cargo, accounting for 16% of the total SSS of the EU-25. It was followed by Italy, the Netherlands and France with shares of 14%, 11% and 10% respectively, the four countries together represented more than 50% of the EU-25 SSS. With 4.7 million

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[6] Commission of the European Communities (2006), Impact Assessment, Commission Staff Working Document.

TEUs in 2005, Germany led the EU-25 Member States with regard to SSS of containers in volume terms, closely followed by Italy (4.4 million TEUs). Rotterdam was the largest EU-25 port in 2005 in terms of SSS for all types of cargo except Roll-on/Roll-off units. Regarding Roll-on/Roll-off units, the top 5 SSS ports show a preponderance of SSS over the remaining seaborne transport (ocean shipping), with shares above 95%.[7]

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New Concept of SSS in Europe: Motorway of the Sea[8]

The SSS concept is closely linked to the Motorway of the Sea in Europe. The chronological development of the Political and Regulatory Framework that affects SSS began with the creation of the Transport White Paper 2001-2010, "the hour of truth", in which the European Commission proposed the promotion of Short Sea Shipping and the concept of the Motorway of the Sea. The Naples declaration of July 2003 defined the Motorway of the Sea "as the maritime segment that connects two ports (or any combination of ports as a group of the aforementioned segments) interconnected in turn with trans-European networks and intermodal corridors, that by safeguarding social cohesion, make up an efficient intermodal system in which goods are transferred rapidly between different transport modes through the optimization of port operations, overcoming natural barriers and sensitive areas as well as other geographical obstacles.". In numerous declarations, agreements between countries and reports followed by the Paper, an attempt has been made to crystallize this promotion, the most recent milestone of which has been the inclusion of the Motorways of the Sea within the trans-European Transport Network in April 2004.

The Motorways of the Sea includes inland rail and/or inland waterways freight transport services thereby contributing to more sustainable and integrated door-to-door services.[9] Its key objective aims to concentrate the flow of goods in maritime-based logistic links, by achieving benefits generated by the SSS system and eliminating barriers to the SSS development as described above. In implementing the concept of the Motorway of the Sea, it requires the following actions:

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7 Amerini, G. (2006), "Short Sea Shipping of Goods, 2000-2005", Statistics in Focus; Transport, 12/2006.

8 Commission of the European Communities (2006), Impact Assessment, Commission Staff Working Document.

9 Commission of the European Communities (2006), Impact Assessment, Commission Staff Working Document, Commission of the European Communities (2003), Programme for the Promotion of Short Sea Shipping, Communication from the Commission.

- the identification of existing or new and viable maritime links;
- a systematic analysis of the needs of social and economic actors engaged in the new maritime links;
- the identification of the criteria and needs for the implementation of the Motorways of the Sea, essential for the identification of ports to be integrated into the logistic chain of the Motorways of the Sea, taking into account the characteristics of each Motorway of the Sea corridor;
- the selection of Motorways of the Sea links for ensuring port competition, open and transparent;
- the in-depth analysis of the Motorways of the Sea projects from a financial, legal and technical point of view and coordination of community, national, regional and private sector investments for financing the implementation of the Motorways of the Sea;
- the removal of the remaining obstacles that hinder the development of Motorways of the Sea, e.g. by reducing administrative burdens for customs and inspections and by developing electronic one stop shops.

It is helpful to draw useful lessons from the Motorway of the Sea and SSS practices in Europe in order to promote and develop SSS in Asia.

2. Summary of SSS workshop

This Section deals with a summary of major findings from major papers about short sea shipping presented at the international conference organized by the authors on "Strategies to Develop Incheon as a Logistics Hub in Northeast Asia: Short Sea Shipping Approach", October 13-14, 2004 in Korea.

China[10]

[10] Rimmer, P. (2004), China's Changing Regional and International Shipping Connections 1999-2000. Incheon International Logistics Seminar: "Strategies to Develop Incheon as Logistics Hub in Northeast Asia: Short Sea Shipping Approach", organized by Jungseok Research Institute, Inha University, Incheon Korea.

Following an analysis of the company's restructuring of the state-owned China Ocean Shipping (Group) Company (Cosco) and its post-1993 offshoot Cosco Container Lines Company Ltd (Coscon), Rimmer

(2004) undertakes an analysis of changes in both extra- and intra-Asian shipping patterns between 1990 and 2000.The choice of this group is apposite not only because it includes China's leading container carrier but also because the company's strategic adjustments to its intra- and extra-Asian shipping patterns closely parallel shifts in the country's economic geography and the increasingly competitive global economic environment.

The accelerate
d growth of Chinese economy has both influenced and mirrored changes in the scope and operation of China's shipping connections within Asia and with the rest of the world between 1990 and 2000, causing the repercussions on China's extra- and intra-Asian container shipping networks.

In elaborating the maritime environment within which China's leading shipping company operates the country's container ports are allocated to one of three regions or port ranges: the northern range around the Bohai Rim, the central range focused on the Yangzi River Delta and southern range centred on the Pearl River delta. In 1990 Cosco's pattern of extra-Asian shipping services was relative simple. Only three ports - Xingang, Shanghai and Hong Kong, China - were dominant as international hubs. A feature of the trunk Trans-Pacific and Trans-Suez routes, operated jointly by Coscon with Japan's K-Line and Chinese Taipei's Yangming Line, has been the integration of Chinese ports into its schedules as direct ports of call. They include Qingdao and Xingang (Tianjin) in the northern range of ports around the Bohai Rim; Shanghai and Ningbo in the central range on the Yangzi, and Yantian and Shekou in the southern range focused on the Pearl River delta.

All intra-Asian services could be defined as short-sea liner trades. Most countries are located within two to three days reach of Shanghai or Kobe by ships with a speed of 12 knots with a ten-day voyage on the longest route between Kobe and Jakarta.

Overall volume of the Asian short-sea trades grew rapidly during the 1990s with an increasing share of extra-Asian traffic in addition to the intra-regional trades. A JAMRI report[11] argued the region had great potential from a long-term perspective. The key indicators were high-speed growth, the trend towards a bloc economy in the Pacific Basin, the high degree of export ties among Asian economies, higher levels of income to boost consumption and liner cargoes, and strong competitive pressure among shippers.

In the Cosco's intra-Asian shipping network, six routes operated between Northeast Asia and Southeast Asia, including a weekly service between Bangkok and Singapore. Marked ties between China and Japan were revealed by the presence of more than 37 monthly services, the Kobe-Yokohama-Hong Kong, China triangle being pivotal to the network. Inland, the domestic connections were limited in China, and the network's threshold did not extend beyond the country's coastal area. There were only three inland waterborne connections and all of them radiated from Hong Kong, China. These linked the hub port with Zhangjiagang and Wuhan in the Yangzi River delta, and Huangpu in the Pearl River delta.

By 2000 Coscon's feeder and local cargoes were sufficient for the carrier to be ranked among the region's 'millionaire' TEU carriers. However, the carrier's extensive intra-Asian network was under close scrutiny as the carrier sought ways to turn its loss-making operation around. Excluding the company's fleet of barges and inland waterway vessels plying the Yangzi River and Pearl River delta, the company was deploying fifty vessels with an aggregate capacity of 40,000 TEUs. Between 1990 and 2000 Coscon increased its weekly liner services from twenty to fifty-six between 1990 and 2000, deploying larger vessels on several routes, particularly within the China-Japan-Korea triangle.

More specifically, several services — referred to as the Green Express — are offered between China's Shandong ports of Qingdao and Lianyungang and the Japan's metropolitan cores of Keihin (Tokyo/Yokohama) and Hanshin (Kobe/Osaka).

Coscon has intensified traffic within a fully-fledged domestic cabotage maritime circuit between the three port ranges of the Bohai Rim, the Yangzi River delta and the Pearl River delta. This process has confirmed Qingdao, Shanghai and Hong Kong, China as national hubs, the indisputable pivots within these ranges for a large number of domestic links and the bases for tangential services to secondary ports.

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[11] Yamada, H. (1989), Perspective on the short-sea liner trades in Asia, Marintec China, 1989, Shanghai 30 November 1989, unpublished paper

Coscon is bolstering its regional policy by investing in marine terminals, container depots and related service companies. Besides its long standing Hong Kong, China base, the carrier has equity interests in both the ports of Shanghai and Yantai and a financial interest is being sought in the PSA (Port of Singapore Authority) Corporation. As depth problems have limited Coscon's hub development in the largest port of Shanghai, the company is seeking to be involved in the new deepwater cargo handling complex being built at Shanghai's Yangshan deepwater port on the islands of Xiao Yang Shan and Da Yang Shan because the Yangzi region is expected to generate 14.6 million TEUs by 2010 (Fossey, 2000). The realisation of these developments could lead to an overhaul of Coscon's intra-Asian liner services.

Coscon's services can become a realistic choice in multimodal logistical transport chains in the intra-Asian market by building on the strengths of the short-sea liner trades and minimizing any weaknesses.

Hong Kong, China[12]

In their recent survey of multinational corporations' locational preference for regional distribution centers, Oum and Park[13] (2004) identified seven critical determinants for locating distribution centers:

- geo-location, transport and market accessibility;
- market size and growth potential of catchment region;
- port, airport and intermodal transport facilities;
- skill labor force, labor quality, and labor peace;
- modern logistics service providers and costs;
- pro-business government and officials; and
- political stability.

On the basis of the above criteria, Kam (2004) argues that, though Hong Kong, China is well endowed with the above critical qualities, its strength as an international logistic hub

[12] Kam, B. (2004), Competitive Strength of Hong Kong, China as a Regional Logistics Hub. Incheon International Logistics Seminar: "Strategies to Develop Incheon as Logistics Hub in Northeast Asia: Short Sea Shipping Approach", organized by Jungseok Research Institute, Inha University, Incheon Korea.

[13] Oum, T. H. and J.-H. Park (2004) "Multinational Firms' Locational Preference for Regional Distribution Centers: Focus on the Northeast Asian Region", Transportaion Research Part E, Vol. 40. pp. 101-121.

in the coming decade lies not in having the above qualities, but more so, in its ability to harness the potential inherent in these qualities. This argument is put forth in light of two major economic events occurring in the region:

- the challenge posed by the growing significance of the ports of Shenzhen (Yantian, Shekou, Chiwan, and Mawan) in the Pearl River Delta (PRD) region, from which Hong Kong, China currently derives the bulk of mainland China's re-export; and
- China's accession to the World Trade Organization (WTO), which has resulted in China making substantial market access commitments in several economic sectors, including industrial, services and agricultural.

The burgeoning economic development in Southern China, especially the PRD region, is making a threat to the increase of container throughput at the Hong Kong, China. In its current state, the Yantian port has a number of advantages over the port of Hong Kong two of the most significant are low cost and less logistical friction. Not only are land and labor costs considerably higher in Hong Kong, China, its terminal handling charges are among the most expensive in the world. Nonetheless, Seabrooke et al. (2003) contends that the continuous growth of the total cargo pool in the South China region will result in growth of cargo volume in Hong Kong, China, even after accounting for the diversion of cargo into Yantian and other neighboring ports. Hong Kong cargo movement will continue to increase every year through the next decade, albeit at a slower pace.

Hong Kong, China is expected to have the ability to respond to the growing competition through its innovative ingenuity. This is already evident in two aspects: the increased use of river barges to lower transport cost between Hong Kong, China and its PRD hinterland, and the penetration to mainland ports by Hong Kong port operators. In addition, because of Hong Kong's established trading networks, legal system, ease of communications, and efficient support services and with China's accession to the WTO, Zhang (2003) envisaged that China's international trade and investment would further expand and Hong Kong, China would be playing a key role in providing trading services. In this regard, so long as Hong Kong, China is able to continue to attract international logistics operators to base its regional or international operations in Hong Kong, China, the seaport of Hong Kong, China should be able to continue to maintain a competitive edge over the growing seaports in Southern China. In doing so, SSS development in association with the efficiency of entire shipping chain - barging, trucking, consolidating, and other logistics - is critical to attract transhipment cargo for ports in this region.

Japan[14]

Watanabe (2004) examines activities and networks of the Japanese short sea shipping for possibilities to promote innovated logistics links between Japan and the Northeast Asia and argues that most of the Japanese short sea shipping is composed of RORO or Ferry transportation which is essential for the domestic transportation in Japan. The Japanese short sea shipping network comprehensively covers all around the country from the north to the south in 3000 km range. The network involves 23 routes, 48 operators, 101 ships, 112 ports and 196 sailings per week. It also functions to effectively connect each greater economic region. Therefore, shippers who produce high technological goods in a certain region can easily access to other economic regions by the network without suffering from the expensive transportation cost that could occur if the road transportation was used between the regions. On the other hand, shippers who produce agricultural/fishery products in local less populated area can greatly benefit from the network to reach markets in metropolitan areas over long distance. The landscape of Japan is also advantageous for such shippers to use the network because it is long and thin shaped land. The distance between a coast side and opposite one is relatively shorter in any place in the country. This is the greatest advantage when they need to combine the network with the road transportation to reach final destinations that are located inland.

The majority of ships operated by the SSS in Japan are RORO, Ferry and conventional boats. The size and the capacity of them are moderate and handy to accommodate local niche cargo demand. Therefore, most of the ports called by the SSS are relatively smaller ports in local areas even though some routes call bigger ones like the Port of Tokyo. In contrast, most of the container ports are intensively located in the proximity to the greater metropolitan areas, i.e., Tokyo, Yokohama, Nagoya, Osaka, Kobe, Kitakyushu and Hakata. It is very simple of this reason to explain that such metropolitan economy in Japan has deeply depended on the trade with the United States and Europe since after the World War II and the intermodal container transportation has been the best way to

[14] Watanabe, Y. (2004), Japanese Short Sea Shipping, How It Works. Incheon International Logistics Seminar: "Strategies to Develop Incheon as Logistics Hub in Northeast Asia: Short Sea Shipping Approach", organized by Jungseok Research Institute, Inha University, Incheon Korea..

export/import over such intercontinental routes. Since any container port needs great investment to develop, economically stronger metropolitan areas can only afford to invest in the development of bigger container ports.

Because of the above reason, there is obviously big difference in the port of call between the short sea shipping and the container transportation in Japan. The former calls almost every port in Japan whereas the later frequently calls only bigger container ports in the metropolitan area. There is another fact that smaller container ports existed in local areas of Japan have been always called by feeder shipping lines from Korea and China but have very few network established between the major bigger ports in the country, i.e., such container ports have poor ability to attract customers in the metropolitan areas. This is also important point to argue about how the Japanese short sea shipping works. Watanabe points out the reality that the Japanese short sea shipping has been well developed and then suggests the evidence of great possibilities to create the international short sea shipping network in the Northeast Asia.

IV. Concluding Remark

Owing to development of mega-hub ports in Asia and fast economic growth rate in Asia, necessity to construct sustainable intermodal transport system is growing based on strengthening of SSS in order to shift traffic away from road transport which causes high external costs. In this chapter, having identified benefits of SSS and barriers to development of SSS system, we have learned how to solve the barriers based on the lessons drawn from the European case. Governments and public transportation sector may make the primary decision for planning and financing projects of SSS to enhance freight mobility, by a consistent and comprehensive investment approach to identify, evaluate, and implement competing projects, including potential SSS projects. In doing so, in particular, governments can play a leading role in promoting SSS transportation system by interacting with public entities using established communication channels and other mechanisms and preparing legal regulations and procedures for the SSS. A brief review of SSS practices in China, Japan, and Hong Kong, China, (as for Korean SSS, see next section) and Europe has led to seek an SSS viable option for establishing fully integrated logistics chains in Asia.

Korea's Strategic Plan to be Northeast Asia's Logistics Hub:

Toward the Pentaport Approach

I. Introduction

Initially, this report describes key elements of Korea's strategic plan to become Northeast Asia's logistics hub.[15] Then the report proceeds to detail how this national plan is being worked out within the Incheon area by the adoption of the five-pronged Pentaport approach that combines a seaport, airport, technoport, business port and leisure port into a single complex. Finally, areas of future research necessary for implementing Pentaport model in the Incheon area are identified in a concluding comment, which also summarizes proposed collaborative work with the University of Washington. Before detailing Korea's hub strategy it is important to begin by outlining the key maritime developments in East Asia that led to its inception.

II. Korea's Hub Strategy

Port competition has prompted Korean government to adopt a hub strategy. As shipping dominated Korea's international trade this policy was not focused on the then minor port of Incheon but on Busan and the new port of Gwangyang. This observation is borne by an examination of Korea's container throughput and port facilities, container port development plans, and port privatisation and other strategies.

[15] This report was originally written to stimulate discussions among the participants attending the joint Workshop between the Inha University and the University of Washington in 2003. Since then the report has been revised and adapted to the thrust of this report by taking account of the Workshop discussions and the comments of reviewers.

1. Container Throughput and Port Facilities

In 2001 Korea's container throughput was 9.7 million TEUs. The Port of Busan handled 82% of the national total (7.95 million TEUs or 8.07 million of the coastal container trade is included and ranked third in the world behind Hong Kong, China and Singapore after surpassing the Port of Kaohsiung. Busan's share of the national total has been experiencing a slight decline due to inception of Gwangyang as the country's second hub (see Table 2).

Table 2. Container throughput by port in Korea

Year	National TEUs (%)	Busan TEUs (%)	Incheon TEUs (%)	Ulsan TEUs (%)	Gwangyang TEUs (%)	Others TEUs / (%)
1995	4,800,977 (100.0)	4,502,596 (93.8)	236.641 (4.9)	42.567	-	19,173 (0.4)
1996	5,202,898 (100.0)	4,760,507 (91.5)	348,727 (6.7)	47,003 (0.9)	-	46,661 (0.9)
1997	5,820,725 (100.0)	5,233,880 (89.9)	432,795 (7.4)	93,009 (1.6)	-	61,041 (1.1)
1998	6,371,535 (100.0)	5,752,955 (90.3)	401,536 (6.3)	125,829 (2.0)	32,135 (0.5)	59,080 (0.9)
1999	7,393,323 (100.0)	6,310,664 (85.4)	447,162 (6.0)	149,493 (2.0)	415,399 (5.6)	70,605 (1.0)
2000	8,842,628 (100.0)	7,424,871 (84.0)	483,324 (5.5)	236,296 (2.7)	615,327 (7.0)	82,692 (1.0)
2001	9,701,533 (100.0)	7,953,624 (82.0)	537,786 (5.5)	258,468 (2.7)	811,178 (8.4)	140,477 (1.4)

Note: Coastal container cargo (domestic trade) is excluded.

**Source*: Korea Container Terminal Authority

In April 2002 six specialized container terminals in Busan had an annual capacity of 4.66 million TEUs. Since Busan's throughput has surpassed the total capacity of the six specialized terminals, conventional piers have had to be used handling the overflow of 2.6 million TEUs to supplement the gap between supply and demand of container port facilities within the city of Busan. The characteristics of the six container terminals in Busan and those in Gwangyang are shown in Table 3.

Table 3. Characteristics of specialized container terminals in Busan and Gwangyang, April 2002

	The Port of Busan						Gwangyang	
	Jasung -dae	Shinsun -dae	Gamman	New Gamman	Uam	Kam-chon	First Phase	Second P.(II-I)
Construction Period	'74-'96	'85-'97	'91-'97	'95-2001	'95-'99	'88-'97	'87-'2001	'95-2001
Operational	Sep, 1978	June, 1991	April, 1998	April, 2004	Sep., 1996	Nov., 1997	July, 1998	April,2002
Operator	Hutchison	PECT	4+ companies	Dongbu	WTC	Hanjin	4+ companies	KIT, Dongbu
Quay length	1,447 m	1,200 m	1,400 m	826 m	500 m	600 m	1,400 m	1,150 m
Water depth	12.5 m	14-15 m	15 m	12-15 m	11 m	13 m	15 m	12-15 m
Annual Capacity	1.0 mil. TEU	1.2 mil. TEU	1.2 mil. TEU	0.65 mil. TEU	0.27 mil. TEU	0.34 mil. TEU	1.2 mil. TEU	0.81 mil. TEU
Berthing Capacity	50,000 DWT*4; 10,000 DWT*1	50,000 DWT*4	50,000 DWT*4	50,000 DWT*2 5,000 DWT*1	20,000 DWT*1 5,000 DWT*2	50,000 DWT*2	50,000 DWT*4	50,000 DWT*2 20,000 DWT*2
Con. Cranes	11	11	12	7	4	4	8	

Note: + HJ (Hanjin), Hutchison, Sebang, Korea Express

**Source*: Korea Container Terminal Authority

Table 3 shows that three terminals in Busan can handle about one million TEUs, respectively, with each terminal capable of accommodating four 50,000 dwt ships. The other three terminals can handle 3,000 to 6,000 TEUs per terminal. The Jasungdae terminal was developed in two phases as the country's first specialized container terminal. Originally, it operated by a state-run company before its privatization in September 1999.

The Port of Busan lacks container yard areas within the terminal and therefore, most of containers have to be transferred to the 26 Off-Dock Container Yards (ODCY) dispersed throughout the city and it environs. This dispersal increases traffic congestion within the city.

2. Container Port Development Plans

To ensure that Korea has the port facility capacity to meet the growing demands of shippers, the Ministry of Maritime Affairs and Fisheries (MOMAF) has sought to:

- develop Busan and Gwangyang as the twin hub ports in the so called Two-Port System;
- establish feeder service system;
- forge connections with the inland transportation system;
- attract private capital for timely development of several ports; and
- develop and introduce duty-free zones in the hinterland with a view to alleviating congestion in the hub ports (Y. Kim 2000).

Within framework of the Two Port System, Busan plans to develop Gaduk New Container Port in two phases by 2011, with a view to providing 30 berths with an annual capacity of 6.0 million TEUs. The eight berths at Gwangyang, built between 1995 and 2003 (first phase 4 berths, second phase stage one (II-I), will be augmented by the second phase stage one two plan (II-II). This development will provide two berths for 50,000 dwt ship class and another two berths for 20,000 dwt ship class, resulting in the annual capacity of 3.02 million TEUs in total.

In 1991 the Korean government established Korea Container Terminal Authority (KCTA) to expedite the construction of container port facilities and to manage all container terminals in Korea. Before 1991, port income from the container terminals together with the proceeds from the general cargo and bulk terminals were transferred directly to the National Treasury, which is controlled by the Ministry of Economy and Finance (MOFE). The Budget Authority allocated the entire funds for the development and operation of ports. However, securing the allocation of the port budget involved interminable wrangling as the process not only involved the Budget Authority but also ministerial discussions and consent from the Korean Parliament. Under these arrangements it was very difficult to obtain sufficient finance for port development because it ranked lowly against other types of infrastructure.

The establishment of the KCTA changed these circumstances. The Authority was allowed to assume control over the existing container terminals from the then Korea Maritime and Port Authority (KMPA) without payment. Consequently, the Authority took over the management of Jasungdae, and Shinsundae terminals and the semi-exclusive container terminal in the Port of Incheon (terminal 4).[16] As the Authority was given the right to issue government guaranteed bonds to finance container port investment it was able to attract huge funds from international financial institutions. Also KCTA had the right to lease terminals to the private sector for rent because its role was to manage terminals but not to operate them. Finally, the Authority was empowered to construct new container terminals (H. Kim 2000). Since its inception the Authority has developed 22 berths in both Busan and Gwangyang including Gamman Terminal, Uam Terminal and Gwangyang Port Terminals. The Authority is expected to play a leading role in the future container terminal developments outlined in Table 4.

[16] In 1996 the Korea Maritime and Port Authority (KMPA) became part of the Ministry of Maritime Affairs and Fisheries (MOMAF).

Table 4. Korea's container development plan (number of berths)

	Busan				Gwangyang				Total			
Financial source	G.	K	P	total	G.	K	P	total	G.	K	P.	total
Till '01	7	14	-	21	-	8	-	8	7	22	-	29
2002-11	12	8	10	30	-	25	-	25	12	33	10	55
Total	19	22	10	51	-	33	-	33	19	55	10	84

**Source*: KCTA

Note: G. stands for government; K for KCTA; P for private sectors.

The Korean government has ambitious plans for developing Busan and Gwangyang as a twin port regional hub complex. Not only is Busan the cheapest cargo handling port in East Asia after Shanghai but also it is an important transhipment port (KMI 1999, KCTA, 2000). In 2001 2,94 million TEUs of the 8.07 million TEUs handled by Busan were transhipments — 36% of the total (Table 5). This sharp increase in transhipments led to Busan leapfrogging Kaohsiung in to third position in the world container port rankings.

Table 5. Container throughput in Korea, 1998-2000 (Units in 10,000 TEUs)

		1998	1999	2000(a)	2001(b)	Growth (b/a)
National Total	Total cargo	673	767	912	999	1.10
	T/S	(127)	(166)	(245)	(311)	1.27
Busan	Total	595	644	754	807	1.07
	T/S	(127)	(163)	(239)	(294)	1.23
Gwangyang	Total	11	48	68	86	1.26
	T/S	(0)	(3)	(6)	(17)	2.83
Others	Total	67	75	90	106	1.17
	T/S	(0)	(0)	(0)	(0)	

**Source*: Kim, H. (2000)

This upsurge in transhipments has prompted the Korean government to amend it original container forecasts (see Table 6). To accommodate the expected increase in throughput, the government has boosted the required annual berth productivity from 250,000 TEUs to 300,000 TEUs to reduce the necessity of building new terminals

Table 6. Amended prediction container cargo in Korea (Units in 1,000 TEUs)

1999 (actual)		2001	2006	2011	Growth (%)
Original prediction	7,670	9,854	13,955	19,224	7.9%
	(1,661)	(1,740)	(2,663)	(4,076)	(7.8%)
Amended prediction	7,670	11,031	19,266	29,668	11.9%
	(1,661)	(3,219)	(8,005)	(13,176)	(18.8%)

**Source:* MOMAF

Note: Parenthesis indicates transhipment cargoes.

3. Port Privatization and Other Strategies in Korea.

In 2001 container cargoes in Korea were transported predominantly by highway (86.6%) and then railway (11.0%); coastal shipping handled only 2.4%. This heavy reliance on roads caused congestion, pollution and other types of environmental stress. To resolve this problem, the government is seeking to increase coastal shipping's proportion of the domestic transportation of containers. Also, the government has sought to induce private investment in port construction from both domestic and foreign sources. The government seeks to attract foreign investment to both the second phase of the Gwangyang port development and new port developments in Busan, where already a consortium of private companies is constructing ten berths (see Table 3).

Simultaneously, the government has been attempting to privatize ports. Private companies have been allowed to takeover port operations, and port development and management have been delegated to local municipalities, such as Busan and Incheon. The delegation to municipalities, however, has been protracted because of differing views between central agencies and local governments over the financial clearance of accumulated debts. The most conspicuous obstacle to private sector participation has been the attitude of the docker's union. The union has resisted the decasualization policy proposed by the government. To cope with this situation, the government plans a fundamental overhaul of the docker's current employment system. Three new berths in New Gamman Terminal and four new berths in the port of Gwangyang are already being operated by private companies.

In 2002 the government introduced Customs Free Zones (CFZs) not only in Busan and Gwangyang but also in Incheon. The main purpose of these CFZs is to stimulate a wider range of activities such as those operating in competing East Asian ports to meet the demand of their customers for a more efficient control over supply chain management. As this approach is so recent, it is difficult gauge its likely impact. However, the success of the introduction of the CFZs in other East Asian countries augurs well for their future in Korea.

