HEC Montréal

The Impact of using air cargo in multimodal transportation systems

-Economic and environmental perspective

Master of science in administration
Global supply chain management

By
Dongjin Li

Thesis Supervisor:
Jacques Roy
HEC Montréal

November, 2017
Dongjin Li, 2017

HEC MONTRĒAL

Comité d'éthique de la recherche

CERTIFICATE OF ETHICS APPROVAL

This is to confirm that the research project described below has been evaluated in accordance with ethical conduct for research involving human subjects, and that it meets the requirements of our policy on that subject.

Project No.: 2017-2682

Title of research project:
Impact of using air cargo in the multimodal transportation system - Economic and environmental development perspective

Principal investigator:
Dongjin Li,

Research director(s):
Jacques Roy
HEC Montréal

Date of project approval: March 16, 2017

Effective date of certificate: March 16, 2017

Expiry date of certificate: March 01, 2018

Maurice Lemelin
Président du CER de HEC Montréal

Abstract

In the logistics industry, the multimodal transportation method, which is to transport goods by the combination of multiple transportation modes, has been widely used to transport products in order to reduce transportation costs and provide relatively high service levels. However, air cargo in the multimodal transportation system is a relatively new topic. Due to the high cost of transported items by air, freight forwarders are deciding whether to use air transportation modes only, or a combination of multimodal transportation modes with the exception of the air mode. To determine whether to use an air cargo transportation mode, it is necessary to identify whether the transported item is time sensitive.

In this thesis, we focus on items or products of different monetary values, varying from low to high; however, they all require high relative transport speeds, for example, perishable goods and fashion products with low value and electronic goods and jewelry with high value. Considering the total transportation cost and total transit time, the top five itineraries, taking into account transportation costs and transportation transit time, within city pairs in Europe, Asia, North America and Africa are selected. Furthermore, the environmental impact of using an air cargo method is investigated, with a comparison between air cargo only and the use of a combination of air cargo and other transportation modes.

The main methodology used in the thesis is the analysis of data combinations in order to choose the best one—with a relatively low price and high speed between any two city pairs from the selected cities in three main continents (Europe and Asia [Eurasia], North America, and Africa). We conclude our study by generating a separate cost and time comparison chart of each main city pair in the three continents. We expect that the result of this research will be beneficial to shippers and freight-forwarding companies in making their transportation decisions.

Key words: Air cargo, multimodal transportation systems, data analysis, transportation costs, transit time, transport environmental concern.

Sommaire

Dans le secteur de la logistique, le transport multimodal, qui consiste à transporter des marchandises en combinant plusieurs modes de transport, a été largement utilisée pour transporter des produits afin de réduire les coûts de transport et de fournir des niveaux de service relativement élevés. Cependant, le fret aérien dans le système de transport multimodal est un sujet relativement nouveau de nos jours. En raison du coût élevé du transport des articles par avion, les transitaires décident s'ils utilisent uniquement les modes de transport aérien ou une combinaison de modes de transport multimodal, à l'exception du mode aérien. Pour déterminer s'il faut utiliser un mode de transport de fret aérien, il est nécessaire d'identifier si l'article transporté est sensible au temps.

Dans cette thèse, nous nous concentrons sur des articles ou des produits de différentes valeurs monétaires; cependant, ils exigent tous des vitesses de transport relativement élevées, par exemple, des produits périssables et des produits de mode à faible valeur et des biens électroniques et des bijoux de grande valeur. Compte tenu du coût total du transport et du temps de transit total, les cinq meilleurs itinéraires, en tenant compte des coûts de transport et du temps de transport, dans les paires de villes en Europe, Asie, Amérique du Nord et Afrique sont sélectionnés.
En outre, l'impact environnemental de l'utilisation d'une méthode de fret aérien est étudié, avec une comparaison entre le fret aérien uniquement et l'utilisation d'une combinaison de fret aérien et d'autres modes de transport.

La méthodologie principale utilisée dans la thèse est l'analyse des combinaisons de données afin de choisir la meilleure - avec un prix relativement bas et une grande vitesse entre deux paires de villes sélectionnées dans trois continents principaux (Europe et Asie [Eurasie], Amérique du Nord et Afrique). Nous terminons notre étude en générant un graphique comparatif des coûts et des temps de chaque paire de villes principale dans les trois continents. Nous prévoyons que le résultat de cette recherche sera bénéfique pour les expéditeurs et les sociétés d'expédition de fret dans leurs décisions de transport.

Mots clés: Fret aérien, systèmes de transport multimodal, analyse de données, coûts de transport, temps de transit, préoccupations environnementales liées aux transports.