III. Pentaport Approach in Incheon Area

It was not until the implementation of the CFZs that Incheon figured prominently in Korea's hub strategy. The opening of the new Incheon International Airport in March 2001 revived the prospects of revitalizing the Port of Incheon, constrained by vessels having to enter into a dock complex because of the marked difference in the tidal range between high and low water. With the proposed technoport, the City of Incheon is now conspicuously well placed to become a logistical platform to serve Seoul and to cater for the burgeoning trade with China. These prospects were enhanced with the proposed addition of a leisure port and a business port to the complex that was called Pentaport (literally a five–pronged port). Seoung-Yong Hong, now President of Inha University, conceived this wider concept when formulating Korea's long-term visionary plan for the Ministry of Maritime Affairs and Fisheries (MOMAF) as its then Vice-Minister. In 2000 the Pentaport plan was announced formally in *Ocean Korea 21* (OK 21) — a blueprint to guide MOMAF's policy implementation.

1. Pentaport

The Pentaport prospect is buoyed by major long-term trends in world history. While the Mediterranean Sea is the Sea of History and the Atlantic Ocean is the Sea of the Past Era, the Pacific Ocean is that not only Sea of the Present but also the Sea of the Future. Today the economies encompassed by the Asian Pacific Economic Cooperation (APEC) forum account for 50% of world trade and 65% of world gross domestic product (GDP) and, therefore, provide the economic backbone of the contemporary world. Northeast Asia is the core growth engine as the region contributed 17 % to world GDP in 2000 with the expectation of 30% in 2010.

The remarkable economic growth of Northeast Asia is attributed to several factors. First and foremost has been the advent of WTO, which has stimulated free trade around the world. Likewise, Free Trade Agreements developed primarily in North America and Europe have also contributed considerably to expanding world trade. China's recent entry into the WTO is likely to accelerate Northeast Asia's economic growth. Secondly, the digital economy is playing a pivotal role in expanding the world trade. In 1999 E-commerce via the Internet has reached US$95 billion and is projected to be US$132 billon in 2003. Thirdly, Northeast Asia has become the economic growth engine for the world economy, attracting Foreign Direct Investment (FDI) from global companies. Intra-regional trade within Northeast Asia has also experienced a sharp increase. Fourthly, the region's logistics infrastructure has been improved though there is still need for integration between different modes and sub-regions. Not only are the world's five largest container ports located in East Asia but also Korea, Japan and Hong Kong, China have constructed world-ranking hub airports, and China and Chinese Taipei have similar plans. The United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) is pursuing projects to complete the Trans-Asia railway and highway systems. Already railway systems are providing a landbridge between Asia and Europe, notably the Trans Siberian Railway (TSR) and the Trans China Railway (TCR). Also the two Koreas are opening up the Trans Korea Railway (TKR) by reconnecting the original Korean railways that existed until the commencement of the Civil War in 1950. Lastly, major liner shipping companies based in the region provide trunk routes and efficient feeder service networks.

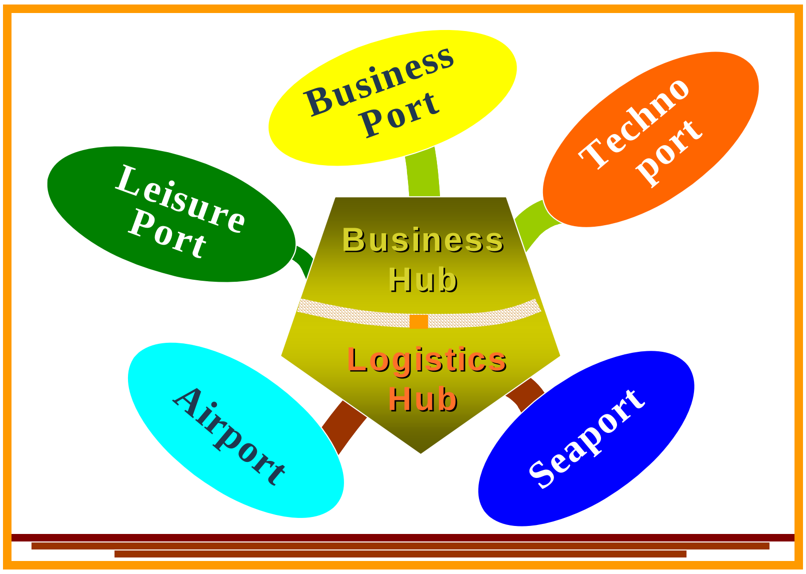
In January 2002 President Kim Dae Jung sought to take advantage of the favourably regional conditions by announcing his plan to transform Korea into Northeast Asia's Business Hub. This plan is designed to develop Korea not only as a logistics hub but also as a banking and financial center and a production base for the region's multinational corporations. In pursuing this plan the government has identified several projects in the Incheon City Hub:

- Songdo New Town in Incheon as high-tech industry area and also international business center;
- Incheon Airport as a key international logistics area;
- Young-Jong Island in Incheon area as commerce and residential area; and
- Kimpo area reclaimed in the vicinity of Incheon as international finance center, and tourism and leisure area.

As noted Incheon has been designated as a CFZ with Busan and Gwangyang. All official documents in these Zones are in English and independent administrative units have been established to ensure that the Zones will be transformed into cities that meet international standards. Thus the overall aim is to develop Korea into Northeast Asia's international logistics center and business center.

Clearly, Incheon is ideally suited to the implementation of all aspects of the government's plan for a Northeast Asian Logistics and Business Hub because it has already has a long-standing seaport with modernized facilities, a state-of-the art airport and is a designated center for international business, leisure, high-tech (knowledge-based) industries and nominated both a CFZ and a FEZ. Thus it was but a short step to package the traditional seaport and airport areas with three additional functional ones to make five ports (therefore called Pentaport). As noted, the Pentaport concept comprises: (1) Seaport, (2) Airport, (3) Business Port, (4) Technoport, and (5) Leisure Port. This concept is one step beyond the Triport — Seaport, Airport and Teleport — advertised by the City of Incheon during the mayor's election campaign in the early 1990s, and the Dutch Brainport comprising Seaport, Airport and Distripark. This suggests that Pentaport offers the most advanced concept and approach to regional development, interlinking different modes and clusters of futuristic industries via advanced telecommunications networks in a single place. Such an approach will have a marked synergistic effect substantiating the economic theory that states improved transportation systems together with a clustering of business, education, research, leisure and other socio/techno-economic activities can facilitate increased trade and economic growth within a given region (Browning, 2003).

Figure 1. Pentaport



Courtesy: Seung-Hee Lee.

Arguably, the Pentaport approach is unique. Similar changes, however, can be foreseen elsewhere. These areas include the Greater Seattle region with its: seaports (Seattle and Tacoma), airport (SeaTac), logistics facilities in the Kent/Auburn Valley, high-tech companies (Microsoft and Boeing), rapidly growing cruise industry, and dependence upon international business and higher education facilities (University of Washington) (see

Browning, 2003). Other examples occur in Singapore, Hong Kong, China, New York, London, Rotterdam and Tokyo. Thus, the Pentaport approach may loom large as an ideal future regional development framework around the world even though Korea seems to be in the vanguard.

2. Strategies

Given Korea's pathfinder's role a more elaborate discussion is provided of the strategies adopted to develop the Pentaport concept. Although each component — airport, seaport, business port, technoport and leisure port — is discussed separately all five are integrated into the logistics hub/business hub.

- Airport

Since its inception in 2002 the Incheon International Airport has handled 170,000 planes, 27 million passengers and 1.7 million tons of cargo. According to an evaluation by the International Air Transport Association (IATA), the airport ranked fourth in the world in customer satisfaction. After the completion of the airport's final phase of development in 2010 the airport is expected to handle 530,000 planes, 100 million passengers and 7 million tons of cargo annually. Incheon's progress is benchmarked on Amsterdam, which expects to increase its sea/air transhipments from 2,000 tons in 1992 to 18,000 tons in 2010. By 2010 Incheon anticipates it will handle between 10,000 TEUs and 50,000 TEUs sea/air transhipments, which will realize US$100-500 million in value-added terms.

- Seaport

Incheon is developing into main feeder port of international shipping routes, networking with the Busan and Gwangyang in Korea and a range of Chinese ports on the Yellow Sea.

By developing Songdo New Port, Incheon is able to specialize in coastal cargoes enabling freight forwarder to substitute land transport by shipping in inland freight transportation. Also Incheon is positioned strategically to boost its transhipment cargoes to and from China, particularly by establishing efficient SSS routes. The SSS system has been developed in the European Commission for several years and similar efforts are being made in USA, particularly on the Gulf Coast.[17] To build up efficient SSS system in Yellow Sea Rim economies requires advanced technologies such as a train-ferry service system, floating container terminals because of the significant tidal differences in the Yellow Sea, and high-speed container vessels. These technologies have been developed in Europe and Japan. In addition, the SSS system needs to develop faster handling of container cargoes in the terminals and to standardize institutional arrangements among the region's ports.

- Business Port

A threefold strategy has been developed for the business port. First, MOFE designated on August 5, 2003 the three districts of Songdo, Yeongjong and Cheongna covering 209.5 km^2 in the Incheon area as a Free Economic Zone (FEZ). The Zone's development is scheduled for completion by 2020. The Songdo district has been chosen for cutting-edge industries including international business and IT, the Yeongjong district for aviation and international logistics, and the Cheongna district for tourism, leisure and international finance.[18] The Free Economic Zone (FEZ) is likely to increase FDI by providing tax incentives to multinational corporations. In particular, the Korean government aims to attract FDI to logistics, tourism, biotechnology and the international business center. Multinationals, including Gale and VaxGen, have already made substantial investments in the FEZ and AMEC and DHL are expected to follow in the near future.

Secondly, the Incheon CFZ is being designed to attract various logistics service (stevedoring, assembly, processing, packaging) benchmarking Singapore's CFZ in its

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[17] EU Parliament Resolution (A5-0139/2000)

[18] http://english.mofe.go.kr/news/n_body.php?t=eh_news_press&i=485

employment, value-added services and FDI targets. Singapore's CFZ has attracted 6,000 logistics companies, 560,000 employees and $US60 billion in sales revenue. Initially, Incheon is seeking to generate 8,000 jobs and create $US750 million in value-added services. The Incheon International Airport is also being developed to boost a range of logistics businesses, notably stevedoring, transportation, warehousing, display, marketing, processing, parts supply, repair, finance and insurance.

Thirdly, the MOFE's other key strategy is to develop Korea's human resource capacity in both logistics and business by developing the population's multilingual capabilities. The MOFE has announced that it plans to make life more convenient for foreign residents by planning to establish 100 elementary, middle and high schools including five international schools, and three satellite campuses of foreign prestigious universities. Medical facilities, including hospitals, will be expanded. Incheon University, affiliated with the City of Incheon, will move to Songdo New Town to support capacity building within the FEZ. Further, Inha University, affiliated with the Korean Air Line and Hanjin Shipping conglomerate, will open the Asia-Pacific School of Logistics, funded by Ministry of Education. Also Inha University plans to establish the U-7 consortium of universities by its fiftieth anniversary on April, 24, 2004, whose major purpose is to explore collaboration among seven universities worldwide in the areas of faculty and student exchanges, collaborative research and teaching.

- Technoport.

Songdo New Town will be developed into a base for international business and knowledge-based industries. The regional headquarters of multinational corporations and centers of international business will be invited to locate in the New Town, which will feature the networking and clustering of advanced knowledge-based industries, notably Information Technology (IT), Bio-Technology (BT) and Nano-Technology (NT). Some 264 hectares have been allocated to knowledge-based industries in the New Town: 188 hectares will be for IT, BT and NT; 43 hectares for the Techo-Park hosting university and private company research centers; and the remaining 33 hectares for convention centers, exhibition sites and shopping malls. By 2010 the entire New Town area will be connected by an advanced computer network system as befits the state-of-the-art Information and Digital city. Already, significant progress has been made in attracting FDI to the New Town. In 2001 the VaxGen Company from the United States has contracted to invest US$150 million in producing new biotechnology products. Then in 2002, the Gale Company, another company from the United States, has decided to invest $US12.7 billion in an international business center and convention center (with the prospect of a further US$120 billion investment as the site progresses). All sites in the Techno-Park sites have been sold.

- Leisure Port

The leisure port strategy is designed to develop the tourism resources within the Islands of Yong-Yu and Moo, and the reclaimed Gimpo area. The island areas will be major waterfront and marine tourism sites. Therefore, international joint ventures, similar to Disney, Seaworld and Universal Studio, have been sought to meet the exploding marine tourism demand stemming from metropolitan Seoul and China's Yellow Sea Rim. These marine resort areas will host marina facilities and other types of marine recreation amenities on a scale hitherto unparalleled in Korea to usher in the change from the My Car Era to the My Yacht Era. This strategy involves adding waterfront space, leisure functions, marina facilities and high-quality ferry terminals within the seaport. MOFE has announced that 60% of the area of FEZs will be developed into parks, green areas, and leisure and sport facilities to provide residents with a more attractive environment.

IV. Conclusion

This report has described Korea's overall strategic plan to be Northeast Asia's logistics hub before detailing steps in developing the Pentaport approach for the Incheon area, which combines a seaport, airport, technoport, business port and leisure port into a single complex. Areas of future research necessary for implementing the Pentaport model have been identified. Although the Pentaport project is still at conceptual stage, the project has captured academic attention outside Korea. In July 2003 the Pentaport approach was introduced at the Summer Conference of the US Transportation Research Board (TRB).[19] In 2004 the TRB organizers have suggested that an international session should be focused on elucidating the Pentaport approach. Apart from these international initiatives, research has commenced at Inha University in August 2003 funded by MOMAF to formulate a strategic plan to implement the Pentaport model in the Incheon area.

Looking ahead, the Pentaport model leaves still considerable scope for researchers to test hypothetical issues. At worst, conducting research on Pentaport will assist concerned City Hub regions to comprehend and manage major developments in a more comprehensive way. At best, it may provide a paradigm shift that will usher the wider global community into a new world marked by efficiency in logistics, a better quality of life, and sustainability of resources.

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[19] Jesse Browning introduced the workshop between Inha Univ. and Univ. of Washington in the TRB meeting.

PART II

REPORT ON THE PHASE II: CARGO FLOW MODEL OF SHORT SEA SHIPPING IN THE CASE STUDY REGION

1. **Description of Short Sea Shipping Industry in the Case Study**

   - Cargo Flow Analysis of Coastal Shipping in Korea

   - Forecasting of SSS Traffic in Korea and Policy Implications

2. **Optimization Model for The Intermodal Routing Problem of International Container Cargos in Korea Using Genetic Algorithms**

3. **Optimization Model for the Intermodal Routing Problem of International Container Cargoes in Korea Using Linear Programming Model**

REPORT ON THE PHASE II: CARGO FLOW MODEL OF SHORT SEA SHIPPING IN THE CASE STUDY REGION

Description of Short Sea Shipping Industry in the Case Study

Cargo Flow Analysis of Coastal Shipping in Korea

1. Introduction

Logistics in the 21st Century is changing rapidly as a result of globalization and is accompanied by localization. As the process unfolds, only a fewer but larger sea and airports will serve as a hub for economic region with intermodal transportation networks linking local ports and neighboring hinterlands. As the number of post-Panamax vessels calling at hub ports increases, smaller vessels needed for feeder services among small ports and serving hub ports will also increase. Short sea shipping to compete with land transport mode is also becoming important in many regions to reduce road and rail congestion as well as reduce environmental impacts. (Browning and Lee, 2004) The European Union have explored to develop more efficient SSS in the last decade for the region even by abolishing cabotage system, which endowed domestic carriers with invincible monopoly power to carry domestic cargoes in shipping history. Similar trends can be observed in North American continent in recent years. The major reasons for this growing importance of short sea shipping arise from concerns of environment and road-congestion and the need to develop more sustainable mode of transportation.

In recent years, Korean government has initiated a strategy to build a logistic hub of the Northeast Asia in Korea and a great deal of efforts have been made to implement the strategy(Chang 2003). In spite of these efforts, many people argue that there is great inefficiency in transporting international trade cargoes, in particular in the capital region of Korea. Although thirty three per cent of cargoes of national container export and import were generated in this region as of year 2001, most of these cargoes had to be handled in farthest seaports such as the Port of Busan and the Port of Gwangyang rather than its vicinity ports like the Port of Incheon and the Port of Pyeongtaek. This phenomenon causes many problems including road congestion on and damage to major highways between Seoul and Busan, environmental degradation, inefficient infrastructure investment and notably truck drivers' illegal and intentional strike on major highways to block major cargo flows for their bargaining power (the strike started on April 28, 2003 and ended on September 5, 2003.). Under these circumstances, Korean government and industries as well as general public have begun to explore more diverse transportation network for the capital region's cargoes among coastal shipping, railway, truck and also air transportation.

This report describes a research framework of a recently conducted study by our research team on coastal shipping in Korea with a particular focus on cargo flow analysis of the coastal shipping. This research has recently started as a contract project with Ministry of Maritime Affairs and Fisheries. The Ministry is trying to match the balance between the demand for coastal shipping in Korea and supply of vessels since there has been long-standing oversupply problem over the years. Although we should admit in general that the supply of vessels and demand for the vessel service should be matched by free market economy system and nothing to do with the control of market, there are some people including government officials arguing that the imbalance has been caused by too small number of buyers of the service (mostly large scale shippers enjoying monopoly power) and too many number of sellers. They argue that this imbalance can be ascribed to too free entry system of coastal shipping business, which leads to severe competition, price-cutting war and therefore, no incentives and motivations for shipping companies to improve service quality and invest new vessels. They claim that one remedy to resolving this problem can be introduction of more scrupulous market entry system and publishing right amount of shipping fleet on regular basis by government, let's say every five years, to provide coastal shipping companies with guidelines for their vessel investments. To this end, it is the first step to analyze cargo flows of coastal shipping in Korea by port and cargo type. This report intends to describe the research plan for this purpose and discuss potential issues in analyzing the cargo flows and possible options to solve the issues.

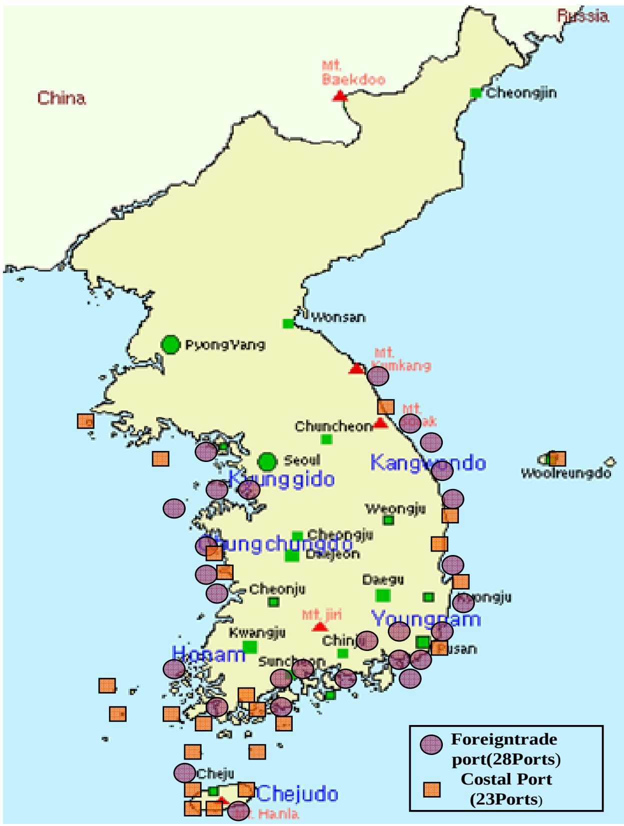
From literature survey, two studies are noteworthy. The first study on the cargo flow analysis on Korea's coastal shipping was done by Lee and Lee (1989). They used data between 1978 and 1987 and it seems a little outdated to use their results today due to the changes in trade pattern and industrial structure since then. Another relevant study is one by Cho (2000). This study described issues and problems facing coastal shipping in Korea, however, did not delve into any level of cargo flow analysis.

This report is structured as follows: Next section deals with current status of coastal shipping in Korea. Section 3 describes methods of cargo flow analysis prior to handling a pilot study on cargo flow analysis at the Port of Incheon in section 4. Finally major issues and possible options are discussed.

2. Coastal shipping in Korea

Statistical Year Book of Maritime Affairs and Fisheries, 2003 shows that there are 28 Foreign Trade Ports including Busan, Incheon, Pohang and Yosu and 23 Coastal Ports (see figure 2). From figure 2, it can be seen that Foreign Trade Ports are developed along the West, South and East coasts of Korea evenly, but the Coastal Ports are concentrated around Mokpo and Wando on the West coast and Jeju Island on the South and Pohang on the East.

Figure 2. Port Location of Korea



The coastal shipping in 2002 transported sand (35.3% of total inbound costal cargoes), oil products (22%), cement (13%), and steel products (8.0%) in the descending order of quantity transported. In terms of total inbound and outbound cargoes by port, the Port of Incheon handled the most cargoes taking 19.8% of the total coastal volume, followed by Gwangyang (10.7%), Ulsan (7.8%) and Busan and the rest of the ports (36.2%).

Table 7. Inbound Costal Cargo Traffic by Cargo Type (2002)

(unit: thousand R/T)

Total (100%)	Natural Sand	Oil Products	Cement	Steel Products	Iron Ores and Other Ores	Crude Oil	Chemical Product	Others
138,296 (100%)	48,764 (35.3%)	30,413 (22.0%)	17,929 (13.0%)	11,117 (8.0%)	10,900 (7.9%)	3,282 (2.4%)	2,514 (1.8%)	13,377 (9.7%)

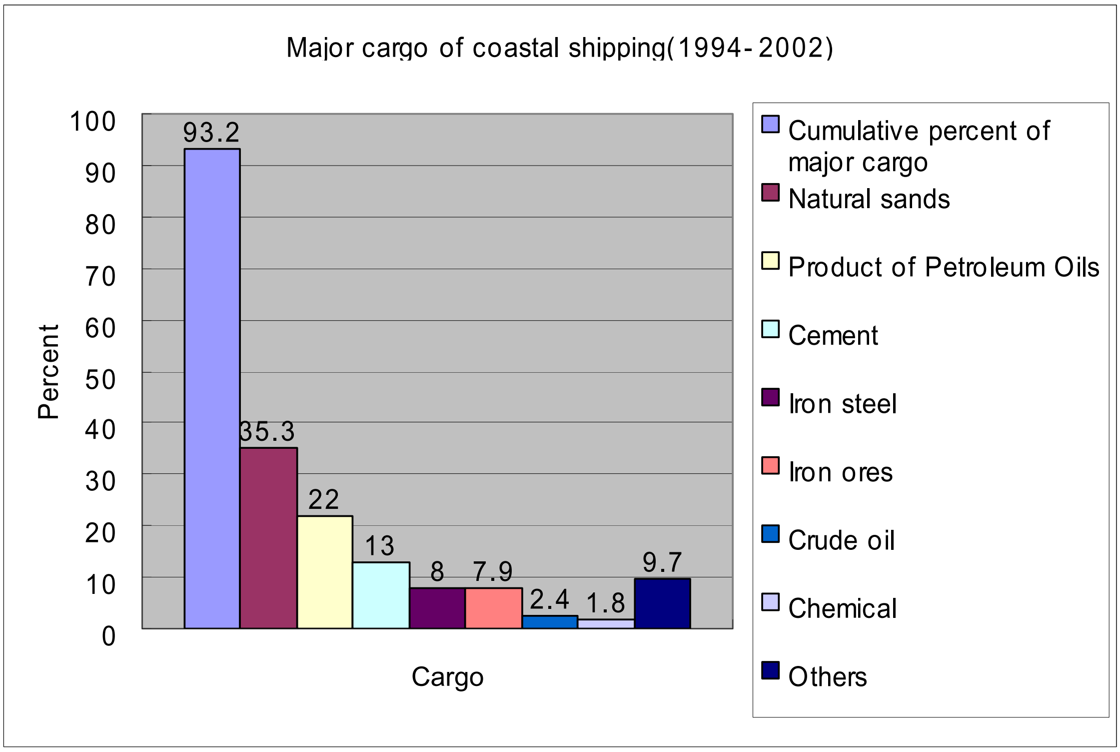
Table 8. Coastal Cargo Handling by Major Port (2002)

(unit: thousand R/T)

Port	Handling	percent	Cumulative percent
Incheon	54,909	19.8	-
Gwangyang	29,689	10.7	30.5
Ulsan	21.434	7.8	38.3
Busan	15,417	5.6	43.9
Pohang	13,215	4.8	48.7
Donghae	10,805	3.9	52.6
Daesan	7,722	2.8	55.4
Masan	6,923	2.5	57.9
Mokpo	6,652	2.4	60.3
Gunsan	5,169	1.9	62.2
Jeju	2,519	0.9	63.1
Yeosu	2,225	0.8	63.9
Others	100,137	36.1	100
Total	276,816	100	-

Major six cargoes comprised 93.2% of the total coastal cargoes over the period of 1994 to 2002 in Korea. This implies that focusing on these six cargoes seem to be sufficient for analyzing the cargo flows for the research to the extent that they can represent major portion of data. However, more difficulties lie in the issue of addressing how many ports should be covered up in the research since there are so numerous small ports and, therefore, taking only major ports' throughput in the sampling of the research would still leave large portion of data not covered like 44.7%.

Figure 3. Major Cargoes of Coastal Shipping in Percentage



The current status of coastal shipping companies as of Dec., 2003 is as follows: There were 927 companies of coastal shipping in Korea, the largest group was sand-carrying companies with 347 companies owning 634 ships, followed by general cargo carrying company group and oil products carrying company group, respectively. In terms of owning number of vessels per company, 675 companies out of 927 total coastal companies owned less than two ships per company comprising 73% of the total fleet. This shows that most of coastal companies are run on a very small scale and this characteristics of small sized business was again seen from the size of capital assets since 72% of the total companies had less than 200 million won capital asset per company.

Table 9. Coastal Shipping by Ship Type (31 Dec 2003)

	Total	Tanker	General Cargo	Sand carrier	Cement carrier	Container	Steel products	Wastes carrier	Tug
No. of companies	927	226	311	347	6	2	9	26	-
No. of ships	2,131	328	420	634	25	7	50	50	617
Ship Tonnage (1,000 G/T)	1,530	468	324	362	129	20	108	70	49

Notes: 752 barges having 482,000 G/T were classified into respective ship type group. Sand carrier group included 433 barges (155,000 G/T) owned by 191 companies used for carrying construction materials within the boundary of port authorities.

Table 10. Number of Companies by Number of Owning Ships

Total	One ship	Two ships	Three	Four	Five	Six and over
927	430	245	94	63	25	70

Table 11. Number of Companies by Size of Capital Asset

(unit: million Won or No. of companies)

Total	50	50 ~ 100	100 ~ 200	200 ~ 300	300 ~ 500	500 ~ 1,000	Over 1,000
927	282	204	177	46	53	43	122

3. Methods of Cargo Flow Analysis

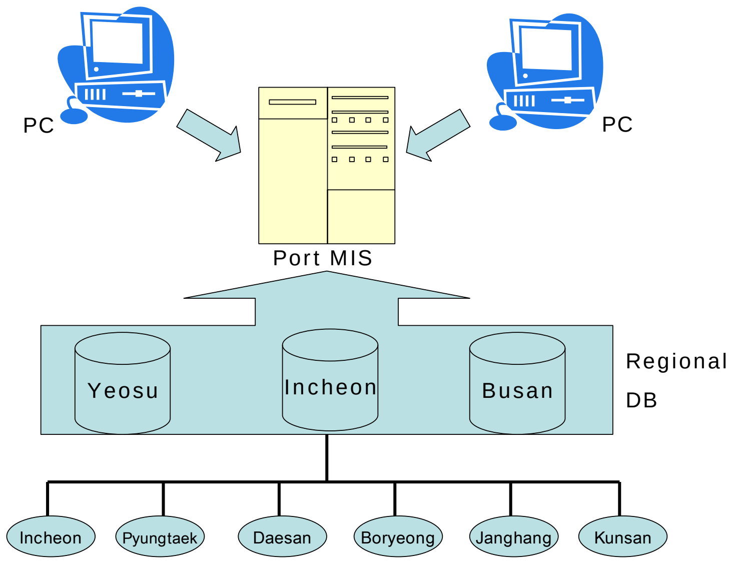
Our research is based on the database of Port-MIS (Management Information System)[20] developed by MOMAF since 1986. The Port-MIS was designed and developed jointly by Korea Maritime Institute (KMI) and Korea Advanced Institute of Science and Technology (KAIST) from 1986 to 1991 through feasibility study. The implementation started in 1992 from the Port of Busan then gradually expanded into other regions till finally covering up the whole nation in 1999. The repercussion of this system was a great deal of reduction in time and cost in handling documentation. For instance, the Port of Busan could reduce the number of required documents from 75 to 22 types after the implementation of the system, resulting in reduction of 3.5 million documents and 25 billion Won of logistics cost annually.

One problem in using the Port-MIS is data loss in the process of integrating data and information from regional data base to central data base since the former excludes detailed level of information available from the latter f-or aggregating purpose on national level. Our research team, therefore, needed to contact staffs of the regional data base management system to collect detailed level of data for cargo flow analysis.

Next diagram shows conceptual structure of Port-MIS system. As shown in the diagram, Port-MIS collects data from three regional database center, namely Busan, Incheon and Yeosu and these regional center aggregates data from individual ports which are controlled by respective regional centers. Once collected and aggregated into central Port-MIS, anyone using internet can have the access to the system. The Port-MIS provides vessel traffic information and port operation information

[20] http://multi.portincheon.go.kr/

Figure 4. Port-MIS in Korea



4. Pilot Study of Cargo Flow Analysis Using Incheon Data

Our research team collected data on the coastal shipping over the period of 1996 to Sept., 2004 from the Incheon Regional Port-MIS database. These data included all coastal shipping using only the Port of Incheon not other ports which are under the authority of the Incheon Regional Port-MIS system. Over the period of seven and half years, the total inbound coastal cargoes were 224,318,000 Revenue Tons (R/T), of which natural sand cargoes were 219,821,000 R/T comprising 98% of the total cargoes. These sand cargoes were originated, for the most part (89%), from other ports. Table 9 shows origin ports of inbound sand cargoes at the Port of Incheon. Figure 5 shows sand was dominating coastal cargoes at the Port of Incheon.

Table 12. Origin ports of inbound sand cargoes at the Port of Incheon

(1996-Sept. 2004)

(Unit: R/T)

Inbound Traffic for Port of Incheon		Natural sand	Distance
Origin port	**Total Throughput for the period**	**Natural sand**	**Distance(km)**
Gunsan	3,715	-	226
Daesan	224,332	4,412	70
Masan	114,914	-	746
Mokpo	7,420	-	432
Busan	61,933	4,601	752
Yeosu	1,410,170	-	620
Ulsan	930,682	-	806
Jeju	16,520	-	489
Pyeongtaek	7,871	-	70
Pohang	709,280	-	900
Incheon	24,214,436	24,147,872	1
Others	196,617,431	195,664,854	-
TOTAL	224,318,694	219,821,739	

Figure 5. Coastal Shipping Cargoes at the Port of Incheon

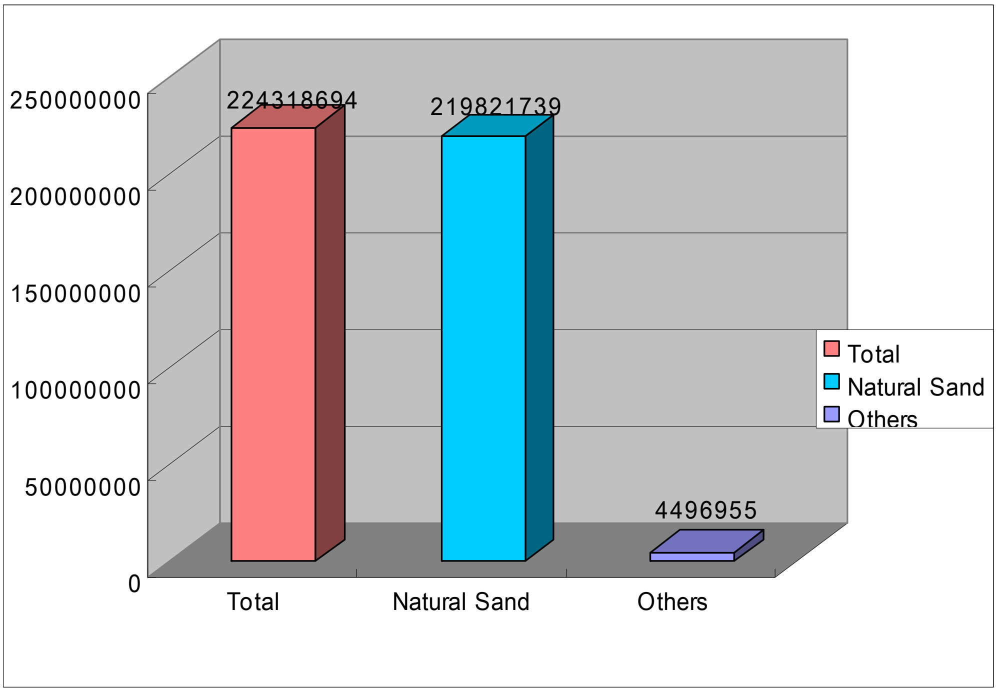


Table 13 shows the origin port of inbound cargoes at the Port of Incheon over the period of 1996 to Sep. 2004. From the table, it can se seen that the inbound cargoes were largely originated from Yeosu, Ulsan, Daesan and Gwangyang. Sand was the major cargo taking 49% of the total cargoes at the Incheon Port having 2.2 million tons out of 4.5 million tons of total volume. The large part of these sands (89%) was originated from various small ports as shown in Table 13 and Figure 6. The most unique characteristics of Extend Incheon Port was that the natural sand cargoes took about half the total coastal shipping cargoes.

Table 13. Origin ports of inbound cargoes at the Extend Port of Incheon (1996-Sept. 2004)

Origin Port	Total Cargo(R/T)	Percent(%)	Cumulative Percent(%)	Distance (km)
Others	211,261,463	46.58	46.58	1
Yosu	53,183,406	11.73	58.30	620
Ulsan	41,961,664	9.25	67.55	806

Daesan	32,281,068	6.92	74.47	70
Gwangyang	31,389,397	6.92	81.39	665
Incheon	25,522,379	5.63	87.02	1
Onsan	17,175,516	3.79	90.81	806
Samchok	11,713,465	2.58	93.39	1015
Okhye	7,304,771	1.61	95.00	1059
Donghae	7,167,633	1.58	96.58	1028
Busan	5,486,164	1.21	97.79	752
Pyeongtaek	2,980,921	0.66	98.45	70
Pohang	1,568,438	0.35	98.79	900
Pohang-newport	1,452,977	0.32	99.11	900
Geoje	1,219,786	0.27	99.38	691
Gunsan	559,125	0.12	99.51	226
Sokcho	288,286	0.06	99.57	1119
Mokpo	273,739	0.06	99.63	432
Masan	126,931	0.03	99.66	746
Boryeong	115,095	0.03	99.68	156
Dangjin	112,304	0.02	99.71	70
Taean	93,620	0.02	99.73	
Cheju	90,946	0.02	99.75	489
Gohyun	89,267	0.02	99.77	691
Janghang	60,939	0.01	99.78	226
Yeocheon	54,506	0.01	99.79	661
Mukho	11,306	0.0	99.80	1028
Okpo	11,257	0.0	99.80	630
Tongyoung	9,190	0.0	99.80	669
Mipo	8,660	0.0	99.80	806
Jinhae	2,745	0.0	99.80	739
Seogwipo	1,042	0.0	99.80	546
Shamchonpo	85	0.0	99.80	639
Total	453,578,091	99.80	99.80	-

Figure 6. Origin ports of inbound cargoes at the Extend Port of Incheon (1996-Sep 2004)

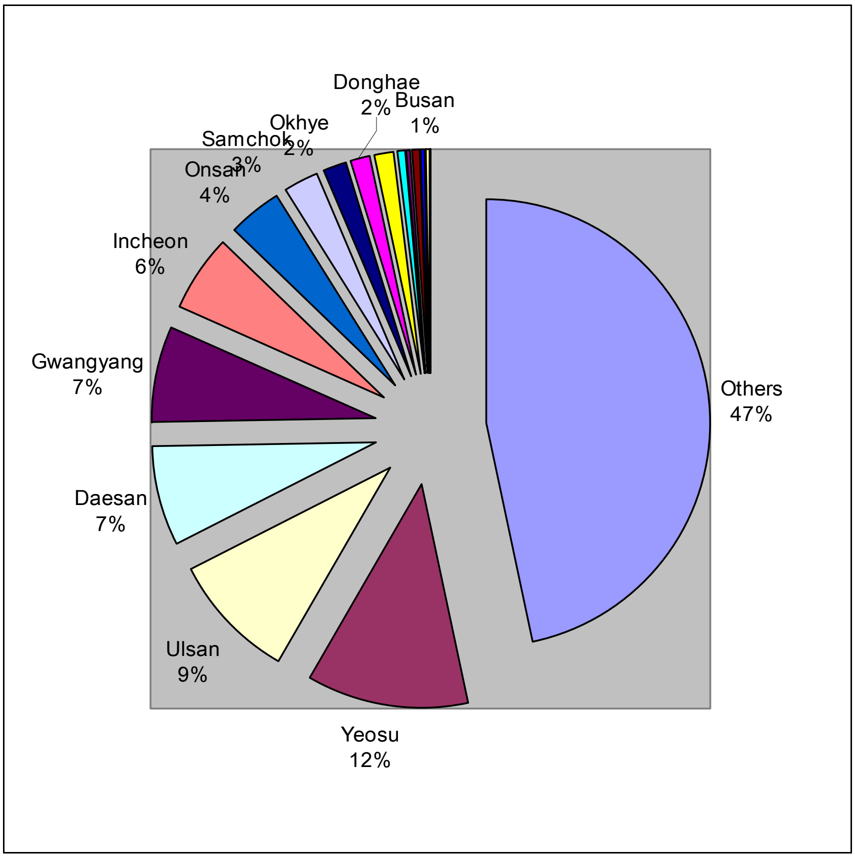
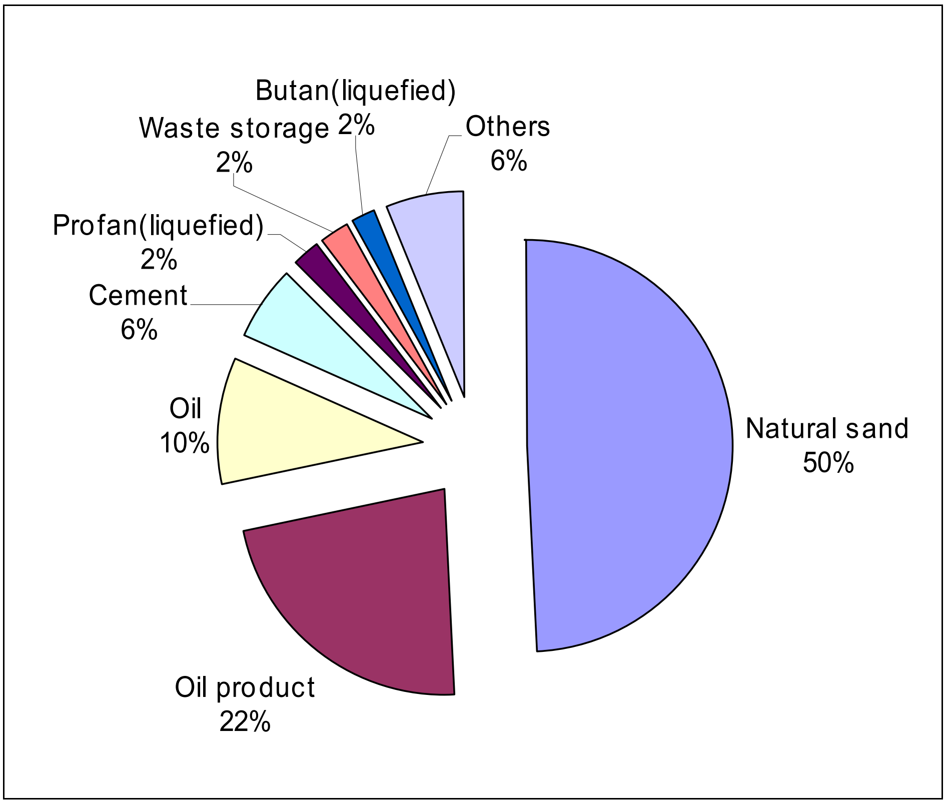


Table 14. Top 7 Ranking Cargoes at the Extend Port of Incheon (1996-Sept. 2004)

Cargo	Total Cargo(R/T)	Percent(%)	Cumulative Percent(%)
Natural sand	222,988,476	49.16	49.16
Oil product	101,455,645	22.37	71.53
Oil	46,343,092	10.22	81.75
Cement	26,276,188	5.79	87.54
Profane (liquefied)	10,026,532	2.21	89.75
Waste storage	9,714,223	2.14	91.89
Butan (liquefied)	8,506,860	1.88	93.77
Others	28,267,075	6.23	100.00
Total	453,578,091	100	100

Figure 7. Top 7 Ranking Cargoes at the Extend Port of Incheon (1996-Sept. 2004)



5. Issues

Some issues have to be addressed in future research of this Project. The first issue is how to collect detailed level of data from respective regional database. To do this, the research team should contact operational staffs of the database assuming they have the detailed information in their DB. The second issue is to match inbound and outbound flows among coastal ports since the Port-MIS seem to contain only origin information of coastal cargoes learning from the pilot study. If this is the case, the research team should find a way to match the origin and destination among various ports. This is not an easy problem at all since there are so many ports like twenty eight Foreign Trade Ports and twenty three coastal ports and therefore, matching the origins and destinations among them can be not any mathematical solution but just a matter of guess. One possible solution to this matching problem may be conducting sampled interviews with some relevant parties of coastal shipping business like shippers, shipping companies and forwarders if any. From the interviews the origin and destination can be estimated in the case areas of interviews. Then the research team can simulate the whole origin/destination matrix using the ratios or data taken from the interviews. In addition, the research team plans to visit actual sites of coastal shipping business like ports, shipping companies and shippers' origin/destination sites. From these interviews and site trips, some other issues may further arise. Whatever issues arise, they should be addressed in combinational efforts of using Port-MIS data and field data from interviews and site visits. These are the areas that the research team plans to explore in the near future.

Forecasting of SSS Traffic in Korea and Policy Implications

1. Introduction

Korea is in the beginning stages of a debate about what is generally referred to as short Sea shipping (SSS). There is hot discussion about the differences between SSS and traditional coastal shipping. It is a concept that even before it gets to the starting line is fraught with problems, the first one being how to properly define it.

According to the definition by EU committee, SSS may be defined as “maritime highway transportation system” and it includes canal, river, other inland waterway as well as coastal shipping system. They emphasized the strengths of SSS as follow;

- Reducing the congestion and delay on the road transportation system
- More competitive cost than other modes such as railroad and highway
- Cost and time savings from crossing the strait or bay
- Environmental advantage from less air pollutions

Since logistic environments in the 21st Century are changing rapidly as a result of globalization and are accompanied by localization, Northeast Asia and Korea should take advantages from adopting and spreading SSS beyond the traditional coastal shipping conventions. As the process unfolds, only a fewer but larger sea and airports will serve as a hub for economic regions with inter-modal transportation networks linking local ports and neighboring hinterlands. Short sea shipping to compete with land transport mode is also becoming important in many regions to relieve road and rail congestion as well as reduce environmental impacts.

However, Korean SSS system is on the very early stage rather than that of Europe and North America. Under an elaborate investigation of short sea shipping system, we should find a right way to reach Korean SSS and Northeast SSS from the current domestic coastal shipping system. Therefore, it is very important to predict the future demand (required by cargo owner) and project supply (provided by carriers) related to Korean SSS circumstances. To do this, Korean governmental party such as costal planning and management division in the Ministry of Maritime Affairs and Fisheries (MOMAF) has started a survey and research project aimed to find the optimal tonnage of coastal vessel freight.

They are trying to estimate the potential and volume of Korean SSS through an analysis of freight flow among coastal ports. Moreover, there have been a few researches to develop coastal transportation SSS model focused on container freights. According to Lee (2004), several issues have to be resolved to satisfy the growing freight demand between two Korean major ports, Incheon and Busan; First of all, some vessels only used in domestic coastal shipping are needed and should be developed. For example, it takes nine hours to deliver some freight by truck from Busan to Incheon. To overcome the time and cost disadvantages with coastal shipping, high-speed and highly efficient vessel and loading-unloading facilities should be devised. Second issue is related to the lack of the berth and facilities which are dedicated to coastal shipping. Thirdly, the coastal shipping should adopt a door-to-door delivery service. The burdens of report works and modal changes may cause the shippers turn away the coastal shipping. So, the inter-modal connecting transportation system should be developed and applied.

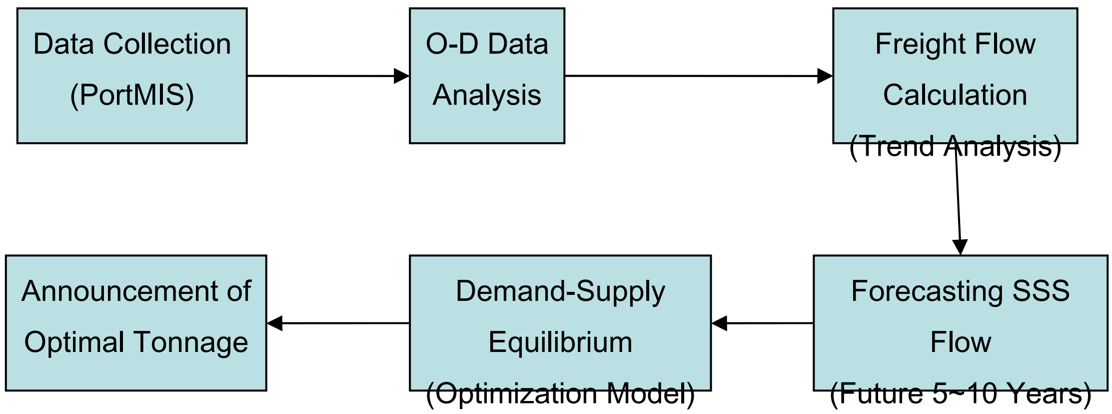
In this report, we developed a systematic method to predict freight flow in Korean coastal shipping system. Using the predicted freight flow, we can calculate the optimal carrier's supply quantity to satisfy the shipper's demand. The prediction method is composed of data collecting techniques, forecasting method, and application.

2. Systematic way to estimate optimal demand-supply in Korean SSS system

We will take an equilibrium supply-demand modeling approach in order to simultaneously represent in a consistent way the decisions of shippers and carriers. To develop the shipper's model, we have investigated the capacity of the designated coastal ports. Also, the input flow and outflow data are collected via data-base which stores the transaction information of the vessel at the port. Based on the flow data, we configured an O-D (origin-destination) matrix table out by assuming the accumulated data presenting the real origin port and destination port. Then, a variety of forecasting techniques can be applied using this O-D matrix. By many criteria (analyzing dimension) such as vessel type, product type, and O-D route, we could acquire future prediction for the shipper's future demand.

The ultimate objective of the study is to find the optimal carrier's supply. Using shipper-carrier equilibrium model, we can find the optimal tonnage for each vessel type. The trend of optimal tonnage during next five years can be applied to announce the appropriate regulation guide to coastal shipper's industry. These steps can be depicted as follows. (See Figure 8)

Figure 8. Systematic Analysis for Demand-Supply Calculation



3. Introduction to Forecasting Methods

The forecast of shipper demand forms the basis for all strategic and planning decisions in a carrier supply. However, there are several characteristics of forecasting which should be aware of the decision makers.

A. Forecasts are always wrong and should thus include both the expected value of the forecast and a measure of forecast error. The forecast error (or shipper demand uncertainty) must be a key input into the optimal tonnage decisions. An estimation of demand uncertainty is unfortunately often missing from forecasts, resulting in estimates that vary widely among different stages of decisions.

B. Long-term forecasts are usually less accurate than short-term forecast; that is, long-term forecasts have a large standard deviation of error relative to the mean than short-term forecasts. There are different forecasting methods between short-term range and long-term range. They use moving average techniques and exponential smoothing methods for short-term forecasts. Comparatively, regression analysis is usually used for the long-term range forecasting.

C. Aggregate forecast are usually more accurate than disaggregate forecasts as they tend to have a smaller standard deviation of error relative to the mean. For example, it is easy to forecast the Gross Domestic Product (GDP) of the United States for a given year with less than 2 percent error. However, it is much difficult to forecast yearly revenue for a company for a given product with the same degree of accuracy. The key difference between the three forecasts is the degree of aggregation. The GDP is an aggregation across many companies and the earnings of a company are an aggregation across several product lines. The greater the degree of aggregation, the more accurate the forecast. Similarly, the shipper-carrier model found in the Korean SSS systems shows the same characteristics. It is easier to forecast next year total sum of every product type which have been loaded and unloaded in a port than that of each product type.

To forecast the SSS flow, we are to be knowledgeable about the numerous factors that are related to the demand of shipper. Some of these factors are listed as follows:

- Past demand (past freight flow among coastal ports)
- Time information (transportation time between ports and loading/unloading time)
- State of the economy
- Supply plan by carriers

Forecasting methods are classified according to the following four types:

A. Qualitative: Qualitative forecasting methods are primarily subjective and rely on human judgment. They are most appropriate when there is little historical data available or when experts have market intelligence that is critical in making the forecast. Such methods may be necessary to forecast demand several years into the future in a new port.

B. Time series: time series forecasting methods use historical demand to make a forecast. They are based on the assumption that past shipper's demand history is a good indicator of future demand. These methods are most appropriate when the basic demand pattern does not vary significantly from one year to the next year. These are the simplest methods to implement and can serve as a good starting point for a demand forecast.

C. Causal: Causal forecasting methods assume that the demand forecast is highly correlated with certain factors in the environment (e.g., the state of the economy like IMF event during 1998 in Korea, disaster of unpredictable events like Kobe earthquake 1995 in Japan). Causal forecasting methods find this correlation between demand and environmental factors and use estimates of what environmental factors will be to forecast future demand.

D. Simulation: Simulation forecasting methods imitate the carrier choices that give rise to demand to arrive at a forecast. Using simulation, we can combine time series and causal methods to answer such questions as: What will the impact of introduction of new vessel be? What will the impact of a competing port opening a new port nearby be?

In fact, several studies have indicated that using multiple forecasting methods to create a combined forecast is more effective than any individual method.

In this report, we deal primarily with time series methods, which are most appropriate when future demand is expected to follow historical patterns. When to forecast demand based on history, then the historical demand, growth patterns, and any seasonal patterns will influence the forecast. Moreover, with this forecasting method, there is always a random element that cannot be explained by historical demand patterns.

4. Case Study: Prediction of Korean SSS Flows

To predict the future demand of SSS freight flows in Korean coastal shipping system, an O-D Matrix can be defined using the following notations.

Notations:

Q: total transportation volume of coastal shipping during a specific year

Q_j: total input flow volume of coastal shipping into port j.

$$Q_j = \sum_i f_{ij}$$

f_{ij}: total volume of freight flow from port i to j.

$$f_{ij} = \sum_{k=1}^{K} f_{ij}^{k}$$

f_{ij}^{k} : volume of k type product freight flow from port i to j.

K means the number of product type

The number of product types which have been treated by the coastal shipping mode is very large. However, according to the analysis of cargo flow in Korea, the majority of product types comprise of oil, steel, cement, and machineries. The portion of these products is about 90% or more than it.

The Algorithms to predict f_{ij}^{k} (volume of k type product freight flow from port i to j.), Q, Q_j, and f_{ij} start from O-D (origin and destination) analysis. We used PortMIS database to acquire the real O-D data matrix. PortMIS is the management information system to support the transaction management for each port. The detail structures and functions can be identified in (Chang & Hong, 2004).

The goal of any forecasting method is to predict the systematic component of demand and estimate the random component. By the static methods, the forecast in year *y* for shipper's demand in year *y+l* is given as follows.

$$\hat{F}_{y+l} = [L + (y+l)T]S_{y+l}$$

Where, *L* = Estimate of level at year 0 (the deseasonlaized demand estimate during year =0)

T = Estimate of trend (increase of decrease in demand per year)

S_y = Estimate of seasonal factor for year *y*.

$\hat{F}_y$ = Forecast of demand for year *y*.

The forecast of demand can be categorized into total demand volume (total volume of transportation), total input flow volume, and detail product by product input flow, denoted *Q*, Q_j, and f_{ij} in respect.

When there is no observable trend or seasonality, we can use moving average method. In this case, we can assume that systematic component of demand equals to the level. The level of year *y* can be estimated as the average demand over the most recent *Y* years. This represents an Y-year moving average. Thus, we have the following:

$$L_y = [D_y + D_{y-1} + ... + D_{y-Y+1}]/Y.$$

The current forecast for all future years is the same and is based on the current estimate of level. The forecast is stated as follows:

$F_{y+1} = L_y$ and $F_{y+l} = L_y$

After observing the demand fore year y+1, we revise the estimates as follows:

$$L_{y+1} = [D_{y+1} + D_y + ... + D_{y-Y+2}]/Y,\ F_{y+2} = L_{y+1}$$

Where, L_y and D_y means the estimate of level at the end of year y and actual demand observed in year y respectively. That is, to compute the new moving average, we simply add the latest observation and drop the oldest one. The revised moving average serves as the next forecast. The moving average corresponds to giving the last Y years of data equal weight when forecasting and ignoring all data older than this new moving average.

Refer the following tables showing the projected demand for each dimension.

Table 15. Forecast for total volume Q (Incheon seaport)

Year	Total Volume (Actual)	Forecast
1998	43,082,286	
1999	45,663,272	
2000	50,978,060	
2001	54,157,465	
2002	54,600,284	
2003	55,934,259	
2004		58,627,125
2005		61,319,991
2006		64,012,857
2007		66,705,723
2008		69,398,588

Table 16. Forecast for input flow (into Incheon port) (1)

(RT/year)

Ports (Origin)	Year	Others	Yeosu	Ulsan	Daesan	Gwang-yang	Incheon	Onsan	Samchok
Actual	1996	26497014	9204216	8615252	1171217	8149366	389	2617987	635310
	1997	28942645	8627644	7528895	1367237	8361523	373	2730918	1074532
	1998	19701969	2350927	4338586	2559370	5704695	1262620	2517434	1095554
	1999	17664478	4648553	5144947	4105540	4153104	4318804	2176661	1074747
	2000	21862249	6690619	4189559	6874181	1002677	4666045	1552051	1356959
	2001	26856054	3997269	3476904	7270801	1044250	4701566	1581099	1719594
	2002	30518079	5316928	3275325	3584853	996630	3972909	1413151	2003424
	2003	29901622	7219315	2861626	2922557	1427919	4834988	1425306	1731881
Projected Forecast	2004	32603133	7402640	2510526	2941143	1117869	5316693	1204674	1912747
	2005	35304643	8078460	2118917	2959728	1146667	5798398	984041.9	2093612
	2006	38006154	8754281	1727307	2978314	1172271	6280103	763409.8	2274478
	2007	40707665	9430101	1335698	2996899	1216182	6761808	542777.8	2455344
	2008	43409175	10105922	944089	3015485	1163247	7243513	322145.7	2636210

Table 17. Forecast for input flow (into Incheon port) (2)

(RT/year)

Ports (Origin)	Year	Okhye	Donghae	Busan	Geoje	Kunsan	Mokpo	Masan
Actual	1996	246661	1005161	1175173		123351	17305	29120
	1997	418688	1064108	1157436	8983	61262	4969	21664
	1998	968269	660580	771259	419044	39536	11571	18778
	1999	809625	527522	506975	4566	41558	49952	7788
	2000	783177	639793	444488	198574	52178	45162	6572
	2001	943999	741880	341132	273872	75780	25226	16230
	2002	1200241	940304	331778	147281	56480	40370	20290
	2003	1237038	1049580	373280	80216	91980	51336	4393
Projected Forecast	2004	1313510	1143450	298455.9	46196.09	101425.4	55625.8	3685.54
	2005	1389982	1237319	223631.9	12176.17	110870.7	59915.6	2978.08
	2006	1466454	1331189	148807.8	46196.09	120316.1	64205.4	2270.62

	2007	1542925	1425058	73983.77	34856.11	129761.5	68495.2	1563.17
	2008	1619397	1518928	148807.8	31076.12	139206.9	72785	855.714

Table 18. Forecast for input flow (into Incheon port) (3)

(RT/year)

Ports (Origin)	Year	Geoje	Kunsan	Mokpo	Masan	Boryeong	Dangjin	Taean
Actual	1996		123351	17305	29120	2920		
	1997	8983	61262	4969	21664	868		
	1998	419044	39536	11571	18778	1250		21867
	1999	4566	41558	49952	7788	6775	6907	6380
	2000	198574	52178	45162	6572	6554	9955	14774
	2001	273872	75780	25226	16230	5899	16528	19716
	2002	147281	56480	40370	20290	184	13982	8369
	2003	80216	91980	51336	4393	21489	37579	9267
Projected Forecast	2004	46196.09	101425.4	55625.8	3685.543	23796.63	39886.63	7778.686
	2005	12176.17	110870.7	59915.6	2978.086	26104.26	42194.26	6290.371
	2006	46196.09	120316.1	64205.4	2270.629	28411.89	44501.89	4802.057
	2007	34856.11	129761.5	68495.2	1563.171	30719.51	46809.51	3313.743
	2008	31076.12	139206.9	72785	855.7143	33027.14	49117.14	1825.429

5. Limitations

There are some limitations in this study. We have not collected all the data from other ports. Under the system such as PORTMIS, the authority to manage and control database is distributed in each regional agency. Therefore, data acquisition from the other regions and data collection and calibration should be followed. Besides only two forecasting method, the other methods will be applied for picking the best results.

MODEL BUILDING

Our research team have employed two quantitative models in building cargo flow network in the case region. One model is a kind of heuristic approach, particularly using Genetic Algorithms, and the other is traditional mathematical program - linear programming. The objective of each model is to find the minimum logistics cost to handle international trade cargoes in Korea, namely export and import container cargoes from and to the capital region and the whole country Korea, respectively. We describe each model approach in the next.

Optimization Model for the Intermodal Routing Problem of International Container Cargos in Korea Using Genetic Algorithms

1. Introduction

In recent years, Korean government have initiated a strategy to build a logistic hub of the Northeast Asia in Korea and a great deal of efforts have been made to implement the strategy. In spite of these efforts, many people argue that there is great inefficiency in transporting international trade cargoes, in particular in capital region of Korea. Although thirty three per cent of cargoes of national container export and import were generated in this region as of year 2001, most of these cargoes had to be handled in farthest seaports such as port of Busan and port of Gwangyang rather than its vicinity ports like port of Incheon and port of Pyeongtaek. This phenomena cause many problems including road congestion on and damage to major highways between Seoul and Busan, environmental degradation, inefficient infrastructure investment and notably trucker drivers' illegal and intentional strike on major highways to block major cargo flows for their bargaining power. Under these circumstances, Korean government and industries as well as general public have begun to explore more diverse transportation network for the capital region's cargoes among coastal shipping to and from the vicinity ports, railway system through Inland Container Depot in the region, truck and also air transportation. To address these issues, one has to find the optimal solution to handle the cargoes in terms of not only total logistics costs, but also time and risks involving the transportation of cargoes. However, to the best of our knowledge, no studies have ever been undertaken to address these issues.

We attempt to address these issues by trying to optimize the total transportation network. We focus on the intermodal freight routing problem (IFRP) of international container cargo between three seaports and 33 metropolitan areas in Korea. To this end, we first analyze container cargo flows of the capital region prior to estimating the transportation costs and times as well as risks (time variations). Then we try to find optimal solution in considering the three factors of cost, time and risk by building integer goal programming model. Using different scenarios in shipping companies' policy for their routing choices, we calculate how much the optimal solution can reduce total logistics costs for the regional cargoes. Genetic Algorithm is applied to the model in solving the solution since it is more flexible and capable of handling larger sizes of variables and cases and easily extended into unquantifiable qualitative variables when needed later on.

Besides, this report quantitatively suggests the effectiveness of cost-reduction for the inland transportation by comparing logistics costs between the current and optimal scenarios. More specifically, the purposes of this report is fourfold: first, we analyze and estimate the current cargo flows and logistics costs between the metropolitan area and seaports (including the import and export); second, the report finds not only optimal seaport's location as one of key nodes, with minimum logistics costs, but also optimal routes; third, we analyze the effect of cost-reduction through the comparison between current status and two optimal cases; and fourth, this report quantitatively suggests which seaports should be developed from the perspective of minimizing the logistics costs, time, and risk factor.

We use various types of data ranging from government's database (PORTMIS for cargo and vessel characteristics in major ports), recent research output done by several research institutes (cargo origin/destination data) and shipping and logistics companies' internal data (shipping, trucking and terminal costs and times) to our own sampled data.

2. Literature review

2.1 Vehicle routing problem (VRP) and Intermodal freight routing problem (IFRP)

Intermodal freight (or container) routing problem (IFRP) is more complex than single mode problem. Vehicle (or freight) routing problems (VRP) under considering intermodal transport reflect the combination of at least two modes of transport, that is, road, rail, inland waterway, and ocean-going vessel, in a single transport chain without a change of container for the goods. Compared with the growing importance of intermodal problems, not many studies have been conducted yet. Macharis and Bontekoning (2004) emphasize opportunities for OR in this emerging research field by describing the operational models currently used and the modeling problems, which need to be addressed.

The VRP, which have usually considered the uni-modal transportation, is one of the prominent topics in the transportation or logistics problems with various kinds of mathematical models that minimize the total routing distance ([Tarantilis and Kiranoudis (2002)], [Javier Faulin, 2003]) or total route costs ([Lin, 2001], [Leung and Lai, 2002]), or total operating time of carriers. In the Leung and Lai's mixed integer programming model (2002), the total costs are composed of transportation cost, hire cost, inventory cost, and allowance with several constraints that must be satisfied in the cross-border logistics problem in Hong Kong, China. And Toth and Vigo (2002) present a review on many kinds of vehicle routing models and algorithms only subject to the vehicle capacity constraints. In addition, there is a recent study, which is dealing with realistic problems, implemented by Ruiz, Maroto, and Alcaraz (2004). They developed a decision support system for a real vehicle routing problem. The model is large-scale, integer programming model for optimal routes, with an implicit enumeration algorithm for generating all feasible routes. Furthermore, Tarantilis and Kiranoudis (2002) developed the high quality spatial decision support system (SDSS) for solving the VRP with using the geographical information system (GIS). Even though various studies have been done on in VRP, it is unfortunately and not easy to find some studies about intermodal freight routing problems (IFRP).

To our knowledge, there are only a few reports published or in-press dealing with the IFRP. Macharis and Bontekoning (2004) categorize the IFRP as the operational decision-making interested by the intermodal operators and explain three reference reports in their review ([Barnhart and Ratliff (1993)], [Boardman et al. (1997)], [Hokey Min (1991)]). Table 19 shows comparisons of three previous studies in the IFRP.

Table 19. Comparisons of previous studies in the IFRP

	Hokey Min (1991)	Barnhart and Ratliff (1993)	Boardman et al. (1997)
Name of model by author	International intermodal choice model	Intermodal freight routing model	Decision Support System for intermodal transportation
Mode considered	Truck, airplane, ocean-ship	Truck and rail	Truck, rail, (airplane, barge)
Considering factors	Cost, time, and risk factor as time variability	Cost	Cost and time
Structure of costs	1. Total distribution cost including handling, storage, and in-transit inventory carrying costs	1. Total transportation cost (drayage costs + line rail haul costs) 2. Inventory cost (in-transit inventory cost + the cost of additional stock resulting from the transit time)	1. Total average transportation rates of each mode 2. Transfer costs if happened
Mathematical model and methods	Chance-constraint GP model	1. Shortest path finding procedure (1st step) 2. Weighted b-matching algorithms (2nd step)	K-shortest path algorithms
Software used	Solve using LINDO software	N/A	MS Visual Basic, MS Access
Selection	Selecting the most service-cost effective transportation mode	Selecting firstly minimum cost routings and secondly optimal routings with constraints	Selecting the least cost combination of transportation modes (truck, rail, air, barge)
Key contribution	1. Good example in the international intermodal choice problem 2. Considered Risk factor as time-variability	1.Comparing intermodal with unimodal (truck) 2.Two types of decision settings 3.Incorporate non-monetary constraints	Development DSS using GIS

Future research addressed	Hypothetical data set	Just two types of modes considered	1. Inventory cost not considered 2. Using average transportation rates of each mode (Low reality)
	No report *has yet suggested* ***"cost-reduction"*** *by the intermodal freight transport*		

As Macharis and Bontekoning (2004) mentioned, we also agree that the Min's model is an exemplar of the international intermodal freight routing problem that we are considering. Hence, the model in this report is based on his GP model, which considered the decision-making of a given company's perspective with hypothetical data sets.

However, our model considers the decision-making of a given country or society, which is much larger scale in logistics business than a company, as well as a real-world problem in the Metropolitan society (or areas) in Korea. These conditions make our model larger and more complex since the model should simultaneously take lots of nodes (sites) and several kinds of transportation modes into consideration. Therefore, the larger and complex model encourages us to solve the problems with the Genetic Algorithms, as a heuristic optimization technique, which will be explained in the following section.

2.2 Overview of the Genetic Algorithm

Introduced by Holland (1975) to tackle the combinatorial problems, the Genetic Algorithm (GA) technique has ever been widespread seen in numerous applications of various kinds of research areas. Especially in the application of the VRP, there have continuously been many studies since the early 1990's. Those kinds of previous studies such as VRPs incorporating time windows[21], the VRP with backhauls, mulit-depot routing problem, and school bus routing problem are given in the recent report by Barrie and Ayechew (2003). In addition to the report, more reports using the GA technique have been published in recent years, for example, with some applications of rerouting shortest paths in dynamic and stochastic network (Cedric and Pawan, 2003),

[21] Nine reports related with GA application to VRPs incorporating time windows were introduced in their literature from 1992 to 1996.

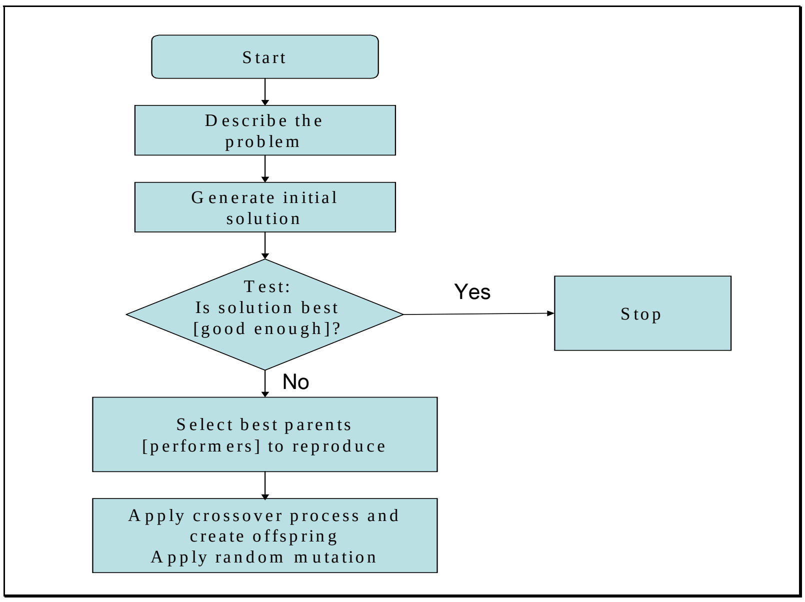
route selection and capacity flow assignment (Lin, Kwok, and Lau, 2003), and the VRP with genetic local search with distance preserving recombination operator (Andrzej and Pawel, 2003). However, there is unfortunately no report, to our knowledge, using the GA technique to solve the intermodal freight routing problem. The following sub-section gives a brief overview of the GA technique and should not be considered to cover the whole variety of the Genetic Algorithms.

2.2.1. Operation Process of Genetic Algorithms

The Genetic Algorithm (GA) is the iterative process of searching the satisfactory alternative of decision-making, which is represented by the combination of the chromosome (or string of genes) due to the fitness (or objective) function. This searching process is illustrated in the figure 9 ([Turban, E. and J. E. Aronson, 2001], [Choo, 2002]).

The GA cannot always ensure the convergence to the optimal solution but can find the near-optimal or satisfactory solution. Nevertheless, the GA is the simple but strong optimization technique because the satisfactory alternative (or solution) can be found by the fitness function to determine whether the alternative is good or bad in the case that it is impossible to represent a numerical expression and to know the method for problem-solving ([Gen, M.& R. Cheng, 1996], [Dhar, V. and R. Stein, 1997]).

Figure 9. Flow Diagram of GA Process



The search efficiency of the Genetic Algorithm depends on several factors. But one of the important factors is the genetic operator. The genetic operators consist of reproduction, crossover, and mutation (Goldberg, L.R., 1989). It is important to relevantly combine genetic operators in order that the found solutions should be the optimal (global) solutions.

2.2.2 Genetic Operators

(1) Crossover

The crossover forms new offsprings between two randomly selected ‘good parents’. That is, the crossover operates by choosing a random position in the gene string of the parents and exchanging the segments either to the right or to the left of this point with another string partitioned similarly to produce two new offsprings ([Turban, 2001], [Choo, 2002]). There are several kinds of methods for the crossover such as the arithmetic crossover and the heuristic crossover used in this report.

In the method for the arithmetic crossover, two new offsprings are generated by the linear combination of two randomly selected strings of the parents by means of the equation 1.1. In the method for the heuristic crossover, a new offspring is reproduced by the rule such as the equation 1.2 in which r is the random number between 0 and 1 and parents x_2 is superior to parents x_1. Therefore, an inequality of $f(x_2) \geq f(x_1)$ can be used in the maximizing problems and $f(x_2) \leq f(x_1)$ can be also used in the minimizing problems. The heuristic crossover, which is dependent on the value of the objective function for deciding the searching direction, may generate one new offspring or may not reproduce new offspring ([Taguchi, T., K. Ida and M. Gen, 1998], [Michalewicz, Z., 1999]).

$$S_v^{t+1} = a \cdot S_w^t + (1-a) \cdot S_v^t \quad \text{and} \quad S_v^{t+1} = a \cdot S_v^t + (1-a) \cdot S_w^t \tag{2.1}$$

$$x_3 = r \cdot (x_2 - x_1) + x_2 \tag{2.2}$$

(2) Mutation

Mutation is the genetic operator which randomly and infrequently changes the gene string of the chromosomes in order not to prevent the found solution in the Genetic Algorithm from falling into the local area in the solution space and plays an important role in recovering destructive characteristics in the population and then sustaining the variety of genetic characteristics for better solutions. This operator occurs only with some probability, which is called the mutation rate that should be given low at the beginning of searching and needs to be given more or less high at the convergence phase of the solution. The method of operating mutation is classified such as the uniform (or boundary) mutation and the non-uniform mutation using in this report, and so on ([Gen, 1996], [Michalewicz, 1999], [Choo, 2002]).

3. Pre-analysis and real data sets

In order to estimate the current logistics costs and then compare with optimal solutions, we firstly collected the real data sets of the full-container[22] cargo quantities and a series of cost, time, and time-variance as a risk factor, via seaports, between the metropolitan area in Korea and their five major international trade areas, that is, China, Europe, Japan, Southeast Asia, and the U.S. Table 20 shows a part of cargo quantity data sets, which were investigated by Korean government, considering Origin/ Destination (O/D).[23] These real data sets, actually, are critical to capture logistic flows of cargos in the region as well as redesign and decide investments on considering infrastructures such as seaport, airport, railway, highway, etc., to increase the effectiveness and efficiency of current logistics/transportation system. It is noteworthy that 99.7 percents of international (importing and exporting) cargo flows in Korea are handled through seaports, especially the Busan, Gwangyang, and Incheon seaports.

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[22] Without any special notice, **container** below in this report means '**Maritime import/export full-container'**.

[23] We got the data sets of full-container cargo quantities in/out Korea, as a softcopy just for research purpose, from the *Korea Maritime Institute* (KMI) which conducted actual survey in seaports to get sampling over 2000 to 2001.

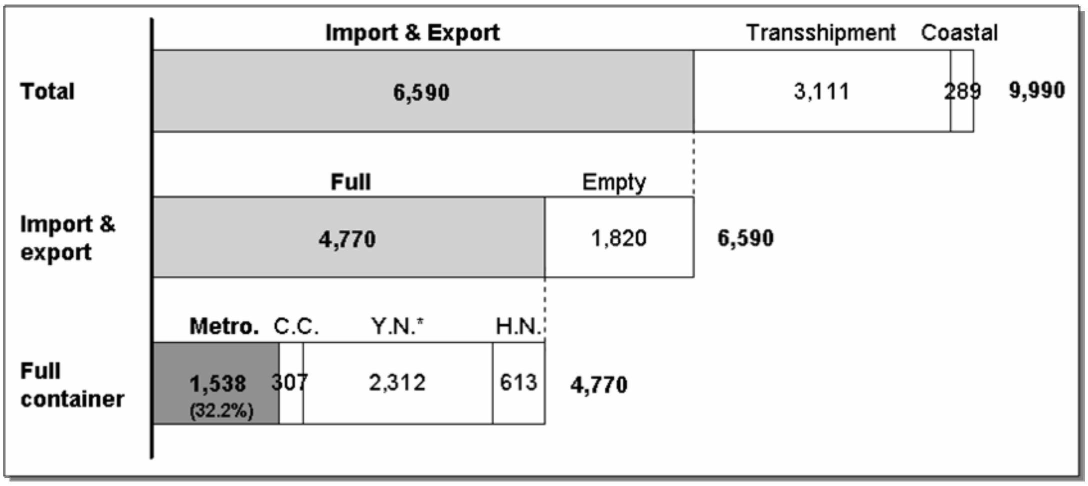
Table 20. An example of the '*Foreign-Ports-Metropolitan*' O/D data with container throughput (TEU, 2001)

		Busan port					Incheon port					Gwangyang port				
		US	Japan	China	Europe	SE Asia	US	Japan	China	Europe	SE Asia	US	Japan	China	Europe	SE Asia
33 districts	Seoul	13,665	5,243	15,757	10,830	7,074	40	42	902	124	1,044	30	2	3	9	39
	Incheon	13,987	5,550	17,406	13,488	5,305	11,886	5,431	29,447	15,671	82,921	420	-	11	62	1
	Ansan	2,470	611	610	1,155	261	246	2,313	2,621	1,450	1,114	53	-	0	19	-
	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
	Yongin	2,617	587	921	1,126	435	18	14	59	0	365	-	-	-	-	-

All of data sets of cargo quantities from the KMI are based on transporting by road carrying in/out their domestic seaports due to the easiness of the O/D survey. But, despite that the survey was confined to the road transportation, it's still important data because the container cargo traffic[24] by road comprised about 86.6 percents of total import and export cargoes in 2001, whereas much less proportion of cargoes were transported by rail and coastal way (rail: 11.0%, coastal: 2.4%). Because of this road-dominant transportation system, a number of experts of logistics have addressed that it's one of the root causes of the inefficient transportation system in Korea as well as it has brought an astronomical direct logistic cost to the country ([Shin, 2002], [Ha et al., 2003]). For example, Ha et al. (2003) described that the road-dominant transportation system in Korea resulted in more than 90 per cents of total transportation costs in the region.

[24] Korean Container Terminal Authority's report (Cargo Traffic by Transportation Mode at Busan Port, 2001) is available at the website, http://www.kca.or.kr/

Figure 10. Import/Export Full-container throughput in Korea (1,000 TEU, 2001)

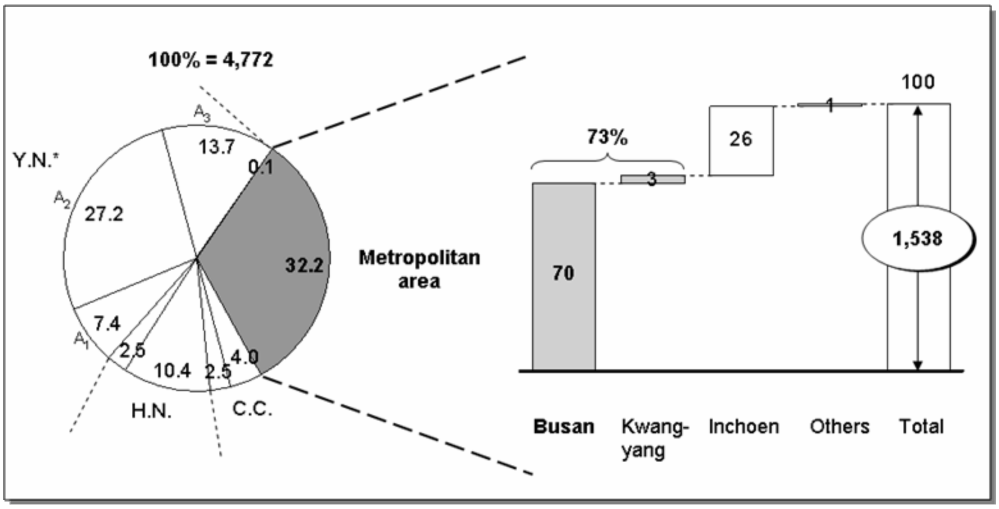


Note: C.C.=Chung-Choeng Province, Y.N.*=Young-Nam Province with Kangwon area, H.N.=Honam-Nam Province

Figure 10 shows total container throughput, 9,990 thousands TEUs, in Korea. Of these total cargoes, 1,538 thousands TEUs, comprised the metropolitan area, which is mainly considered in this report. We consider the 76% of total metropolitan cargos, 1,170 thousands TEUs, in the pre-analysis since it is confined to five international trade areas as foreign O/Ds and three seaports as key logistic points in domestic as well as it excludes the cargo quantities by rail and costal transportation in order to increase efficiencies of analyses and easily to build the mathematical model for solving the problems. However, when we optimize the system later on, we will focus on the whole metropolitan cargo amount regardless of the cargoes taken by truck, shipping or railway at present.

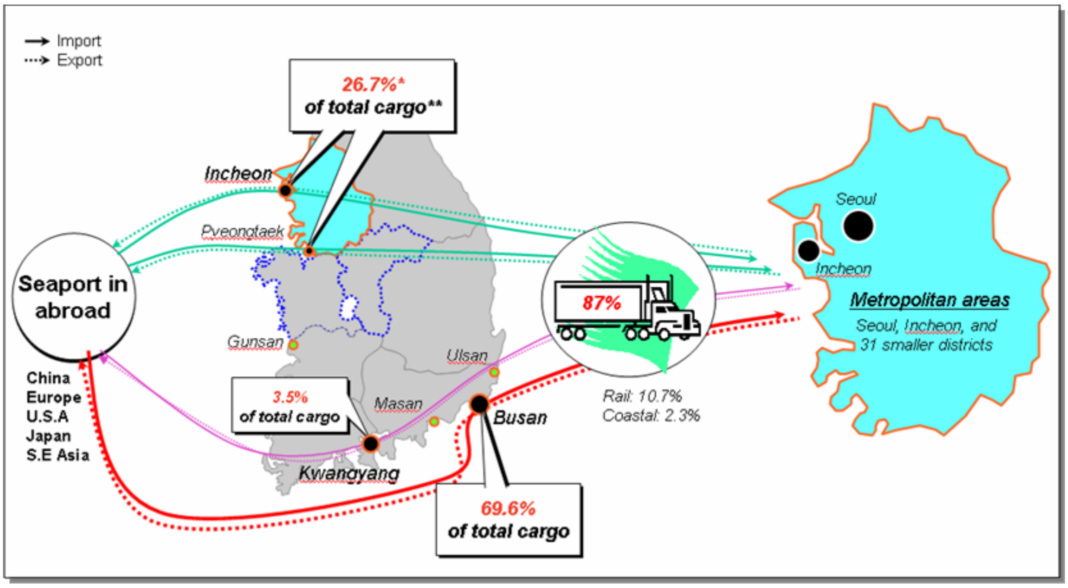
Figure 11 describes that 73% of total cargo in/out the metropolitan areas is 32.2% of total domestic cargo in/out Korea, flows through the Busan (mostly) and Gwangyang (a little) seaports, while the Incheon seaport, which is the nearest to the metropolitan area, carried only 27% in/out.

Figure 11. Container throughput rates of the Metro. Area by the domestic seaports



Note: * The Y.N. area consists of A1 (Busan), A2 (Kyeongnam), A3 (Kyeongbuk), and Kangwon province.

Figure 12. Container's cargo flows of the Metro. Area, Korea in 2001



Notes: * Incheon seaport (26.1%), Pyeongtaek seaport (0.6%)

** Total cargos between seaports and the Metro. Areas, 1,538 thousands TEUs, are 32.2 per cents of total domestic cargos.

From Table 21 focusing on container quantities from the foreign origins/destinations, we can derive the following findings. In case of the U.S. and Europe, most of all (about 92%) containers were carried through the Busan seaport, and in Asia, some cargos (58%) moved in/out by the Busan seaport and others (42%) by the Incheon seaport. Especially, in case of China having the largest quantities (27.2% of total), the Busan seaport (58%) were more used for transporting the container than the Incheon seaport (42%) even if the Incheon seaport's shipping distance from China is much less than the Busan seaport. In case of the Southeast Asia, the portion (55%) of using the Incheon seaport is a little higher than the Busan.

Table 21. Container throughput between the Metro. area and the Foreign O/D countries (1,000 TEUs, 2001)

	By Busan port		**By Incheon port**		
	Import	Export	Import	Export	**Sum. (%)**
U.S.	**114**	**113**	13	6	21.2
Europe	**103**	**99**	17	2	19.0
China	**76**	**108***	**37**	**95***	**27.2**
Japan	33	**87**	8	36	14.1
S.E. Asia	24	73	**92**	27	18.6

Note: * It includes the cargo quantities of the Far East Asia (Hong Kong, China, Mongol, etc.)

So far, we looked into the quantities and their O/Ds of container cargos between our study areas. As for these O/Ds, we collected the real-world data sets of cost, time, and time-variability as a risk factor from many kinds of sources[25]. Table 22 shows three types of cost data sets such as ocean shipping cost, terminal handling charge in seaports, and inland transportation cost for using road, rail, or near-sea (coastal)

[25] All sources of real-data sets are shown in the *References* part.

transit.[26] We can see the data sets of time and time-variability of each node-to-node by each mode in Table 23

Table 22. An example of cost data set (Unit: Korean Won (KRW) per TEU)

			Ocean shipping cost			*Terminal handling charge*			*Inland transportation cost*										
									Only road			Railway &			Road	Coastal &			Road
			B	G	I	B	G	I	B*	G	I	B*	G	I	UW	B	G	I	I
U.S. (Import.)	33 Metro. Areas	Seoul				118,000	118,000	118,000	487,000	410,750	170,500	381,400	351,400	-	139,000	456,000	400,500	-	170,500
		Incheon				118,000	118,000	118,000	555,500	508,500	189,500	399,400	369,400	-	157,000	475,000	419,000	-	189,500
		⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
U.S. (Export.)	33 Metro. Areas	Seoul				118,000	118,000	118,000	487,000	410,750	170,500	381,400	351,400	-	139,000	403,500	350,500	-	170,500
		Incheon				118,000	118,000	118,000	555,500	508,500	189,500	399,400	369,400	-	157,000	422,500	359,500	-	189,500
		⋮	:	:	:	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	-	⋮	⋮	⋮	-	⋮

Notes: * This cost also includes the container tax 20,000 KRW, which is charged only at the Busan seaport, when using road and railway.

** Actually, we consider additional four areas such as China, Japan, Europe, S.E. Asia and one other F.E. Asia only in exporting cases.

*** B→ Busan seaport, G→ Gwangyang seaport, I→ Incheon seaport, UW→ Uiwang ICY

Table 23. An example of transit time (and time-variability*) data set (Unit: hh:mm:ss)

	Ocean shipping time			*Staying in port (Lead time)*			*Inland traveling time*										
							Only road			Railway &			Road	Coastal &			Road
	B	G	I	B	G	I	B*	G*	I	B	G	I	UW*	B	G	I	I

[26] We have not yet obtained the data set for ocean shipping costs between foreign and domestic seaports. Although it is critical to our future analysis, it is to be included later on when acquiring the data.

U.S. (Im.)	33 Metro. Areas							8:47:50	7:14:52	1:20:26	10:15:00	10:39:00	-	1:12:11	32:23:08	24:18:13	-	1:20:26
								9:12:43	7:39:46	0:14:02	10:15:00	10:39:00	-	1:13:06	32:23:08	24:18:13	-	0:14:02
		⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
U.S. (Ex.)	33 Metro. Areas							8:47:50	7:14:52	1:20:26	10:15:00	10:39:00	-	1:12:11	32:23:08	24:18:13		1:20:26
								9:12:43	7:39:46	0:14:02	10:15:00	10:39:00	-	1:13:06	32:23:08	24:18:13		0:14:02
		⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Notes: * This value of time is estimated by the linear equation, y = 0.0007x + 0.0243 (R^2 = 0.7187), that is obtained by the regression analysis on two real data sets of "distance (x) to traveling time (y)" between the Incheon seaport and the metropolitan areas surveyed in February 2004. And in case of the Busan seaport, we added one hour considering bad road traffic conditions of Busan city.

** Transit time variability has the same structure of transit time data set above. But we couldn't get the variance data in case of road traveling from Busan and Gwangyang to the Metro. areas since there is no correlation between distance and time variability as the real survey of the Incheon seaport.

With container quantities from the Origin/Destination data set in Table 20 and each available cost and time data set in Tables 22 and 23, we calculated, just for the case of inland intermodal routings, some critical values of the current status in 2001. Table 24 represents the results: (a) the current total cost, around 500 billions KRW (415.3 millions USD) for 1,170 thousands TEUs: and (b) the weighted average traveling time by road, 6.3 hours per TEU between seaports and the metropolitan areas of all 363 cases. And then, from (a), we obtained the unit transportation cost per TEU, around 426,000 KRW (355 USD), which is important to easily estimate the cost for the total container quantities by road. Finally we estimated the total inland transportation cost, around 640 billions KRW (530 millions USD) for 1,538 thousands TEUs, including rail and coastal transport costs. As the same estimating context, we obtained the weighted average inland transportation time, 7.74 hours per TEU for all quantities shown in Table 25.

Table 24. Results of current status* (Billions KRW, hh:mm:ss)

	Inland intermodal routings			**International intermodal routings**		
	Cost	Average Time**	Variability	Cost	Time	Variability
Import	213.6	5:59:48		n/a		
Export	284.8	6:35:10				
Total	498.4	6:19:28				

Notes: * As aforementioned, these results are from analysis for about 1,170 thousand TEUs which were handled just in road.

** This value of time means the *cargo-weighted* average transportation time (per TEU) for all traveled routes.

Table 25. Details of the current time analysis between the metropolitan areas and seaports

		Estimated current time for total container cargos			
	Only road	Road	Railway	Coastal	**Total**
Quantity (1,000 TEU)	1,170	1,332	169	37	1,538
	100 (%)	86.6 (%)	11.0 (%)	2.4 (%)	100 (%)
Total time*	7398108:15:15	8772654:39:20	1897154:50:59	1240826:34:49	10793836:05:24
Average time** (per TEU)	**6.32 (hours)** (6:19:28)	**6.32 (hours)** (6:19:28)	**11.22 (hours)** (11:12:50)	**33.62 (hours)** (33:36:57)	**7.74 (hours)** (7:44:00)***

Notes: * Total time = ∑ (Unit time per route) × (quantities in TEU per route)

** Average time per TEU = Total time ÷ Quantity, for example, *6:19:28* = (7398108:15:15) ÷ (1,170).

*** This value is the weighted average traveling time per TEU for portions of cargo by transportation modes.

We, as aforementioned, conducted to estimate logistics cost under the current system of year 2001. In addition, we include the estimations on quantities and total inland transportation costs for considering routes in the year 2004, 2008, and 2011, respectively. Those values, in Table 26, are compared with the equivalent of optimal scenarios found by our model in the Section 5 in order that the report suggest not only cost-reduction of current status in 2001, but that of near future like 2004, 2008, and 2011 with the assumption that transportation patterns or structures remain unchanged or continue to be developed in a similar pattern to current status until 2011.

Table 26. Estimating inland transportation cost[27]

		2001	**2004**	**2008**	**2011**
Quantities (1,000 TEU)		1,538	2,297	3,308	4,067
Cost (**Billion** **KRW**)	Road (86.6%)	567.3	847.2	1,220.4	1,500.2
	Rail (11%)	53.5	79.9	115.0	141.4
	Coastal (2.4%)	16.0	23.9	34.4	42.4
	Total	**636.8**	**951.0**	**1,369.8**	**1,684.0**
Total cost in Million US$		**530.7**	**792.5**	**1,141.5**	**1,430.3**

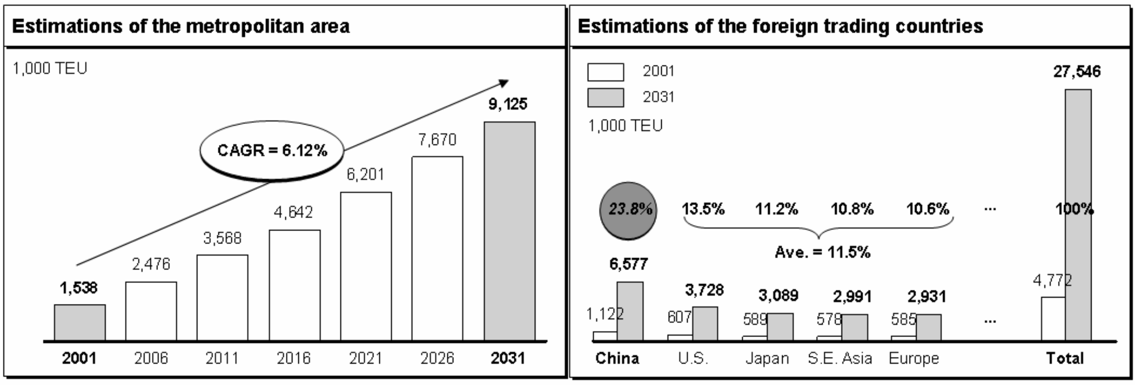
Note: * The Estimations of future quantities are obtained by the interpolation method.

Furthermore, as the long-term estimations based on the data set by the Korea Maritime Institute in Figure 13, total container quantities of the metropolitan areas after 30 years are about 9,125 thousands TEUs, which is comparable to total domestic quantities in 2001, 9,990 thousands TEUs. Especially from China as a foreign O/D in 2031, estimated quantities are about 6,577 thousands TEUs, which is two times of other areas' average quantities as well as around 23.8 per cents of total domestic when

[27] The Estimations of future quantities are obtained by the interpolation method, and furthermore we find the future costs under assumption that the future ratios of container cargo traffic by transportation mode equal those of year 200l.

comparing among 5 major international trade areas. These long-term estimations, perhaps, have critical implications about redesigning and deciding the investment on the Korea's infrastructures related with transportation system. With results on cost-reduction, these will be discussed in detail in Section 6. On the basis of current system, we can formulate the mathematical model especially focusing on cost and time as in the following section.

Figure 13. Long-term (30 years) estimations of cargo flow in/out Korean



Note: CAGR (Compounded Annual Growth Rate) is obtained as the equation, $(FV/PV)^{1/n} - 1$, usually seen in the finance analysis.

4. Modeling the international intermodal container routing problem

4.1 Model Formulation

For our research purpose, the model is formulated in 0-1 integer goal programming model, with 3,267 0-1 variables, to seek optimal combination of routes and service mode. Our logistics network in the model consists of 363 routes. Each route is composed of three nodes: node *i*, five major foreign countries (or seaports) trading with Korea, that is, U.S.A., Japan, Europe, Southeast Asia and China; node *j*, three major domestic seaports in Korea, that is, Busan, Gwangyang, and Incheon; and node *k*, 33 metropolitan districts, that is, Greater Seoul, Greater Incheon, and other thirty one counties and towns in Kyeonggi province. Especially between node *j* and node *k*, the model consider three transportation modes such as truck, rail, and coastal ship for any intermodal choice of decision makers. However, in this model, all nodes and modes between foreign seaports and their local market areas were not considered due to lack of real-data and for our research purpose. Parameters and variables in this model are presented in the followings.

4.2 Parameters and variables

I, J, K Set of all nodes

i ($\in I$) 5 Nodes of importing/exporting foreign seaports (or areas) trading with Korea

j ($\in J$) 3 Nodes of importing/exporting seaports in Korea

k ($\in K$) 33 Nodes of metropolitan districts as the Origin/Destination

M Set of all inland transportation modes in Korea

m ($\in M$) 3 Modes of *three*-types of inland transportation in the Korea

P^m_{ijk} Total transportation costs among three nodes (i, j, and k) via mode t, which consist of the ocean shipping cost, the surcharges in seaport, and overland transportation cost, that is,

$P^m_{ijk} = C_{ij} + C_j + C^m_{jk}$ $(i \rightarrow j \rightarrow k)$ or $C^m_{kj} + C_j + C_{ji}$ $(k \rightarrow j \rightarrow i)$

C_{ij} The ocean shipping cost per TEU from exporting seaport abroad to importing seaport in Korea

C_{ji} The ocean shipping cost per TEU from exporting seaport in Korea to importing seaport abroad

C_j Terminal handling charge[28] of container cargo (TEU) in importing/exporting seaports in Korea

C^m_{jk} Inland transportation cost per TEU from importing seaports in Korea to the destinations in the Metropolitan area

C^m_{kj} Inland transportation cost per TEU from the origin in the Metropolitan area to exporting seaport in Korea

Q^m_{ijk} Annual Importing Quantities among nodes (i, j, and k) via inland mode m from node j to node k

Q_{ij} Annual Importing Quantities from node i to node j

Q^m_{kji} Annual Exporting Quantities among nodes (k, j, and i) via inland mode m from node k to node j

Q^m_{kj} Annual Exporting quantities from node k to node j via inland mode m

T^m_{ijk} Total transit time from exporting seaports abroad to the destinations in the Metropolitan areas

T^m_{kji} Total transit time from the origins in the Metropolitan area to importing seaports abroad

R^m_{ijk} Total variability[29] from exporting seaports abroad to the destinations in the Metropolitan areas

R^m_{kji} Total variability from the origins in the Metropolitan area to importing seaports abroad

w_1 Cardinal weight determined by relative importance of lower total logistics costs

---

[28] In reality, THC (Terminal Handling Charge) is only big one of surcharges in seaport, which includes THC (Terminal Handling Charge) as well as CFS charge, FAF (Fuel Adjustment Factor), EBS (Emergency Bunker Surcharge), CAF (Currency Adjustment Factor), WRS (War Risk Surcharge), PSS (Peak Season Surcharge), documentation fee for B/L, wharfage, container tax and CCC (Container Cleaning Charge).

[29] Total variability means total time variance as a risk factor, which is sometimes caused by a bad weather condition in the ocean, unexpected traffic jam in road, waiting signals in railway, carrier's breakdown, and any labor strike, etc. (Min, 1991)

w_2 Cardinal weight determined by relative importance of earlier shipments

w_3 Cardinal weight determined by relative importance of smaller transit-time variability

x_j 1 if cargo flows (i, j, k) or (k, j, i) pass through node j

0, otherwise

y^m_{jk} 1 if mode m traverses from node j to node k

0, otherwise

y^m_{kj} 1 if mode m traverses from node k to node j

0, otherwise

d^+_1 Positive deviational variable that represents total logistics costs (in U.S. dollars)

d^+_2 Positive deviational variable that represents total transit time (in hours)

d^+_3 Positive deviational variable that represents total transit time variability (in hours)

4.3 Objective function and constraints

Minimize $(w_1 \cdot d^+_1 + w_2 \cdot d^+_2 + w_3 \cdot d^+_3)$ ········· (4.1)

4.3.1 Goal constraints with multiple conflicting (trade-off) objectives with non-linear structure

1. Total logistics cost

$$\sum_{i\in I}\sum_{j\in J}\left\{ Q_{ij}\cdot(C_{ij}+C_j)\cdot x_j \right\} + \sum_{j\in J}\sum_{k\in K}\sum_{m\in M}\left\{ (Q^m_{jk}\cdot C^m_{jk})\cdot x_j\cdot y^m_{jk} \right\} +$$

$$\sum_{j\in J}\sum_{k\in K}\sum_{m\in M}\left\{ (Q^m_{kj}\cdot C^m_{kj})\cdot x_j\cdot y^m_{kj} \right\} + \sum_{i\in I}\sum_{j\in J}\left\{ Q_{ji}\cdot(C_{ji}+C_j)\cdot x_j \right\} - d^+_1 = 0 \quad \text{……… (4.2)}$$

2. Total transit time

$$\sum_{i\in I}\sum_{j\in J}\sum_{k\in K}\sum_{m\in M}(T^m_{ijk}\cdot x_j\cdot y^m_{jk}+T^m_{kji}\cdot x_j\cdot y^m_{kj})\ -d^+_2 = 0 \qquad \cdots\cdots (4.3)$$

3. Risk factor

$$\sum_{i\in I}\sum_{j\in J}\sum_{k\in K}\sum_{m\in M}(R^m_{ijk}\cdot x_j\cdot y^m_{jk}+R^m_{kji}\cdot x_j\cdot y^m_{kj})\ -d^+_3 = 0 \qquad \cdots\cdots (4.4)$$

4.3.2 System constraints

$\sum_{j\in J} x_j = 1$, for every route (*i*, *j*, *k*) or (*k*, *j*, *i*)

$\sum_{m\in M} y^m_{jk} = 1$, for every route (*j, k*)

$\sum_{m\in M} y^m_{kj} = 1$, for every (*k, j*)

x_j, $y^m{}_{jk}$, $y^m{}_{kj}$ = 0 or 1

5. Results and scenario analysis

Using the mathematical model presented in the above, we could find the optimal solutions, with changing the priority of each objective, only for the case of inland freight transport routing. Prior to presenting the results, we show all possible routing combinations of node and mode for each importing and exporting case in Table 27. Four combinations, I_5, I_6 in importing and E_5, E_6 in exporting case, are excluded from our model since there is little possibility to transport by rail or coastal due to their nearness between the Incheon seaport and the metropolitan areas. Hence, this model has all possible 49 mode-node routing combinations and then finds the solutions for all 363 cases. It is a large-scale combinatorial optimization problem, which has number of cases of the astronomical figure like 5.8964 × 10^{306} ($7^{363} = 7^{165} \times 7^{198}$). Therefore, this model tries to solve the problem with Genetic Algorithm technique, which is particularly suitable for those large-scale problems.

Table 27. All possible routing combination

Importing cases		Through *Domestic Seaports*	Exporting cases	
Origin (**O**) : 5 Foreign areas (countries)	Destination (**D**): 33 Metropolitan areas		Origin (**O**) : 33 Metropolitan areas	Destination (**D**) : 5 Foreign areas (countries)
		Busan (B)		
I_1	O→(OS)→B→(T)→D	Ocean-ship, truck	E_1	O→(T)→B→ (OS)→D
I_2	O→(OS)→B→(R)→UW→(T)→D	Ocean-ship, rail and road	E_2	O→(T)→UW→(R)→B→(OS)→D
I_3	O→(OS)→B→(CB)→I→(T)→D	Ocean-ship, coastal barge and road	E_3	O→(T)→I→(CB)→B→(OS)→D
		Incheon (I)		
I_4	O→(OS)→I→(T)→D	Ocean-ship, truck	E_4	O→(T)→I→ (OS)→D
I_5	X (not considering)	Ocean-ship, rail and road	E_5	X (not considering)
I_6	X (not considering)	Ocean-ship, coastal barge and road	E_6	X (not considering)
		Gwangyang (K)		
I_7	O→(OS)→K→(T)→D	Ocean-ship, truck	E_7	O→(T)→K→ (OS)→D
I_8	O→(OS)→K→(R)→UW→(T)→D	Ocean-ship, rail and road	E_8	O→(T)→UW→(R)→K→(OS)→D

*I*9	O→(OS)→K→(CB)→I→(T)→D	Ocean-ship, coastal barge and road	*E*9	O→(T)→I→(CB)→K→(OS)→D

Note: (OS): Ocean-ship, (T): Truck, (R): Rail, (CB): Coastal Barge, UW: Uiwang ICY

First, when the 1st goal of (4.2) has the priority (P_1 >> P_2 >> P_3=0)[30], that is, when decision makers have the priority on minimizing the total logistic cost, the model obtains the optimal solutions that the routings in all of cases are through the Incheon seaport and then transport containers by truck. It's simply because those routes, despite of transport by road, require relatively lower price than other cases due to its nearness to the metropolitan areas. Therefore, the results are that the total inland logistic cost is 286.6 billions KRW (238.8 millions USD) with around 0.98 (0:59:20) hours per TEU as the weighted average routing time (WART). On the contrary, when traveling time minimization as the 2nd goal of (4.3) has the priority (P_2 >> P_1 >> P_3=0), the results show the same as the former case for the same reason, or its nearness. This means that if there are no other factors that cause shippers reluctant to be served in the Incheon seaport, it is guaranteed that the optimal routes are through the Incheon seaport with truck being the inland transportation from the perspective of cost and time. However, the real-world, as we know, is somewhat different from optimal situations. In reality, most of bigger ocean ships, especially on the trans-Pacific routes and Europe routes, usually transport containers mainly through the Busan seaport for the following reasons: (a) the Incheon seaport is not on the trunk route of the world's ocean-shipping lines, and (b) also have a big tidal difference, and (c) other port's services are more comprehensive. Therefore, we design the second scenario in the model for reflecting the current situation.

In the second scenario, we added the constraint that there is no route through the Incheon seaport when trading between the metropolitan areas and the U.S. and Europe areas. Hence, in Table 28, the combinations I4, E4 are also not considered in the model in addition to the I5, I6, E5, and E6. With this constraint, the model results in 381.9 billions KRW (318.3 millions USD) as the total logistics cost and 5.8 (5:46:06) hours as the WART when the priority is minimizing the total logistics cost. On the contrary, when we take priority over minimizing the WART, the results are 3.4 (3:22:48)

30 'P_3=0' means that the model doesn't consider the risk factor in this report since we don't have any real data or equivalent estimated about time variability.

hours as the WART and 470.5 billions KRW (392.1 millions USD) as the total cost. In upper two cases, there are many intermodal choices as transport by mode although three international trade areas, except the U.S. and Europe, also have the same route-choice, which is to transport through the Incheon seaport and by road, as the former scenario. In cases of the U.S. and Europe, however, the Gwangyang seaport is chosen as the main gateway from/to the ocean and then containers are transported by road when the priority is to the time factor ($P_1 << P_2$). Conversely, when the P_1 is prior to the P_2, cargos are carried by the intermodal transportation over land, that is, rail to road, or coastal to road. Especially in exporting cases, there are lots of transports by costal way due to its cost structure that the market price of transporting from 'Incheon to Busan port' is less expensive than that of the reverse even though most of importing cases choose the inland transportation by railway. In other words, there is little difference for the price competitiveness of transport by between rail and coastal way. These results are similar to a previous study of the KMI about the strategy for revitalization of the container transport by the coastal way involving the Kyeongin [31] areas in Korea (2003, Park).

Table 28. Cost and time reduction (Year 2001 basis)

	Current case	**Two scenarios**		
		Scenario I (optimum)	Scenario II (realistic optimum)	
		(P_1>>P_2) = (P_2>>P_2)	II-1 (P_1>>P_2)	II-2 (P_2>>P_2)
Average cost per TEU (KRW)	426,000	186,000	248,000	306,000
Total Cost (Billions KRW)	**636.8 (530.7)***	286.6 (238.8)*	381.9 (318.3)*	470.5 (392.1)*
Reduction (Δ_C, Billions KRW)	-	**350.2 (291.9)***	**254.9** (185.4)*	**166.3** (111.6)*
Average time per TEU	7.74	0.98	5.8	3.4

[31] The Kyeongin areas usually include Seoul, Incheon, and other near-Incheon areas. So it is said that these areas are surrounded over the Metropolitan areas because the Kyeonggi provinces include all of near-Incheon areas.

(hours)				
Reduction (Δ_T, hours)	**-**	**6.76**	**1.94**	**4.34**

Note: * Numbers in parentheses represent the values in USD millions (1 USD = 1,200 KRW).

Table 29, in detail, represents the cost and time reduction for two scenarios compared with the current status analyzed in the Section 2. The model in the scenario I not only results in the remarkable cost-reduction, 350.2 billions KRW (291.9 millions USD), but reduces a considerable amount of cost in each case of the scenario II, which is actually transported by the intermodal using rail and coastal barge. In addition to the current cost-reduction in 2001, Table 29 shows the effectiveness of cost reduction from the long-term perspectives until 2011.

Table 29. Cost reduction in the long-term period

(Unit: Billions KRW (Millions USD))

		2001	**2004**	**2008**	**2011**
Quantities (1,000 TEUs)		1,538	2,297	3,308	4,067
Cost	Current system	637 (531)	951 (792)	1,370 (1,141)	1,684 (1,430)
	Scenario I	286.6 (238.8)	426.1 (355.1)	616.4 (513.6)	757.8 (631.5)
	Δ_C	**350.2 (291.9)**	**524.9 (437.4)**	**753.4 (627.9)**	**926.2 (798.8)**
	Scenario II-1	381.9 (318.3)	567.9 (473.3)	821.5 (684.6)	1009.9 (841.6)
	Δ_C	**254.9 (185.4)**	**383.1 (319.2)**	**548.3 (456.9)**	**674.1 (588.7)**
	Scenario II-2	470.5 (392.1)	699.6 (583)	1,012 (843.3)	1,244.1 (1,036.8)
	Δ_C	166.3 (111.6)	251.4 (209.5)	357.8 (298.2)	439.9 (393.5)

6. Conclusion

Thus far we attempted to analyze container cargo flows generated in capital region of Korea and estimated the logistics cost and time. Based on integer goal programming model, we tried to find optimal solutions for international freight routing problems taking into account the three factors of cost, time and risk of handling cargoes. Genetic Algorithms were used to tackle huge number of variables and cases and also considering its flexibility of handling other qualitative variables when our model is extended later on. The most important finding is that Port of Incheon should be utilized in handling the international cargoes of the capital region in both aspects of logistics and time. Under various scenarios such as major liners' calling Incheon or not calling Incheon (as is the case today), using the Port of Incheon shows that we can reduce a great deal of logistics costs and time. This observation can be more vividly reflected in more coming years like year 2008 and 2011 when much increased containers are expected to be generated in the region.

Some caveats should be taken in interpreting the results since the results of this study are intermediate ones constrained by lack of data like more detailed level of cost, time and in particular time variances. These lacking data will be further sampled and investigated in the near future in our study. Despite that our findings are temporary ones, we can derive very important implications from our findings as follows: First, we have to maximize using the regional ports of the capital region, namely the Port of Incheon and Pyeongtaek replacing currently road-and-Busan-port dominant transportation system. Second, we should, therefore, develop container ports in Incheon/Pyeongtaek much earlier that ongoing plan. Third, we need to think about designing the ports in Incheon/Pyeongtaek to accommodate major ocean going shipping lines. Our findings in scenario I and II show that we can reduce hundreds of billion Wons (hundreds of million dollars) solely for the capital regional cargoes even excluding the possibility enducing more international cargoes when attracting major lines. Recent movement of major shipping lines' calling Northeastern Chinese ports in the vicinity of the Port of Incheon and increasing foreign direct investment in container terminals in Incheon are likely to justify this argument. This argument has to be tested asking various stakeholders of the ports whether they would use the ports or not. This remains to be our next step study.

Optimization Model for the Intermodal Routing Problem of International Container Cargoes in Korea Using Linear Programming Model

1. Introduction

To survive in the globally fierce competitive world, Korean government has made many efforts to be a logistic hub of the Northeast Asia. In spite of the effort, it is known that there is still great inefficiency in the transportation of international trade cargoes. One of the reasons may be an ill-balanced cargo flows. That is, most of these cargoes have been handled at seaports of Busan and Gwangyang, far from Seoul and Kyounggi province in which nearly 40% of Korea's population live. Therefore, cargo flows in the transportation network should be redesigned to improve efficiency in the transportation of international trade cargoes in Korea.

In this research, we consider the intermodal routing problem of international container cargoes in Korea (IRP), which is the problem of determining the cargo flow quantity, i.e., volume of container cargoes, and the transportation mode in each trade route, while satisfying the demand of cargoes in foreign seaports and Korean cities with the supply in Korean cities and foreign seaports, respectively, throughout a planning period. The objective of the problem is to minimize the total logistic costs, i.e., shipping and inland transportation costs (more detailed definition for the costs is given later). The IRP can be considered as a special case of the well-known network design problem (See Magnanti and Wong (1984) for more details of the network design problem), in that the IRP determines the flow quantity in each trade route while satisfying the demand and supply. In the IRP, however, we should determine the transportation mode in each trade route and consider two restrictions: maximum cargo volumes capacitated at each seaport and maximum cargo volumes carried by available number of vehicles at each transportation mode.

To the best of our knowledge, there is no previous research article on the IRP. In this research, we suggest a linear programming model to solve the IRP, which is an operations research technique. A case study is performed on the container cargo data in Korea and test results are reported. Also, we draw several implications to improve efficiency in the transportation of international trade cargoes in Korea.
The next section describes the IRP in more detail and suggests the linear programming model. Then, the real data of international container cargoes in Korea is given in Section 3, and test results and policy implications are summarized in Section 4. Finally, this research is completed with concluding remarks as well as future research directions.

2. Model formulation

This section starts by explaining the cargo flow network. Figure 14 shows an example of the network. In the figure, the dotted area represents sea and the shaded area represents the inland of Korea. In the network, each node corresponds to foreign seaports, domestic seaport, inland container depots (ICD), and domestic cities, e.g., nodes F1 and F2 are foreign seaports, D1 and D2 are domestic seaports, I1 and I2 are ICDs, and C1 and C2 are domestic cities. Also, each arrow represents transportation flow of cargoes, i.e., solid arrows present import flows, dotted arrows present export flows, and bolded arrow presents coastal shipping flow. In the figure, the numbers located at the left most side imply the supply and the demand amounts in foreign seaports, while those located at the right most side imply those at domestic cities. For example, 500 twenty foot equivalent units (TEU) and 10000 TEU are the number of supplied cargoes and the number of the demanded cargoes in foreign seaport F1, respectively. The transportation in the country is done by trucks and trains in a direct way to a destination (cities or domestic seaports), by coastal shipping and by way of an

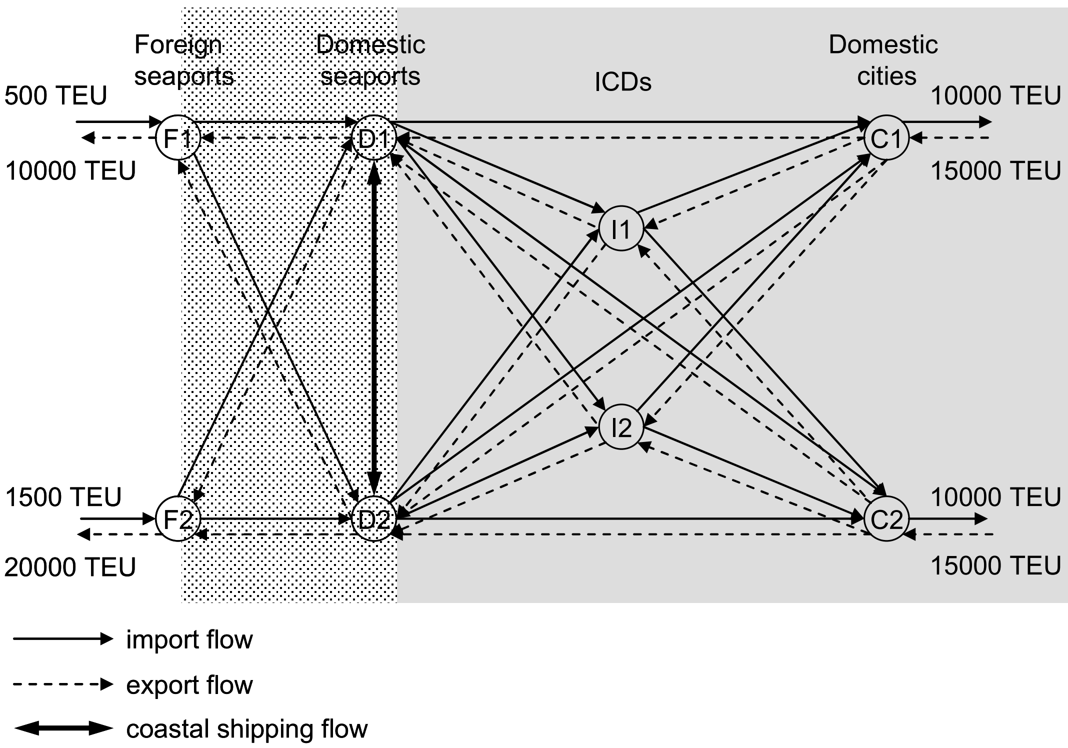
ICD. It is assumed that trains and trucks are operated between seaports and the ICD while trucks are only operated between ICDs and cities, according to the real situation in Korea. Here, the flow between ICDs is assumed not to occur based on the real situation in Korea.

Now, the problem can be described as follows: for a given cargo flow network, the problem is to determine the cargo flow quantity and the amount transported by each transportation mode over one planning period while satisfying the demand of cargoes in domestic cities and foreign seaports using the supply in foreign seaports and domestic cities, respectively, for the objective of minimizing the sum of shipping and inland transportation costs. The shipping cost implies the total cost charged while transporting cargoes between foreign and domestic seaports. The cost includes the holding and carrying costs, and terminal handling charge, where the holding cost implies the cost occurred while cargoes are held during the transportation, the carrying cost implies the cost charged for transporting cargoes, and the terminal handling charge is the cost occurred for the stevedoring service of cargoes at a domestic seaport. Here, we do not take account of the terminal handling charge at foreign seaports since we assume that the charge at foreign seaports is already given before shipping cargoes from foreign seaports. (Note that this model considers cargoes after shipping from foreign seaports.) Second, the inland transportation cost implies the total cost charged while transporting cargoes in the country, which includes the holding and carrying costs.

The problem considers two restrictions: capacity restriction and vehicle restriction. The capacity restriction implies that there is a limitation on the total cargo volume that can be handled at each seaport. The vehicle restriction consists of two restrictions that are different with respect to transportation mode types (This model considers two transportation modes, truck and train, which are main transportation means in Korea). For truck, the restriction is given in the form of the total available time of trucks, which implies the total time of trucks (available at each Korean seaport or Korean city) that can be operated during the planning period. On the other hand, the restriction for train is given in the form of the maximum number of trains, which implies the total number of trains operated on each train line during the planning period.

Finally, other assumptions made in the models are summarized as follows: (a) every parameter used in the model is given and deterministic; (b) single product type is considered (Hence, the model presented below can be called single product type model. The multiple product type model is given in Appendix); (c) one type of ship is used while shipping cargoes from foreign seaports to domestic seaports; (d) while transporting cargoes, one type of container is used, and traffic congestion never

Figure 14. An example of the cargo flow network



occurs; and (e) all transportation modes are perfect in state, i.e., they are not out of order throughout the planning period.

Now, we present a linear programming model to solve optimally. First, the notations used in the single product type model are summarized below. (Note that parameters and variables given below are for one planning period)

Notations

I set of foreign seaports

J set of domestic seaports

K set of domestic cities

C set of ICDs

M set of modes

n_m TEU that can be carried by mode m

nf_i TEU that can be carried by vessel departed from (arriving at) foreign seaport i

t_{ijm} transit time via mode m from depot i to destination j

cd_{ijm} cost of transporting an unit of cargo (TEU) via mode m from depot i to destination j which is calculated as

$$cd_{ijm} = h \cdot t_{ijm} + cm_{ij}$$

where h is the inventory holding cost per TEU and unit time and cm_{ij} is the price per TEU from deport i to destination j

cf_{ij} cost of shipping an unit of cargo from depot i to destination j, calculated as

$$cf_{ij} = cd_{ij4} + thc_j$$

where thc_j is the terminal handling charge per unit TEU

u_j available time of mode m at domestic seaport j

sf_i supply amount from foreign seaport i

sd_k supply amount from city k

df_i demand amount in foreign seaport i

dd_k demand amount in city k

a_j capacity of domestic seaport j

b_c capacity of ICD c

SI_{ij} import amount from foreign seaport i to domestic seaport j

SE_{ji} export amount from domestic seaport j to foreign seaport i

DI_{jk} import amount from domestic seaport j to city k

DE_{kj} export amount from city k to domestic seaport j

AI_{jkm} import amount via mode m from domestic seaport j to city k

AE_{kjm} export amount via mode m from city k to domestic seaport j

CI_{jck} import amount from domestic seaport j to city k via ICD c

CE_{kcj} export amount from city k to domestic seaport j via ICD c

TI_{jcm} import amount from domestic seaport j to ICD c via mode m

TE_{cjm} export amount from ICD c to domestic seaport j via mode m

TI_{ckm} import amount from ICD c to domestic seaport j via mode m

TE_{kcm} export amount from city k to ICD c via mode m

BI_{jbk} import amount from domestic seaport j to city k via domestic seaport b

BE_{kbj} export amount from city k to domestic seaport j via domestic seaport b

Now, the linear programming model is given below.

[P] Minimize $$\sum_{i\in I}\sum_{j\in J} cf_{ij}\cdot(SI_{ij}+SE_{ji})+\sum_{j\in J}\sum_{k\in K}\sum_{m\in\{1,2\}} cd_{jkm}\cdot(AI_{jkm}+AE_{kjm})$$

$$+\sum_{j\in J}\sum_{b\in J\setminus\{j\}}\sum_{k\in K} cd_{jb3}\cdot(BI_{jbk}+BE_{bjk})+\sum_{j\in J}\sum_{c\in C}\sum_{m\in M} cd_{jcm}\cdot(TI_{jcm}+TE_{cjm})$$

$$+\sum_{c\in C}\sum_{k\in K} cd_{ck1}\cdot(TI_{ck1}+TE_{kc1})$$

subject to

$$\sum_{j\in J} SI_{ij}=sf_i \qquad \text{for all } i\in I \tag{1}$$

$$\sum_{j\in J} DE_{kj}=sd_k \qquad \text{for all } k\in K \tag{2}$$

$$\sum_{j\in J} DI_{jk}=dd_k \qquad \text{for all } k\in K \tag{3}$$

$$\sum_{j\in J} SE_{ji}=df_i \qquad \text{for all } i\in I \tag{4}$$

$$\sum_{i\in I} SI_{ij}=\sum_{k\in K} DI_{jk} \qquad \text{for all } j\in J \tag{5}$$

$$\sum_{k\in K} DE_{kj} = \sum_{i\in I} SE_{ji} \qquad \text{for all } j \in J \tag{6}$$

$$\sum_{i\in I}(SI_{ij} + SE_{ji}) + \sum_{b\in J\setminus\{j\}} \sum_{k\in K} (BI_{bjk} + BE_{kjb}) \le a_j \qquad \text{for all } j \in J \tag{7}$$

$$\sum_{j\in J} \sum_{k\in K} (CI_{jck} + CE_{kcj}) \le b_c \qquad \text{for all } c \in C \tag{8}$$

$$DI_{jk} + \sum_{b\in J\setminus\{j\}} BI_{bjk} = \sum_{m\in\{1,2\}} AI_{jkm} + \sum_{b\in J\setminus\{j\}} BI_{jbk} + \sum_{c\in C} CI_{jck} \qquad \text{for all } j \in J \text{ and } k \in K \tag{9}$$

$$DE_{kj} = \sum_{m\in\{1,2\}} AE_{kjm} + \sum_{b\in J\setminus\{j\}} BE_{kbj} + \sum_{c\in C} CE_{kcj} \qquad \text{for all } j \in J \text{ and } k \in K \tag{10}$$

$$\sum_{k\in K} CI_{jck} \le \sum_{m\in\{1,2\}} TI_{jcm} \qquad \text{for all } j \in J \text{ and } c \in C \tag{11}$$

$$\sum_{j\in J} CI_{jck} \le TI_{ck1} \qquad \text{for all } c \in C \text{ and } k \in K \tag{12}$$

$$\sum_{j\in J} CE_{kcj} \le TE_{kc1} \qquad \text{for all } c \in C \text{ and } k \in K \tag{13}$$

$$\sum_{k\in K} CE_{kcj} \le \sum_{m\in\{1,2\}} TE_{cjm} \qquad \text{for all } j \in J \text{ and } c \in C \tag{14}$$

$$SI_{ij} \le nf_i \cdot v_{ij} \qquad \text{for all } i \in I \text{ and } j \in J \tag{15}$$

$$\sum_{k\in K} t_{jk1} \cdot AI_{jk1} + \sum_{c\in C} t_{jc1} \cdot TI_{jc1} \le n_1 \cdot u_j \qquad \text{for all } j \in J \tag{16}$$

$$AI_{jk2} \le n_2 \cdot v_{jk} \qquad \text{for all } j \in J \text{ and } k \in K \tag{17}$$

$$TI_{jc2} \le n_2 \cdot v_{jc} \qquad \text{for all } j \in J \text{ and } c \in C \tag{18}$$

$$\sum_{k\in K} t_{ck1} \cdot TI_{ck1} + \sum_{j\in J} t_{cj1} \cdot TE_{cj1} \le n_1 \cdot u_c \qquad \text{for all } c \in C \tag{19}$$

$$\sum_{k\in K} BI_{jbk} \le n_3 \cdot v_{jb} \qquad \text{for all } j \in J \text{ and } b \in J \setminus \{j\} \tag{20}$$

$$SE_{ji} \le nf_i \cdot v_{ji} \qquad \text{for all } i \in I \text{ and } j \in J \tag{21}$$

$$\sum_{j\in J} t_{kj1} \cdot AE_{kj1} + \sum_{c\in C} t_{kc1} \cdot TE_{kc1} \le n_1 \cdot u_k \qquad \text{for all } k \in K \tag{22}$$

$$AE_{kj2} \le n_2 \cdot v_{kj} \qquad \text{for all } k \in K \text{ and } j \in J \tag{23}$$

$TE_{cj2} \le n_2 \cdot v_{cj}$ for all $j \in J$ and $c \in C$ (24)

$\sum_{k \in K} BE_{kbj} \le n_3 \cdot v_{bj}$ for all $j \in J$ and $b \in J \setminus \{j\}$ (25)

$SI_{ij}, \; SE_{ji} \ge 0$ for all $i \in I$ and $j \in J$ (26)

$DI_{jk}, DE_{kj} \ge 0$ for all $j \in J$ and $k \in K$ (27)

$AI_{jkm}, AE_{kjm} \ge 0$ for all $j \in J$, $k \in K$, and $m \in \{1,2\}$ (28)

$CI_{jck}, \; CE_{kcj} \ge 0$ for all $j \in J$, $c \in C$, and $k \in K$ (29)

$TI_{jcm}, \; TE_{cjm} \ge 0$ for all $j \in J$, $c \in C$, and $m \in \{1,2\}$ (30)

$TI_{ckm}, \; TE_{kcm} \ge 0$ for all $c \in C$, $k \in K$, and $m \in \{1,2\}$ (31)

$BI_{jbk}, \; BE_{kbj} \ge 0$ for all $j \in J$, $b \in J \setminus \{j\}$, and $k \in K$ (32)

The objective function denotes the sum of shipping and inland transportation costs. Constraints (1) - (4) represent the supply and demand restrictions. In more detail, constraints (1) and (2) represent the supply restrictions, which imply that the cargoes going out from a foreign seaport and a domestic city should be equal to the supply amount in the seaport and the city, respectively. On the other hand, constraints (3) and (4) represent that demands in a foreign seaport and a domestic city should be satisfied, respectively. Constraints (5) and (6) represent the flow conservation, which implies that the amount of cargoes coming to a domestic seaport is equal to the amount of cargoes going out from the seaport. Constraints (7) and (8) states that the total amount of cargoes handled at a domestic seaport and an ICD cannot exceed the capacity of the seaport and the ICD, respectively. Constraints (9) and (10) generate the amount of cargoes transported directly (via truck and train), via barge, and by way of an ICD. In constraint (9), the cargoes transported from a seaport come from directly foreign seaports and via the other seaports, which are denoted in the first term and second term, respectively. Constraints (11) - (14) calculate the amount of cargoes transported via truck and train. Constraints (15) - (25) represent that the total transported amount of cargoes cannot exceed the amount that can be transported by available vehicles. In particular constraints (16), (19), and (22) represent that the total time required for using trucks is less than or equal to their available time at each depot. Finally, the other constraints (26) - (32) are the conditions on the decision variables.

3. Data Collection

Data were collected using various sources to test and run the model as formulated in the previous section. Basically the data were collected to be used for the parameter values in the model. Therefore, the data can be grouped in the following table sets:

Table

1. Data Set
   1-1. *I*: set of foreign seaports
   1-2. *J*: set of domestic seaports
   1-3. *K*: set of domestic cities
2. TEU capacity of each mode
3. Capacity of domestic seaport (Except T/S container)
4, Capacity of ICD
5. Supply and demand amount in foreign seaport (Yearly)
6. Supply and demand amount in domestic city
7. Cost
   7-1 Cost between foreign seaports and domestic seaports
   7-2 Cost between each domestic seaports
8. Time
   8-1. Travel time between domestic seaports and cities by truck
   8-2. Travel time between domestic seaports and cities by train
   8-3. Travel time between seaports and ICD by truck
   8-4. Travel time between seaports and ICD by Train
   8-5. Travel time between cities and ICD by Truck
   8-6. Travel time between each seaport by coastal shipping
9. The terminal handling charge per unit TEU
10. Available time
   10-1 Available time at domestic seaport
   10-2 Available time at domestic cities
   10-3 Available time at domestic ICD

11. Number of available mode at each seaport, cities, and ICD

   11-1. Number of available vessels between foreign seaports and domestic seaports

   11-2. Number of available train between domestic seaports and cities

   11-3. Number of available train between ICD and seaports

   11-4. Number of available coastal ships between each domestic seaport

First of all, the data set used for the three nodal points between foreign seaports, domestic seaports in Korea and final inland destination/origin points are presented in the following Tables 30, 31 and 32 set. Table 30 shows what which foreign seaports were selected as the starting nodal point, in case of Korea's import cargoes or as the last nodal point, in case of Korea's export cargoes. Since the main purpose of this project is to focus on short sea shipping (SSS) in the region, our research team attempted to cover up as detailed and numerous level of seaports as possible for the short sea shipping routes whereas covering up only representing major seaports in terms of cargo volumes for the deep sea shipping(DSS) routes. The selected seaports in the short sea shipping route group are major seaports handling Korea's international container cargoes in the region. In sum, thirteen DSS seaports and twenty two SSS seaports were selected for the model.

Table 30. Set of foreign seaports (*i*)

No.	Seaport			
1	Deep Sea Shipping	Europe	West Europe	
2			East Europe	
3		America	North America (except U.S.A)	
4			U.S.A.	Detroit
5				Houston
6				Long Beach
7				New York
8				Savannah
9				Seattle
10			South America	
11		Middle East	Middle East	
12			Central Asia	
13		Africa	Africa	

14	Short Sea Shipping	Asia	South-North Asia	Japan	Yokohama
15					Yamaguchi
16					Tokyo
17					Osaka
18					Nagoya
19					Hakata
20					Others
21				Hong Kong, China	
22				Chinese Taipei	Kaohsiung
23					Keelung
24					Others
25				China	Shanghai
26					Xingang
27					Dalian
28					Qingdao
29					Ningbo
30					Weihai
31					Yantai
32					Others
33			South-East Asia	Singapore	
34				Malaysia	
35				Others	

Next table is the set of domestic seaports in Korea. This is importing or exporting seaports in Korea as the *J*th nodal point in the model. As shown in Table 31, Korea's container cargoes are handled in five seaports such as Busan, Gwangyang, Incheon, Ulsan and Pyeongtaek.

Table 31. Set of domestic seaports (*j*)

No.	Seaport
1	Busan
2	Gwangyang
3	Incheon
4	Ulsan

5	Pyeongtaek

The final nodal point set is domestic cities in Korea as the source of cargo origin for export or destination for import. Table 32 shows that our research team divided the whole region in Korea into forty-three subregions due to data availability and tractability of running the model later on.

Table 32. Set of domestic cities (*k*)

No	1	2	3	4	5	6	7	8	9	10	11
Domestic Cities	KW1	KW2	KW3	KG1	KG2	KG3	KN1	KN2	KN3	KB1	KB2
No	12	13	14	15	16	17	18	19	20	21	22
Domestic Cities	KB3	KJ1	KJ2	DG1	DG2	DJ1	DJ2	PS1	PS2	PS3	SU1
No	23	24	25	26	27	28	29	30	31	32	33
Domestic Cities	SU2	SU3	SU4	SU5	US1	US2	IC1	IC2	IC3	CN1	CN2
No	34	35	36	37	38	39	40	41	42	43	
Domestic Cities	CN3	CB1	CB2	CB3	CUN1	CUN2	CUN3	CUB1	CUB2	CUB3	

KW1: Kangwon1, KW2: Kangwon2, KW3: Kangwon3, KG1: Kyunggi1, KG2: Kyunggi2, KG3: Kyunggi3, KN1: Kyungnam1, KN2: Kyungnam2, KN3: Kyungnam3, KB1: Kyungbuk1, KB2: Kyungbuk2, KB3: Kyungbuk3, KJ1: Kwangju1, KJ2: Kwangju2, DG1: Daegu1, DG2: Daegu2, DJ1: Daejon1, DJ2: Daejon2, PS1: Busan1, PS2: Busan2, PS3: Busan3, SU1: Seoul1, SU2: Seoul2, SU3: Seoul3, SU4: Seoul4, SU5: Seoul5, US1: Ulsan1, US2: Ulsan2, IC1: Incheon1, IC2: Incheon2, IC3: Incheon3, CN1: Cheonnam1, CN2: Cheonnam2, CN3: Cheonnam3, CB1: Cheonbuk1, CB2: Cheonbuk2, CB3: Cheonbuk3, CUN1: Chungnam1, CUN2: Chungnam2, CUN3: Chungnam3, CUB1: Chungbuk1, CUB2: Chungbuk2, CUB3: Chungbuk3

Tables 33, 34, and 35 show the capacity of each mode, domestic seaport and Inland Container Depot (ICD), respectively, in terms of TEU unit. The mode capacity refers to per vehicle carrying capacity and seaport and ICD are annual handling capacity. Table 34 shows that the seaport capacity is the estimate of export/import cargoes excluding transshipment cargoes.

Table 33. TEU capacity of each mode

<table>
<tr><td colspan="3">Transportation mode</td><td>TEU Capacity per vehicle</td></tr>
<tr><td colspan="3">Truck</td><td>1</td></tr>
<tr><td colspan="3">Train</td><td>50</td></tr>
<tr><td rowspan="4">Shipping</td><td colspan="2">Domestic</td><td>215</td></tr>
<tr><td rowspan="3">Foreign</td><td>South-North Asia</td><td>600</td></tr>
<tr><td>South-East Asia</td><td>1100</td></tr>
<tr><td>Deep Sea Shipping</td><td>6000</td></tr>
</table>

Table 34. Capacity of domestic seaport (except T/S container)

Seaport	Capacity (TEU)
Busan	7847811
Gwangyang	1386600
Incheon	1195395
Ulsan	314253
Pyeongtaek	227591

**Source*: Each seaport Authority website

Table 35. Capacity of ICD (Inland container depot)

ICD	Capacity (TEU)
Uiwang	1,400,000
Yangsan	2,000,000

**Source:* Each ICD website

Tables 36 and 37 display annual supply and demand amount in foreign seaports and domestic cities, respectively. These estimates are actual figures calculated from Korea Customs Administration's database in 2005, which is the first official output from the administration. Figure 15 shows the data structure of the database of the Customs Administration. Using this database, the research team could estimate location of cargo origin/destination in Korea, foreign seaport and domestic seaports, vessel arrival time, commodity classification code (SITC), number of TEUs and weight of cargo by individual shipment in 2005. We collected about 600,000 shipment data in 2005 mostly focusing on December shipments. Although we collected the data from December, 2005, we tested if there is any seasonality between March, June, September and December by comparing one week-long data among them. Our finding was that there was no seasonality, Therefore, without worrying about seasonality bias, we upscaled the December figure into annual figure.

Table 36. Supply and demand amount in foreign seaport (Yearly) (unit: TEU)

					Import	Export
Deep Sea Shipping	Europe	West Europe			659592	414295
		East Europe			146124	112354
	America	North America (except U.S.A)			102012	180957
		U.S.A.	Detroit		0	2506
			Houston		3648	3013
			Long Beach		161544	366083
			New York		49164	50201
			Savannah		48240	41404
			Seattle		125544	182113
		South America			167364	355768
	Middle East	Middle East			71808	343669
		Central Asia			59964	173546
	Africa	Africa			22584	178751
Short Sea Shipping	Asia	South-North Asia	Japan	Yokohama	121560	45706
				Yamaguchi	1044	30848
				Tokyo	94116	72168
				Osaka	130056	61287
				Nagoya	68964	47429
				Hakata	101904	27776
				Others	341016	118043
			Hong Kong, China		556032	301084
			Chinese Taipei	Kaohsiung	479580	62347
				Keelung	25008	68662
				Others	13236	23437
			China	Shanghai	185632	206996

				Xingang	205663	234683
				Dalian	134818	106751
				Qingdao	202341	174024
				Ningbo	82663	81057
				Weihai	40196	43575
				Yantai	24866	56309
				Others	108700	19372
		South-East Asia	Singapore		150612	78326
			Malaysia		119544	111331
			Others		17448	402349
Total TEU					4822587	4778220

**Source:* Korea Customs and Trade Development Institute (2005)

Table 37. Supply and demand amount in domestic city

Domestic Cities	KW1	KW2	KW3	KG1	KG2	KG3	KN1	KN2	KN3	KB1	KB2
Import	1545	5365	3150	135168	471827	138460	30257	87091	75570	34504	69230
Export	657	10897	9194	90985	508915	71670	41459	289190	183390	44027	48514
Domestic Cities	KB3	KJ1	KJ2	DG1	DG2	DJ1	DJ2	PS1	PS2	PS3	SU1
Import	88778	11949	11461	67686	16724	40742	7600	124846	56957	97515	97048
Export	286480	235019	17173	63717	37957	105488	6629	176397	39945	43564	36597
Domestic Cities	SU2	SU3	SU4	SU5	US1	US2	IC1	IC2	IC3	CN1	CN2
Import	426534	28509	1777007	184403	28916	54112	326	220836	66609	8393	12639
Export	308764	13196	198946	93818	79159	565335	706	126240	136998	7127	9231
Domestic Cities	CN3	CB1	CB2	CB3	CUN1	CUN2	CUN3	CUB1	CUB2	CUB3	
Import	32756	68092	6035	3150	12843	40051	62972	74371	27717	12843	
Export	320270	165617	5449	3782	95188	96527	79344	81813	33603	9243	

**Source:* Korea Customs and Trade Development Institute (2005)

Figure 15. Seaport O/D data form

	A	B	C	D	E	F	G	H	I	J	K
2	선박	입항일자	수입지역	양하항	적재항	원산지부호	세번부호 (HS code)	FCL_TEU	LCL_TEU	EMPTY TEU	화물중량(KG)
3	10	20040501	120	KRINC	CNYIK	CN	3824909090	0	0	0	1500000
4	10	20040501	120	KRINC	CNYIK	CN	3824909090	0	0	0	450000
5	10	20040501	405	KRINC	RUDKA	RU	4403204000	0	0	0	1434142
6	10	20040501	405	KRINC	RUDKA	RU	4403204000	0	0	0	1462433
7	10	20040501	405	KRINC	RUDKA	RU	4407104000	0	0	0	1456584
8	10	20040501	405	KRINC	RUDKA	RU	4407104000	0	0	0	66398
9	10	20040501	641	KRINC	CNTAO	KZ	7202410000	0	0	0	800000
10	10	20040501		KRINC	CNTAO			0	0	0	
11	10	20040501		KRINC	CNTAO			0	0	0	
12	10	20040501		KRINC	CNTAO			0	0	0	

**Source*: Korea Customs and Trade Development Institute (2005)

Following two tables are cost calculation between foreign seaports and domestic seaports, ICDs and domestics seaports as well as between domestics seaports themselves. The cost here means not only carrying costs, but also inventory costs of cargoes. The carrying costs are collected from official websites of shipping companies and freight forwarders and the holding costs are estimated from previous studies done by our research team. (Chang and Sung, 2002)

Table 38. Cost between foreign seaports and domestic seaports

(Unit: $)

		Busan	Gwangyang	Incheon	Ulsan	Pyeongtaek
West Europe		1860	1960	2060	-	-
East Europe		2,250	-	-	-	-
North America (except USA)		1950	2050	-	-	-
USA	Detroit	3100	3200	-	-	-
	Houston	2850	2950	-	-	-
	Long Beach	1950	2050	-	-	-
	New York	3000	3100	-	-	-
	Savannah	1950	2050	-	-	-
	Seattle	1950	2050	-	-	-
South America		1100	-	-	-	-
Middle East		1400	1400	1500	-	-
Central Asia		2550	-	-	-	-

Africa		1000	1,500	-	-	-
Japan	Yokohama	250	300	350	-	300
	Yamaguchi	300	-	-	-	-
	Tokyo	300	330	350	-	330
	Osaka	250	270	330	-	270
	Nagoya	250	270	330	-	270
	Hakata	250	-	-	-	-
	Others	265	290	340	-	290
Hong Kong		150	150	250	250	150
Chinese Taipei	Kaohsiung	400	400	450	-	400
	Keelung	400	400	450	-	400
	Others	400	400	450	-	400
China	Shanghai	200	230	350	400	230
	Xingang	250	280	400	450	280
	Dalian	230	260	300	400	260
	Qingdao	250	250	350	450	250
	Ningbo	250	280	310	-	280
	Weihai	320	320	420	420	320
	Yantai	400	400	450	-	400
	Others	270	220	250	230	225
South-East Asia	Singapore	250	250	300	-	250
	Malaysia	350	350	400	-	350
	Others	300	300	350	-	300

**Source:* www.schedulebank.com

Note: 20' Full container

Table 39. Cost between each domestic seaport

(unit: $)

	Busan	Gwangyang	Incheon	Ulsan	Pyeongtaek
Busan	0	50	167	0	0

Gwangyang	96	0	163	0	159
Incheon	167	163	0	0	73
Ulsan	0	0	0	0	0
Pyeongtaek	0	159	73	0	0

**Source*: Each seaport website

Table 40. Cost between ICD and domestic seaports

(Unit: $)

	Uiwang ICD	Yangsan ICD
Busan	0	37
Gwangyang	0	47
Incheon	229	0
Ulsan	0	0
Pyeongtaek	211	0

The following six tables show travel time between domestic seaports and cities and ICDs by different mode. The sources of these data vary ranging from government agencies to websites of private transportation and logistics companies. The nil figures in the cells mean that there is currently no link between the nodal points.

Table 41. Travel time between domestic seaport and cities by truck

(Unit: day)

Domestic Cities	KW1	KW2	KW3	KG1	KG2	KG3	KN1	KN2	KN3	KB1	KB2
Busan	0.26	0.33	0.28	0.24	0.19	0.19	0.08	0.05	0.18	0.08	0.05
Gwangyang	0.30	0.37	0.33	0.25	0.20	0.20	0.06	0.09	0.11	0.15	0.14
Incheon	0.18	0.25	0.26	0.10	0.18	0.07	0.18	0.22	0.22	0.19	0.23
Ulsan	0.26	0.33	0.29	0.24	0.20	0.20	0.11	0.07	0.23	0.08	0.06
Pyeongtaek	0.18	0.25	0.26	0.10	0.24	0.29	0.14	0.19	0.19	0.17	0.20

Domestic Cities	KB3	KJ1	KJ2	DG1	DG2	DJ1	DJ2	PS1	PS2	PS3	SU1
Busan	0.08	0.17	0.15	0.06	0.08	0.14	0.14	0.12	0.23	0.06	0.21
Gwangyang	0.14	0.09	0.06	0.12	0.10	0.13	0.13	0.10	0.13	0.10	0.21
Incheon	0.15	0.19	0.17	0.12	0.16	0.10	0.10	0.25	0.23	0.18	0.18

Ulsan	0.11	0.20	0.17	0.08	0.08	0.15	0.15	0.30	0.05	0.06	0.22
Pyeongtaek	0.12	0.16	0.14	0.14	0.14	0.07	0.08	0.19	0.22	0.20	0.29
Domestic Cities	SU2	SU3	SU4	SU5	US1	US2	IC1	IC2	IC3	CN1	CN2
Busan	0.21	0.20	0.21	0.21	0.24	0.30	0.27	0.23	0.21	0.15	0.22
Gwangyang	0.20	0.21	0.20	0.21	0.21	0.13	0.26	0.23	0.21	0.07	0.14
Incheon	0.24	0.06	0.18	0.18	0.20	0.21	0.07	0.12	0.06	0.18	0.18
Ulsan	0.21	0.21	0.21	0.22	0.18	0.07	0.28	0.24	0.22	0.18	0.25
Pyeongtaek	0.06	0.07	0.29	0.29	0.18	0.19	0.10	0.06	0.24	0.14	0.15
Domestic Cities	CN3	CB1	CB2	CB3	CUN1	CUN2	CUN3	CUB1	CUB2	CUB3	
Busan	0.11	0.19	0.17	0.12	0.24	0.19	0.16	0.17	0.16	0.06	
Gwangyang	0.18	0.11	0.09	0.08	0.20	0.18	0.14	0.16	0.20	0.16	
Incheon	0.22	0.13	0.14	0.18	0.20	0.09	0.12	0.11	0.12	0.22	
Ulsan	0.14	0.21	0.20	0.15	0.25	0.19	0.16	0.18	0.17	0.14	
Pyeongtaek	0.19	0.10	0.11	0.15	0.05	0.24	0.08	0.08	0.12	0.20	

**Source:* Korea Expressway Corporation (www.roadplus.com)

Table 42. Travel time between domestic seaports and cities by train

(Unit: day)

Domestic Cities	KW1	KW2	KW3	KG1	KG2	KG3	KN1	KN2	KN3	KB1	KB2
Busan	-	0.50	0.56	-	-	0.51	-	0.24	-	-	-
Gwangyang	-	-	-	-	-	0.49	-	-	-	-	-
Incheon	-	-	-	-	-	-	-	-	-	-	-
Ulsan	-	-	-	-	-	0.52	-	-	-	-	-
Pyeongtaek	-	-	-	-	-	0.00	-	-	-	-	-
Domestic Cities	KB3	KJ1	KJ2	DG1	DG2	DJ1	DJ2	PS1	PS2	PS3	SU1
Busan	0.31	0.32	-	-	-	0.41	-	-	-	-	-
Gwangyang	0.41	0.30	-	-	-	0.40	-	-	-	0.27	-
Incheon	-	-	-	-	-	-	-	-	-	-	-
Ulsan	0.30	-	-	-	-	-	-	-	-	0.23	-

Pyeongtaek	-	-	-	-	-	-	-	-	-	-	-

Domestic Cities	SU2	SU3	SU4	SU5	US1	US2	IC1	IC2	IC3	CN1	CN2
Busan	-	-	-	-	0.23	-	-	-	-	-	-
Gwangyang	-	-	-	-	-	-	-	-	-	-	-
Incheon	-	-	-	-	-	-	-	-	-	-	-
Ulsan	-	-	-	-	-	-	-	-	-	-	-
Pyeongtaek	-	-	-	-	-	-	-	-	-	-	-

Domestic Cities	CN3	CB1	CB2	CB3	CUN1	CUN2	CUN3	CUB1	CUB2	CUB3	
Busan	0.39	0.46	-	-	-	0.50	0.43	0.45	-	-	
Gwangyang	0.22	0.31	-	-	-	0.48	0.41	0.40	-	-	
Incheon	-	-	-	-	-	-	-	-	-	-	
Ulsan	0.29	-	-	-	-	0.42	-	0.44	-	-	
Pyeongtaek	-	-	-	-	-	-	-	-	-	-	

**Source:* Ministry of Construction & Transportation, Statistics data

Table 43. Travel time between seaports and ICD by truck

(Unit: day)

O/D	Uiwang ICD	Yangsan ICD
Busan	0.00	0.03
Gwangyang	0.00	0.16
Incheon	0.07	0.00
Ulsan	0.00	0.00
Pyeongtaek	0.12	0.00

**Source*: Each ICD website

Table 44. Travel time between seaports and ICD by train

(Unit: day)

O/D	Uiwang	Yangsan
Busan	0.34	0.18

Gwangyang	0.31	0.24
Incheon	0.19	0.35
Ulsan	0.33	0.19
Pyeongtaek	0.19	0.33

**Source:* MINISTRY OF CONSTRUCTION & TRANSPORTATION, Statics data

Table 45. Travel time between cities and ICD by truck

(Unit: day)

Domestic Cities	KW1	KW2	KW3	KG1	KG2	KG3	KN1	KN2	KN3	KB1	KB2
Uiwang	0.08	0.07	0.10	0.06	0.02	0.04	0.13	0.13	0.17	0.14	0.17
Yangsan	0.20	0.13	0.24	0.19	0.16	0.16	0.06	0.09	0.01	0.06	0.19
Domestic Cities	KB3	KJ1	KJ2	DG1	DG2	DJ1	DJ2	PS1	PS2	PS3	SU1
Uiwang	0.10	0.13	0.12	0.13	0.12	0.07	0.07	0.16	0.17	0.17	0.02
Yangsan	0.09	0.13	0.12	0.05	0.05	0.10	0.10	0.01	0.00	0.02	0.15
Domestic Cities	SU2	SU3	SU4	SU5	US1	US2	IC1	IC2	IC3	CN1	CN2
Uiwang	0.02	0.04	0.02	0.12	0.16	0.17	0.05	0.02	0.02	0.14	0.15
Yangsan	0.17	0.16	0.16	0.05	0.02	0.03	0.21	0.18	0.17	0.15	0.25
Domestic Cities	CN3	CB1	CB2	CB3	CUN1	CUN2	CUN3	CUB1	CUB2	CUB3	
Uiwang	0.15	0.08	0.11	0.13	0.06	0.08	0.05	0.07	0.03	0.07	
Yangsan	0.07	0.14	0.15	0.10	0.19	0.19	0.12	0.13	0.16	0.12	

**Source:* Ministry of Construction & Transportation, Statistics data

Table 46. Travel time between each seaport by coastal ship

(Unit: day)

	Busan	Gwangyang	Incheon	Ulsan	Pyeongtaek
Busan	-	0.52	1.58	0.30	1.53

Gwangyang	0.52	-	1.37	0.62	1.37
Incheon	1.58	1.37	-	1.68	0.31
Ulsan	0.30	0.62	1.68	-	1.63
Pyeongtaek	1.53	1.37	0.31	1.63	-

*Source: Each seaport website

Table 47 shows terminal handling charge per TEU in each of the domestic seaports in Korea.

Table 47. The terminal handling charge per TEU

(Unit: $)

Port	Busan	Gwangyang	Incheon	Ulsan	Pyeongtaek
Charge	133	108	112	108	108

*Source: Each seaport website

Tables 48, 49, and 50 show available truck times per year in domestic seaports, cities and ICDs to calculate how many hours truck between these nodal points can transport cargoes in the model. The available times come from the source that how many trucks are registered in each area and how many hours truck be operated per year.

Table 48. Available time of truck at domestic seaport

(Unit: day)

Domestic seaport	Day
Busan	466400
Gwangyang	805200
Incheon	6848160
Ulsan	1533400
Pyeongtaek	5042180

Table 49. Available time of truck at domestic cities

(Unit: day)

KW1	KW2	KW3	KG1	KG2	KG3	KN1	KN2	KN3	KB1	KB2
664840	679800	583220	5302880	5773020	5797000	1151920	1348160	1665620	1292720	1246960

KB3	KJ1	KJ2	DG1	DG2	DJ1	DJ2	PS1	PS2	PS3	SU1
1505460	630520	1167320	8454380	581460	1101540	798380	1155220	2779480	2896740	1171060
SU2	SU3	SU4	SU5	US1	US2	IC1	IC2	IC3	CN1	CN2
15161520	1908720	2699180	2369840	459800	1044340	329780	3658600	1073160	983620	842600
CN3	CB1	CB2	CB3	CUN1	CUN2	CUN3	CUB1	CUB2	CUB3	
1368840	2202200	291940	221320	502920	971300	1220340	399740	63360	114180	

Table 50. Available time of truck at domestic ICD

(Unit: day)

Uiwang	40183220
Yangsan	15042280

Finally the following Tables 51, 52, 53, and 54 show number of available vehicle calls per year between nodes of foreign and domestics seaport, ICDs , cities and between domestic seaports themselves. These figures were calculated by our research teams based on current routing data and personal communication with people working in the areas of the modes.

Table 51. Number of available vessels calls per year between foreign seaports and domestic seaports

(Unit: vessel call)

		Busan	Gwangyang	Incheon	Ulsan	Pyeongtaek
West Europe		154	15	12	0	0
East Europe		44	0	0	0	0
North America (except USA)		44	4	0	0	0
USA	1	1	0	0	0	-
	2	1	0	0	0	-
	82	7	0	0	0	-
	16	2	0	0	0	-
	14	2	0	0	0	-
	48	5	0	0	0	-
South America		88	0	0	0	0
Middle East		60	6	5	0	0

Central Asia		39	0	0	0	0
Africa		31	3	0	0	0
Japan	236	23	18	5	0	300
	54	0	0	0	0	-
	235	22	18	5	22	330
	270	26	21	5	0	270
	165	16	13	4	12	270
	217	0	0	0	0	-
	648	61	49	10	19	290
Hong Kong		1190	113	92	17	22
Chinese Taipei	765	72	58	11	0	400
	133	13	10	3	0	400
	52	5	4	2	0	400
China	546	52	42	9	15	230
	612	58	47	10	13	280
	336	32	26	6	9	260
	523	50	41	8	15	250
	231	22	18	5	0	280
	117	12	9	3	5	320
	115	11	9	3	0	400
	178	17	14	4	7	225
South-East Asia	177	17	14	4	0	250
	178	17	14	4	0	350
	323	31	25	6	8	300

Table 52. Number of available train calls between domestic seaports and cities

Domestic Cities	KW1	KW2	KW3	KG1	KG2	KG3	KN1	KN2	KN3	KB1	KB2

Busan	0	6	12	0	0	2290	0	70	0	0	0
Gwangyang	0	0	0	0	0	609	0	0	0	0	0
Incheon	0	0	0	0	0	0	0	0	0	0	0
Ulsan	0	0	0	0	0	12	0	0	0	0	0
Pyeongtaek	0	0	0	0	0	0	0	0	0	0	0

Domestic Cities	KB3	KJ1	KJ2	DG1	DG2	DJ1	DJ2	PS1	PS2	PS3	SU1
Busan	207	99	0	0	0	69	0	0	0	0	0
Gwangyang	4	40	0	0	0	9	0	0	0	33	0
Incheon	0	0	0	0	0	0	0	0	0	0	0
Ulsan	85	0	0	0	0	0	0	0	0	162	0
Pyeongtaek	0	0	0	0	0	0	0	0	0	0	0

Domestic Cities	SU2	SU3	SU4	SU5	US1	US2	IC1	IC2	IC3	CN1	CN2
Busan	0	0	0	0	13	0	0	0	0	0	0
Gwangyang	0	0	0	0	1	0	0	0	0	0	0
Incheon	0	0	0	0	0	0	0	0	0	0	0
Ulsan	0	0	0	0	0	0	0	0	0	0	0
Pyeongtaek	0	0	0	0	0	0	0	0	0	0	0

Domestic Cities	CN3	CB1	CB2	CB3	CUN1	CUN2	CUN3	CUB1	CUB2	CUB3
Busan	89	199	0	0	0	88	177	157	0	0
Gwangyang	2	231	0	0	0	18	66	28	0	0
Incheon	0	0	0	0	0	0	0	0	0	0
Ulsan	1	0	0	0	0	1	0	1	0	0
Pyeongtaek	0	0	0	0	0	0	0	0	0	0

Table 53. Number of available train calls per year between ICD and seaports

	Uiwang	Yangsan
Busan	1645	307

Gwangyang	609	37
Incheon	0	0
Ulsan	20	54
Pyeongtaek	0	0

Table 54. Number of available coastal ship calls per year between domestic seaports

	Busan	Gwangyang	Incheon	Ulsan	Pyeongtaek
Busan		8	499	0	0
Gwangyang	8		2	0	2
Incheon	499	2		0	1
Ulsan	0	0	0		0
Pyeongtaek	0	2	1	0	

4. Test of the Model and Policy Implications

First, the single and multiple product type models suggested in this research are validated using the data given in Section 3 to check whether the models represent real situations in Korea. Then, by relaxing several constraints in the model, we draw several possible policy implications on the development of short sea shipping. In case of multiple product type model, we considered two types of product: low and high value products (hence, two product type model), and the demand ratio was set to 73.1% and 26.1% for the demand and supply data of low and high value products, respectively, based on the real data. Also, the holding cost was set to \$ 0.42 and \$ 25 for low and high value products, derived from our team's previous research (Chang and Sung, 2002), respectively. The multiple product type model is given in Appendix. In the test, the model was generated by coding with a computer language C and solved using CPLEX 9.1, a commercial software package.

Test results are summarized in Table 55, which shows the solution of the CPLEX and the real data on the ratio (share) of the throughput at each domestic seaport versus the total container cargo volume imported into and exported from Korea, and the ratio (share) of the volume transported by each transportation model among total cargo container volume. As can be seen from the table, the models represent the real situation quite well. Therefore, it can be concluded that the model can be used to analyze the possible effect on the cargo flow in Korea when future situation on the international cargo trade in Korea changes.

Table 55. Comparison of the models' result with real data

(a) Share of the total container cargo volume at each domestic seaport (%)*

	Model	Real
Busan	75.8(68.6)**	68.5
Gwangyang	12.5(14.4)	11.4
Incheon	8.4(11.3)	11.0
Ulsan	1.6(3.3)	3.3
Pyeongtaek	1.7(2.4)	2.4

Notes: * throughput / total cargo volume·100

** result in parenthesis refers to that of two product type model

(b) Share of the total container cargo volume by each transportation mode (%) *

	Model	Real
Truck	83.3(64.4)**	87.3
Train	14.0(33.9)	9.9
Coastal shipping	2.6(1.7)	2.8

Notes: * cargo volume / total cargo volume·100

** result in parenthesis refers to that of two product type model

Next, we show the possible effect on the cargo flow in Korea when future situation on the international cargo trade in Korea changes. Note that Table 56 shows that the share of the throughput at each domestic seaport generated by the two product type model gives nearly equal results, but that by each transportation model the result is far from the real situation. Therefore, we use the single product type model to further test to analyze the possible effect. To do that, we relaxed the capacity and vehicle restrictions and changed the speed of vessels operated at each seaport,

First, we discuss the effect if the capacity and vehicle restrictions are relaxed, while the other constraints and data remain the same. The test result is summarized in Table 56.

From the table, the throughput share of seaports of Busan, Incheon, and Pyeongtaek can be reduced as much as nearly 30%, 70%, and 90%, respectively while the throughput share of seaports of Gwangyang and Ulsan can be increased as much as nealy 50% and 850%. Also, the model indicates that by reducing the usage of truck, train and coastal shipping should be promoted to use more.

Table 56. Effect without any capacity and vehicle restrictions

(a) Share of the total container cargo volume at each domestic seaport (%)*

	Future	Current (Real)	Changed Ratio
Busan	48.3	68.5	-29.6
Gwangyang	17.5	11.4	53.5
Incheon	3.0	11.0	-72.8
Ulsan	30.9	3.3	849.2
Pyeongtaek	0.3	2.4	-88.7

Note: * throughput / total cargo volume·100

(b) Share of the total container cargo volume by each transportation mode (%) *

	Future	Current (Real)	Changed Ratio
Truck	34.4	87.3	-60.6
Train	27.7	9.9	179.8
Coastal shipping	37.9	2.8	1254.7

Note: * cargo volume / total cargo volume·100

In order to discuss the effect more precisely, we relaxed only the vehicle restrictions (15) and (21) related to vessels operated between foreign and domestic seaports. As can be seen from Table 57, the throughput of only Busan seaport is reduced while that of the others are increased which implies that it is beneficial to develop the other seaports more than to develop Busan seaport.

Table 57. Share of the total container cargo volume at each domestic seaport (%)*

	No vessel	Original

	restriction	
Busan	68.6	75.8
Gwangyang	14.4	12.5
Incheon	11.3	8.4
Ulsan	3.3	1.6
Pyeongtaek	2.4	1.7

Note: * throughput / total cargo volume·100

Second, we discuss the effect if the speed of vessels operated in area of short sea shipping is changed from 13 knot (considered in the model validation) to 20 knot, while the other constraints and data remain the same. The test result is summarized in Table 58. From the table, there is no effect when vessel speed changes. In fact, if vessel speed is changed, the transportation price may be increased. Therefore, to see the more exact effect of the vessel speed change, we have to consider the vessel speed change as well as the transportation price change, but this analysis may be highly difficult.

Table 58. Share at each Domestic seaport when vessel speed changes (%)*

	Speed change	Original
Busan	75.8	75.8
Gwangyang	12.5	12.5
Incheon	8.4	8.4
Ulsan	1.6	1.6
Pyeongtaek	1.7	1.7

*Note:** throughput / total cargo volume·100

5. Discussions and Conclusion

In this research, we considered the problem of determining the cargo flow quantity and the transportation mode in each trade route, for the objective of minimizing the sum of shipping and inland transportation costs, restricted to maximum cargo volumes capacitated at each seaport and maximum number of vehicles available at each transportation mode. To solve optimally and represent the problem, our research team employed a linear programming model. Test result showed that the model represents closely the real situation. After validation of our model, we tested what would happen if we relax current capacity of port and availability of vehicle constraints. The results show that the port of Busan and Incheon will be less used and other ports will be more used. One of the reasons for this change may be caused by pricing structure, but this time our research team could not incorporate the price change into the model. Further the model output showed that coastal shipping will be enormously increased by over twelve times. This means if we further develop ports and SSS capacity in terms of available number of ships, SSS will develop at rapid speed in the region. Again, we tested what would happen if we only release the vehicle available constraint. The result showed that all underutilized ports will be more used if we only provide more SSS vessel services although we do not change current port capacity. This is very meaningful finding and as we expected from our proposal, this shows important policy implications toward further developing SSS system in the region in the near future.

There are some further research directions. First, it is worth to consider more transportation modes such as airplane. Second, the demand in foreign cities (not that in foreign seaports used in this report) is worth to be considered. In this case, the capacity of foreign seaports and all parameters corresponding to inland transportation should be used. Third, traffic and environmental factors should be considered to reflect externality effects such as congestion and pollution. If we include these externalities into our research scope in the future, it is more likely that Short Sea Shipping will be recommended to be more used in the region.

The main objective of this Project has the specific aim of offsetting and lessening congestion at major hub seaports which is expected to worsen substantially as larger ships call on these seaports and trade doubles over the next two decade. It consists of three sub-objectives: to integrate underutilized seaports to reduce congestion, to create a model in and to facilitate underutilized seaport development.

The project's methodology by phase are as follows: Phase I - Identify and summarize existing coastal marine freight and passenger services flowing through seaports (including ancillary services) along with legal and regulatory considerations between multiple economies in two specified APEC regions; Phase II- Gather data from each of the two regions and build a flow model in which to assess the marine transportation patterns that exist and could exist by application of successful short sea shipping models and technologies and the use of underutilized seaports, and then test the flow models; and Phase III - Run "what if scenarios" using the short sea shipping model. Evaluation of model output, along with analysis and recommendation of successful models for short sea shipping in the APEC regions as well as the clustering of economic activities that promotes the inclusion of underutilized seaports into the supply/demand chain. This report has covered up the scope of Phase II thus far.

The accelerated growth of Asian economy, including high rate of Chinese economy, has both influenced and mirrored changes in the scope and operation of shipping connections within Asia and with the rest of the world, causing the repercussions on extra- and intra-Asian container shipping networks. As a result of that, in Europe, Short Sea Shipping (SSS) has grown steadily over the last two decades. Asia needs an efficient logistics transport system combining the benefits of all modes to maintain and increase competitiveness and prosperity in line with the globalized economy in order to overcome less efficient rail and road transportation system and to make many of Asian main industrial centers get close to waterways. Thus, in many cases, SSS routes in Asia may provide the fastest and most reliable service between destinations. Fast growing trends of SSS has been also seen in Asia according to mega-hub seaport developments and China's high rate of economic growth. Recent years have brought an increasing focus on developing new SSS options that are better suited for moving container cargo, for example in Korea and China, that normally travels by truck and tends to include higher-value and time-sensitive goods.

Fast growth of heavy road transport and related congestion, accidents and pollution are the main economic, social and environmental problems that the policy to promote SSS is worthwhile to address.

The research team have employed two quantitative models in building cargo flow network in the case region. One model is a kind of heuristic approach, particularly using Genetic Algorithms focusing on the capital region of Korea, and the other is traditional mathematical program - liner programming covering up the whole nation's international trade. The objective of both models is to find the minimum logistics cost to handle international trade cargoes in the capital region and the whole Korea, respectively.

Prior to building the cargo flow network models, the team first analyzed the data of Korea's coastal shipping and predicted future demand for the shipping using Origin-Destination matrix of cargoes.

Our research team attempted to analyze container cargo flows generated in capital region of Korea and estimated the logistics cost and time. Based on integer goal programming model, we tried to find optimal solutions for international freight routing problems taking into account the three factors of cost, time and risk of handling cargoes. Genetic Algorithms were used to tackle huge number of variables and cases and also considering its flexibility of handling other qualitative variables when our model is extended later on. The most important finding is that seaport of Incheon should be utilized in handling the international cargoes of the capital region in both aspects of logistics and time. Under various scenarios such as major liners' calling Incheon or not calling Incheon (as is the case today), using the seaport of Incheon shows that we can reduce a great deal of logistics costs and time. This observation can be more vividly reflected in more coming years like year 2008 and 2011 when much increased containers are expected to be generated in the region.

Despite that our findings are temporary ones, we can derive very important implications from our findings as follows: First, we have to maximize using the regional seaports of the capital region, namely the seaport of Incheon and Pyeongtaek replacing currently road-and-Busan-port dominant transportation system. Second, we should, therefore, develop container seaports in Incheon/Pyeongtaek much earlier that ongoing plan. Third, we need to think about designing the seaports in Incheon/Pyeongtaek to accommodate major ocean going shipping lines. Our findings in scenario I and II show that we can reduce hundreds of billion Wons (hundreds of million dollars) solely for the capital regional cargoes even excluding the possibility inducing more international cargoes when attracting major lines. Recent movement of major shipping lines' calling Northeastern Chinese seaports in the vicinity of the seaport of Incheon and increasing foreign direct investment in container terminals in Incheon are likely to justify this argument. This argument has to be tested asking various stakeholders of the seaports whether they would use the seaports or not. This remains to be our next step study.

Next problem considered in this project is the intermodal routing problem of international container cargoes in Korea, which can be defined as the problem of determining the cargo flow quantity and the transportation mode in each trade route while satisfying the demand. The objective is to minimize the sum of shipping and inland transportation costs. There are two major constraints: maximum cargo volumes capacitated at each seaport and maximum cargo volumes that can be carried by available vehicles of each transportation mode. In order to solve optimally and represent the problem, our research team employed a linear programming model, which is an operations research technique. The problem is formulated by extending the well-known network design problem by considering the two major constraints. The model is solved using CPLEX, a commercial linear programming software. The test results using a real cargo flow data in Korea show that the model represents closely the real situation. After validation of our model, we tested what would happen if we relax current capacity of port and availability of vehicle constraints. The results show that the port of Busan and Incheon will be less used and other ports will be more used. One of the reasons for this change may be caused by pricing structure, but this time our research team could not incorporate the price change into the model. Further the model output showed that coastal shipping will be enormously increased by over twelve times. This means if we further develop ports and SSS capacity in terms of available number of ships, SSS will develop at rapid speed in the region. Again, we tested what would happen if we only release the vehicle available constraint. The result showed that all underutilized ports will be more used if we only provide more SSS vessel services although we do not change current port capacity. This is very meaningful finding and as we expected from our proposal, this shows important policy implications toward further developing SSS system in the region in the near future.

In sum, Short Sea Shipping has been supported by European Union in the past decade and similar advocacy can be observable in North American continent. It seems to be high time that Asia-Pacific region should develop SSS as early as possible in view of expected benefits ranging from reduced logistics costs, and environmental protection to further utilization of underused seaports in the region. The research team attempted to capture current practices of SSS in major maritime regions and to build cargo flow network model. Our findings from the models are clear: SSS will provide more transportation and logistics routing choices for various stakeholders; reduce logistics costs; encourage currently underdeveloped or less-utilized seaports to be further developed and/or used in the future. To do this, new technology such as faster ship and turnaround in major intermodal nodes and policy formulation to expedite cargo movements need be incorporated into the SSS system in the near future.

Some caveats should be taken in interpreting the results since the results of this study are intermediate ones constrained by lack of data like more detailed level of cost, time and in particular time variances. These lacking data will be further sampled and investigated in the near future in our study if the Phase III-work is approved by APEC in the future as proposed in the original proposal. Even if we attempted to build up the cargo flow network model to test how Short Sea Shipping can affect the total logistics and transportation network in terms of cost and time in the case study, a great deal of factors need to b e further considered in the future to analyze more detailed impacts of the SSS in the APEC region by providing APEC economywise specific data and evaluate the validity of our model in these numerous cases. This can be done by WHAT-IF type analysis as proposed in our proposal.

APPENDIX

Multiple Product Type Model

The model is obtained by simply adding notation p representing product type into single product type model.

$$\text{Minimize } \sum_{i\in I}\sum_{j\in J}\sum_{p\in P} cf_{ij}^{p}\cdot(SI_{ij}^{p}+SE_{ji}^{p})+\sum_{j\in J}\sum_{k\in K}\sum_{m\in\{1,2\}}\sum_{p\in P} cd_{jkm}^{p}\cdot(AI_{jkm}^{p}+AE_{kjm}^{p})$$

$$+\sum_{j\in J}\sum_{b\in J\setminus\{j\}}\sum_{k\in K}\sum_{p\in P} cd_{jb3}^{p}\cdot(BI_{jbk}^{p}+BE_{bjk}^{p})+\sum_{j\in J}\sum_{c\in C}\sum_{m\in M}\sum_{p\in P} cd_{jcm}^{p}\cdot(TI_{jcm}^{p}+TE_{cjm}^{p})$$

$$+\sum_{c\in C}\sum_{k\in K}\sum_{p\in P} cd_{ck1}^{p}\cdot(TI_{ck1}^{p}+TE_{kc1}^{p})$$

subject to

$$\sum_{j\in J} SI_{ij}^{p}=sf_{i}^{p} \qquad \text{for all } i\in I \text{ and } p\in P \qquad \text{(A1)}$$

$$\sum_{j\in J} DE_{kj}^{p}=sd_{k}^{p} \qquad \text{for all } k\in K \text{ and } p\in P \qquad \text{(A2)}$$

$$\sum_{i\in I} SI_{ij}^{p}=\sum_{k\in K} DI_{jk}^{p} \qquad \text{for all } j\in J \text{ and } p\in P \qquad \text{(A3)}$$

$$\sum_{k\in K} DE_{kj}^{p}=\sum_{i\in I} SE_{ji}^{p} \qquad \text{for all } j\in J \text{ and } p\in P \qquad \text{(A4)}$$

$$\sum_{j\in J} DI_{jk}^{p}=dd_{k}^{p} \qquad \text{for all } k\in K \text{ and } p\in P \qquad \text{(A5)}$$

$$\sum_{j\in J} SE_{ji}^{p}=df_{i}^{p} \qquad \text{for all } i\in I \text{ and } p\in P \qquad \text{(A6)}$$

$$\sum_{i\in I}\sum_{p\in P}(SI_{ij}^{p}+SE_{ji}^{p})+\sum_{b\in J\setminus\{j\}}\sum_{k\in K}\sum_{p\in P}(BI_{bjk}^{p}+BE_{kjb}^{p})\le a_{j}$$

$$\text{for all } j\in J \qquad \text{(A7)}$$

$$\sum_{j\in J}\sum_{k\in K}\sum_{p\in P}(CI_{jck}^{p}+CE_{kcj}^{p})\le b_{c} \qquad \text{for all } c\in C \qquad \text{(A8)}$$

$$DI_{jk}^{p}+\sum_{b\in J\setminus\{j\}} BI_{bjk}^{p}=\sum_{m\in\{1,2\}} AI_{jkm}^{p}+\sum_{b\in J\setminus\{j\}} BI_{jbk}^{p}+\sum_{c\in C} CI_{jck}^{p}$$

$$\text{for all } j\in J,\ k\in K, \text{ and } p\in P \qquad \text{(A9)}$$

$$DE_{kj}^{p} = \sum_{m\in\{1,2\}} AE_{kjm}^{p} + \sum_{b\in J\setminus\{j\}} BE_{kbj}^{p} + \sum_{c\in C} CE_{kcj}^{p} \qquad \text{for all } j \in J, k \in K, \text{and } p \in P \qquad \text{(A10)}$$

$$\sum_{k\in K} CI_{jck}^{p} \le \sum_{m\in\{1,2\}} TI_{jcm}^{p} \qquad \text{for all } j \in J, c \in C, \text{ and } p \in P \qquad \text{(A11)}$$

$$\sum_{j\in J} CI_{jck}^{p} \le TI_{ck1}^{p} \qquad \text{for all } c \in C, k \in K, \text{and } p \in P \qquad \text{(A12)}$$

$$\sum_{j\in J} CE_{kcj}^{p} \le TE_{kc1}^{p} \qquad \text{for all } c \in C, k \in K, \text{and } p \in P \qquad \text{(A13)}$$

$$\sum_{k\in K} CE_{kcj}^{p} \le \sum_{m\in\{1,2\}} TE_{cjm}^{p} \qquad \text{for all } j \in J, c \in C, \text{ and } p \in P \qquad \text{(A14)}$$

$$\sum_{p\in P} SI_{ij}^{p} \le nf_i \cdot v_{ij} \qquad \text{for all } i \in I \text{ and } j \in J \qquad \text{(A15)}$$

$$\sum_{k\in K}\sum_{p\in P} t_{jk1} \cdot AI_{jk1}^{p} + \sum_{c\in C}\sum_{p\in P} t_{jc1} \cdot TI_{jc1}^{p} \le n_1 \cdot u_j \qquad \text{for all } j \in J \qquad \text{(A16)}$$

$$\sum_{p\in P} AI_{jk2}^{p} \le n_2 \cdot v_{jk} \qquad \text{for all } j \in J \text{ and } k \in K \qquad \text{(A17)}$$

$$\sum_{p\in P} TI_{jc2}^{p} \le n_2 \cdot v_{jc} \qquad \text{for all } j \in J \text{ and } c \in C \qquad \text{(A18)}$$

$$\sum_{k\in K}\sum_{p\in P} t_{ck1} \cdot TI_{ck1}^{p} + \sum_{j\in J}\sum_{p\in P} t_{cj1} \cdot TE_{cj1}^{p} \le n_1 \cdot u_c \qquad \text{for all } c \in C \qquad \text{(A19)}$$

$$\sum_{k\in K}\sum_{p\in P} BI_{jbk}^{p} \le n_3 \cdot v_{jb} \qquad \text{for all } j \in J \text{ and } b \in J \setminus \{j\} \qquad \text{(A20)}$$

$$\sum_{p\in P} SE_{ji}^{p} \le nf_i \cdot v_{ji} \qquad \text{for all } i \in I \text{ and } j \in J \qquad \text{(A21)}$$

$$\sum_{p\in P}\sum_{j\in J} t_{kj1} \cdot AE_{kj1}^{p} + \sum_{p\in P}\sum_{c\in C} t_{kc1} \cdot TE_{kc1}^{p} \le n_1 \cdot u_k \qquad \text{for all } k \in K \qquad \text{(A22)}$$

$$\sum_{p\in P} AE_{kj2}^{p} \le n_2 \cdot v_{kj} \qquad \text{for all } k \in K \text{ and } j \in J \qquad \text{(A23)}$$

$$\sum_{p\in P} TE_{cj2}^{p} \le n_2 \cdot v_{cj} \qquad \text{for all } j \in J \text{ and } c \in C \qquad \text{(A24)}$$

$$\sum_{k\in K}\sum_{p\in P} BE_{kbj}^{p} \le n_3 \cdot v_{bj} \qquad \text{for all } j \in J \text{ and } b \in J \setminus \{j\} \qquad \text{(A25)}$$

$$SI_{ij}^{p},\ SE_{ji}^{p} \ge 0 \qquad \text{for all } i \in I, j \in J, \text{and } p \in P \qquad \text{(A26)}$$

$$DI_{jk}^{p}, DE_{kj}^{p} \ge 0 \qquad \text{for all } j \in J, k \in K, \text{ and } p \in P \qquad \text{(A27)}$$

$$AI_{jkm}^{p}, AE_{kjm}^{p} \geq 0 \qquad \text{for all } j \in J, k \in K, m \in \{1,2\}, \text{ and } p \in P \quad \text{(A28)}$$

$$CI_{jck}^{p},\ CE_{kcj}^{p} \geq 0 \qquad \text{for all } j \in J, c \in C, k \in K, \text{ and } p \in P \quad \text{(A29)}$$

$$TI_{jcm}^{p},\ TE_{cjm}^{p} \geq 0 \qquad \text{for all } j \in J, k \in K, m \in \{1,2\}, \text{ and } p \in P \quad \text{(A30)}$$

$$TI_{ckm}^{p},\ TE_{kcm}^{p} \geq 0 \qquad \text{for all } c \in C, k \in K, m \in \{1,2\}, \text{ and } p \in P \quad \text{(A31)}$$

$$BI_{jbk}^{p},\ BE_{kbj}^{p} \geq 0 \qquad \text{for all } j \in J, b \in J \setminus \{j\}, k \in K, \text{and } p \in P \quad \text{(A32)}$$

REFERENCES

Amerini, G. (2006), “Short Sea Shipping of Goods, 2000-2005”, *Statistics in Focus*; Transport, 12/2006.

Baird, A. (1999), “Container Vessels in the New Millennium: Implications for Seaports”, *Proceedings of the 1999 Halifax Conference*, IAME, pp. 141-173.

Baker, B. M. and M.A. Ayechew (2003), “A Genetic Algorithm of the Vehicle Routing Problem”. *Computers & Operations Research*, Vol. 30, pp. 787-800.

Barnhart, C. and H. Donald Ratliff (1993), “Modeling Intermodal Routing”. *Journal of Business Logistics*, Vol. 14 (1), pp.205-223.

Boardman, B. S., E. M. Malstrom, D. P. Butler and M. H. Cole (1997), “Computer Assisted Routing of Intermodal Shipments”. *Computers & Industrial Engineering*, Vol. 33 (1-2), pp.311-314.

Brooks, M. R, J. R. Hodgson and J. D. Frost (2006), Short Sea Shipping on the East Coast of North America: An analysis of opportunities and issues. Canada-Dalhousie University Transportation Planning/Model Integration Initiative Project ACG-TPMI-AH08 Final Report.

Browning, J. and S. H.Lee (2004). “Short Sea Shipping and Innovations for Intermodal Containers Logistics in Northeast Asia”. *Journal of International Logistics and Trade*, Vol. 1 (2), pp. 25-53.

Browning, J. (2003), “Development of Logistics and Transportation Systems in Promoting Trade and Economic Growth: Comparing Incheon and Seattle Areas”, *Korea Observer*, Vol. 34.(3), pp. 589-611

Browning, J. (2004), Innovations in Logistics and Barge Carrier Design for Coastal and Inland Water Shipping. Incheon International Logistics Seminar: “Strategies to Develop Incheon as Logistics Hub in Northeast Asia: Short Sea Shipping Approach”, organized by Jungseok Research Institute, Inha University, Incheon Korea.

Chang, Y.-T. (2003), “Korea’s Strategic Plan to Be Northeast Asia’s Logistics Hub: Towards the Pentaport Approach”. *Korea Observer*, Vol. 34 (3), pp. 437-460.

Chang, Y.-T. (2000), "Port Competition in East Asia and Korean Strategy", *Journal of Korea Port Economic Association*, Vol. 17 (2), pp. 29-59.

Chang, Y.-T. and S.-K. Sung (2002), “Revisit to Estimate the Time Cost of Ships and Cargoes,” *Journal of Korean Navigation and Port Research*, Vol. 26 (4), pp. 383-390.

Cho, K.-S. (2000), *Contemporary Issues of Coastal Shipping in Korea and Development Strategy*, Contract Research Report by KMI.

Cho, K.-S. (2004), Constraints to Korea’s Coastal Shipping and Northeast Asian SSS. Incheon International Logistics Seminar: “Strategies to Develop Incheon as Logistics Hub in Northeast Asia: Short Sea Shipping Approach”, organized by Jungseok Research Institute, Inha University, Incheon Korea.

Choo, H. (2002), *Introduction to Knowledge Science: Cognitive Models & Intelligent Reasoning*. Yonsei Knowledge Science Research Center, Seoul, pp. 490-491.

Chopra, S. and P. Meindl (2004), *Supply Chain Management: Strategy, Planning, and Operations*, Prentice-Hall International, Singapore.

Clarkson Research Studies (2001), *Container Intelligence Monthly,* March 2001.

Commission of the European Communities (2006), *Impact Assessment*, Commission Staff Working Document.

Commission of the European Communities (2003), *Programme for the Promotion of Short Sea Shipping*, Communication from the Commission.

Container Railway-Transport Cost Info. Homepage. Korea Logistics Association of Railroad Users, Seoul. www.klaru.or.kr/system/ss_container.php. Accessed March 5- July 20, 2004.

Container Railway-Transport Time Info. Homepage. Korean National Railroad, Daejeon, www.logis.korail. go.kr/driveinfo/TrainDriveGuideg.jsp. Accessed March 5- July 20, 2004.

Container Road-Transport Cost Info. Homepage. DTC Express, Incheon. www.dtc.co.kr/service/tariff.php. Accessed March 5- July 20, 2004.

Container Road-Transport Cost Info. Homepage. Global Enterprises, Ltd., Seoul. www.global.co.kr/dis_ index.html. Accessed March 5- July 20, 2004.

Davies, C. and P. Lingras (2003), "Genetic Algorithms for Rerouting Shortest Paths in Dynamic and Stochastic Networks". *European Journal of Operational Research*, Vol. 144, pp. 27-38.

Dhar, V. and R. Stein (1997), *Intelligent Decision Support Methods: The Science of Knowledge Work*. Prentice Hall, New Jersey.

Faulin, J (2003), "Applying MIXALG Procedure in a Routing Problem to Optimize Food Product Delivery". *Omega*, Vol. 31, pp. 387-395.

Fernandez, J., J. Cea Ch, and A. Soto (2003), "A Multi-modal Supply-Demand Equilibrium Model for Predicting Intercity Freight Flows", *Transportation Research Part B*, Vol. 37, pp. 615-640.

Fossey, J. (2000), *Fast track. Containerisation International*, 33(4), pp. 83-85

Friesz, T., J. Gottfried, and E. Morlok (1986), "A Sequential Shipper-Carrier Network Model for Prediction Freight Flows", *Transportation Science*, Vol. 20, pp. 80-91.

Gaudry, M. (2002), *The Four Approaches to Origin-Destination Matrix Estimation for Consideration by the MYSTIC Research Consortium*, Working Report No. 2000-10, Department of Economy Science, University of Montreal.

Gen, M. and R. Cheng (1996), *Genetic Algorithms and Engineering Design*. John Wiley and Sons, Inc., New York, Ch. 1-2.

Goldberg, L. R (1989), *Genetic Algorithms in Search, Optimization and Machine Learning*. Addison-Wesley, Reading, New York, Ch. 1.

Ha, H. K., K. Lee, and J. Lee (2003), *Strategies to Decrease National Logistics Costs for Improving National Competitiveness: Determining Factors for National Logistics Costs*. (written in Korean) Publication KOTI Research Series 2003-03. KOTI, Korea Transport Institute.

Hanjin Transportation Co. Ltd., Seoul. Container Coastal-Transport Cost and Time Info. Homepage. www.hanjin.co.kr/business/shipping/container.htm. Accessed March 5- July 20, 2004

Harrison, R. and M. Bomba (2004), Changing U.S.-Asian Maritime Shipping Patterns: Is There a Role Short Sea Shipping?. Incheon International Logistics Seminar: “Strategies to Develop Incheon as Logistics Hub in Northeast Asia: Short Sea Shipping Approach”, organized by Jungseok Research Institute, Inha University, Incheon Korea.

Holland, J. H. (1975), *Adaptation in Natural and Artificial Systems*, University of Michigan Press, Ann Arbor.

Informa Maritime and Transport, *Containerisation International Yearbook 2000*, May 2000.

Informa Maritime and Transport, *Containerisation International Yearbook 2001*, May 2001.

Jaszkiewicz, A. and P. Kominek (2003), “Genetic Local Search with Distance Preserving Recombination Operator for a Vehicle Routing Problem”. *European Journal of Operational Research*, Vol. 151, pp. 352-364.

Kam, B. (2004), Competitive Strength of Hong Kong, China as a Regional Logistics Hub. Incheon International Logistics Seminar: “Strategies to Develop Incheon as Logistics Hub in Northeast Asia: Short Sea Shipping Approach”, organized by Jungseok Research Institute, Inha University, Incheon Korea.

KCTA (2000), *Enlarging transshipment cargoes*, Research report, September 2000.

Kim, H. (2000), *Port Privatization in Korea,* Proceedings of KASS and KOMARES International Symposium: Challenge of the World Shipping and Response of the Korean Shipping in the 21st Century, Nov. 10-11, 2000, Seoul, Korea.

Kim, Y. (2000), *Development Status and Its Future Direction of Korea Ports,* Proceedings of KASS and KOMARES International Symposium: Challenge of the World Shipping and Response of the Korean Shipping in the 21st Century, Nov. 10-11, 2000, Seoul, Korea.

KMI (1999), *Port Tariff Setting for the Port of Busan,* Research Report, May, 1999.

Korea Shipping Association (2005), *Vision and Development Strategy for Innovation of Coastal Shipping*. (in Korean version) Seoul, Korea.

Lee, C.-H. and C.-Y. Lee (1989), “A Study on Estimating Optimal Tonnage of Coastal Cargo Vessels in Korea”, *Journal of the Korean Institute of Navigation Science*, Vol. 13, pp. 21-53.

Lee, J.-T. (2004), Application of Short Sea Shipping Model to Korean Coastal Container Transportation. Incheon International Logistics Seminar: “Strategies to Develop Incheon as Logistics Hub in Northeast Asia: Short Sea Shipping Approach”, organized by Jungseok Research Institute, Inha University, Incheon Korea.

Lee, T.-W. (2004). Tailer-made Logistics Solution for Coal Transshipment Operation: A Trial Case in East Kalimantan, Indonesia. Incheon International Logistics Seminar: “Strategies to Develop Incheon as Logistics Hub in Northeast Asia: Short Sea Shipping Approach”, organized by Jungseok Research Institute, Inha University, Incheon Korea.

Lee, T-W and K. Cullinane (ed.) (2005). *World Shipping and Port Development*, London: Palgrave MacMillan.

Lee, T-W, M. Roe, R. Gray and M. Shen (ed) (2002), *Shipping in China*. London: Ashgate.

Lee, S.-H. (2004), A Model for Short Sea Shipping System for the Yellow Sea at a Standpoint of Incheon. Incheon International Logistics Seminar: “Strategies to Develop Incheon as Logistics Hub in Northeast Asia: Short Sea Shipping Approach”, organized by Jungseok Research Institute, Inha University, Incheon Korea.

Leung, S. C. H., Y. Wu, and K. K. Lai (2002), “An Optimization Model for a Cross-Border Logistics Problem: A Case in Hong Kong”, *China. Computers and Industrial Engineering*, Vol. 43, pp. 393-405.

Lin, C. C (2001), “The Freight Routing Problem of Time-Definite Freight Delivery Common Carriers”. *Transportation Research Part B*, Vol. 35, pp. 525-547.

Lin, X., Y. K. Kwok, and K. N. Vincent Lau (2003), “A Genetic Algorithm Based Approach to Route Selection And Capacity Flow Assignment”. *Computer Communications*, Vol.26, pp. 961-974.

Lloyd's List (2001), *Lloyds Shipping Economist* (2001), Vol. 23.

Macharis, C., and Y. M. Bontekonning (2004), "Opportunities for OR in Intermodal Freight Transport Research: a Review". *European Journal of Operational Research*, Vol. 153, pp. 400-416.

Magnanti, T. and R. Wong (1984), "Network Design and Transportation Planning: Models and Algorithms". *Transportation Science*, Vol. 18, pp. 1-55.

Mao, S. (2002), *Calibration of the Gravity Model for Truck Freight Flow Distribution*, Research Report No. UVACTS-5-14-14, Center for Transportation Studies, University of Florida.

Michalewicz, Z (1999). Genetic Algorithms + Data Structure = Evolution Programmes (3rd Revised and Extended ed.). Springer, Berlin, Ch. 4, 6-7.

Min, H. (1991) "International Intermodal Choices via Chance-Constrained Goal Programming". *Transportation Research Part A: General*, Vol. 25, pp. 351-362.

Ministry of Maritime Affairs and Fisheries (1998 , 1999, 2000, 2001, 2002, 2003, 2004), *Statistical Year Book of Maritime Affairs and Fisheries*, Seoul.

Ministry of Maritime Affairs and Fisheries, PORTMIS Homepage. Seoul. multi.portincheon.go.kr/. Accessed March 5- April 20, 2004.

Oum, T. H. and J.-H. Park (2004) "Multinational Firms' Locational Preference for Regional Distribution Centers: Focus on the Northeast Asian Region", *Transportation Research Part E*, Vol. 40. pp. 101-121.

Park, Y. A. (2003), *Revitalization of Coastal Shipping in the Capital Region of Korea. (written in Korean) Publication KMI In-House Report 2003-11*. KMI, Korea Maritime Institute.

Rimmer, P. (2004), China's Changing Regional and International Shipping Connections 1999-2000. Incheon International Logistics Seminar: "Strategies to Develop Incheon as Logistics Hub in Northeast Asia: Short Sea Shipping Approach", organized by Jungseok Research Institute, Inha University, Incheon Korea.

Rimmer, P. and Y.-T. Chang (2003), Incheon Pentaport – Five Ports in One: Seeking Its Conceptual Underpinning. Presented at Three Consecutive Events

Celebrating 50th Anniversary of Inha University, Inha University, Incheon, Korea.

Ruiz, R., C. Maroto, and J. Alcaraz (2004), "A Decision Support System for a Real Vehicle Routing Problem". *European Journal of Operational Research*, Vol. 153, pp. 593-606.

Seabrooke, W., E.C.M. Hui, W.H.K. Lam, & G.K.C. Wong (2002), "Forecasting Cargo Growth and Regional Role of the Port of Hong Kong". *Cities*, 20(1), pp. 51-64.

Shin, S. S. (2002), *Origin/Destination Analysis of Container Cargoes in Korea*. (written in Korean) Publication KMI Issue Analysis 2002-01. KMI, Korea Maritime Institute.

Song, D.-W. (2004), Regional Logistics Hubs in the Context of Short Sea Shipping. Incheon International Logistics Seminar: "Strategies to Develop Incheon as Logistics Hub in Northeast Asia: Short Sea Shipping Approach", organized by Jungseok Research Institute, Inha University, Incheon Korea.

Taguchi, T., K. Ida and M. Gen (1998), "A Genetic Algorithm for Optimal Flow Assignment in Computer Network". *Computer & Industrial Engineering*. Vol. 35 (3-4), pp. 535-538.

Takemura, J. (2004), Short Sea Shipping Practices in Japan. Incheon International Logistics Seminar: "Strategies to Develop Incheon as Logistics Hub in Northeast Asia: Short Sea Shipping Approach", organized by Jungseok Research Institute, Inha University, Incheon, Korea

Tarantilis, C. D. and C. T. Kiranoudis (2002), "Using a Spatial Decision Support System for Solving the Vehicle Routing Problem"*. Information and Management*, Vol. 39, pp.359-375.

Toth, P. and D. Vigo (2002), "Models, Relaxations and Exact Approaches for the Capacitated Vehicle Routing Problem". *Discrete Applied Mathematics*, Vol. 123, pp. 487-512.

Turban, E. and J. E. Aronson (2001), *Decision Support Systems and Intelligent Systems* (6th ed.). Prentice Hall, New Jersey, pp. 664-671.

United States Government Accountability Office (2005), *Short Sea Shipping Option Shows Importance of Systematic Approach to Public Investment Decisions*. Gao-05-768.

Watanabe, Y. (2004), Japanese Short Sea Shipping, How It Works. Incheon International Logistics Seminar: "Strategies to Develop Incheon as Logistics Hub in Northeast Asia: Short Sea Shipping Approach", organized by Jungseok Research Institute, Inha University, Incheon Korea.

Yamada, H. (1989). *Perspective on the short-sea liner trades in Asia, Marintec China*, Shanghai, 30 November 1989, unpublished paper.