Table of content

List of figures

List of tables

List of abbreviations

SH	SHANGHAI
SGP	SINGAPORE
BGD	BANGLADESH
MB	MUMBAI
ISTB	ISTANBUL
ATHS	ATHENS
RM	ROME
MD	MADRID
AMSD	AMSTERDAM
HMB	HAMBURG
LD	LONDON
MSC	MOSCOW
TKY	TOKYO
MTL	MONTREAL
HLF	HALIFAX
NYC	NEWYORK
MIA	MIAMI
NOL	NEWORLEANS
LA	LOS ANGELES
STL	SEATTLE
VCV	VANCOUVER
CR	CAIRO
CPT	CAPETOWN

Acknowledgement

This thesis marks the end of my journey to obtain my M.Sc. degree. I take great pleasure in thanking those who significantly contributed to the success of the study.

First, I would like to offer my most sincere and humble thanks to my thesis supervisor, **Professor Jacques Roy.** Whenever I faced difficulties and challenges, he always pointed me in the right direction and provided instructions. When I was unable to find potential participants for my interviews, he shared almost all his contacts in the research field with me to complete my thesis. Without his help and guidance, I would have been lost in finding the right solution to my thesis results.

I would also want to thank my **parents,** who provided me with substantial support while completing the entire journey in the University.

In addition, I give my thanks to those who helped me with the completion of my thesis.

1 Introduction

1.1 Research problem

The trade-off between transportation costs and lead time has long been recognized, and the trade-off between inventory holding costs and transportation costs has been present throughout the history of logistics. In the short life cycle of fast-changing product industries, for example, the fashion industry, companies use air cargo methods to move high-value products to various destinations.

Those product industries seldom use any algorithms to optimize the route design that would include air cargo in their combination of transportation modes (multimodal transportation systems).

1.2 Purpose and objective of the study

Previous studies were done to determine the economic and environmental effects of the multimodal transportation system. However, there are few studies done on the use of air cargo methods in multimodal transportation systems. As we know, the cost of air transport is high, but the transit time is fast. Therefore, the proper products to be transported by air can only be short life-cycle products, such as perishable goods; fashion products, which can be low value but demand high speed; and high-value products. To transport those products, we must determine whether shipping via air can be used in the multimodal transportation system to obtain a similar outcome to an air-only method, for example, to transport goods with smaller total costs but similar transporting speeds (high speed).

Through different combinations of the prices and transit times of four different transportation modes (air, sea, road, and rail) between major cities in the world, we can observe the best relative combinations with the help of Excel’s filter function and vertical lookup function, and some visual basics for application (VBA) coding languages.

1.3 Research questions

- Are there any possible itineraries using multimodal transport methods (air mode included) that create better economic effects and service levels than air-only transport modes in time-sensitive, low-value and high-value products?

- Are there any itinerary differences between transporting small cargos and heavy cargos?

- Are there any itinerary differences between short-distance city pairs and long-distance city pairs in different regions (Eurasia, North America and Africa) with regard to transporting products?

- What are the itinerary differences between different regions, for example, Eurasia and North America, and cross-continent city pairs?

The remainder of the thesis is organized into seven key sections. Section 2 is a literature review that provides general insights into the multimodal transport system and into air cargo within this system in terms of economic and environmental issues. Section 3 explains the methodology, and Section 4 introduces the logic and means of data collection. Section 5 presents both the results of the data analysis and the discussion of the results, while Section 6 consists of the interview sections for validating our research results. Section 7 provides our conclusion, and Section 8 describes both managerial and academic implications, including the limitations of the research, and shares future research opportunities.

2 Literature review

2.1 Definitions

2.1.1 Multimodal transport[1]

Multimodal freight transport is the operation of freight transport with more than one transport mode (UNECE, 2009). Basically, the main components of multimodal transport are air, road, rail, and maritime.

Figure 1. ***Detail of a multimodal transport system***

Origin/Supplier →									**Destination /Customer**
Physical Base	Depot	Road/Rail	Terminal	Sea Trunk /Leg	Terminal	Road/Rail	Depot		
Commercial System	Cost & Delivery	Pack	Inland Movement	Papers	Port to Port	Papers	Inland Movement	Unpack	Cost & Delivery
Management & Co-ordination	Packing	Container Positioning	Inland Movement	Terminal Operations	Ship	Stowage	/ Route	Scheduling	
Flow of Information	Booking	Waybill	Invoice	Manifest	Delivery	Instructions	Release of	Cargo	
Liability Network	Forwarder	Road	Rail	Terminals		Sea	Forwarder		

Source: Ruth Banomiyong, 2000

Details of multimodal transport are presented in the figure above. From the origin, which is the supplier, to the destination, which is the customer, physical base, commercial system, management and coordination, the flow of information, and a liability network are different in different steps. (Modal transit)

The physical base in the chart means the place where the goods are placed during the transportation period; the commercial system is the system dealing with specific transport works; the section of management and coordination is the action along with the transportation; the flow of information is the direction of transaction information flows from the supplier to the customer; and the liability network is the main responsibilities that the carriers pay in the transportation chain.

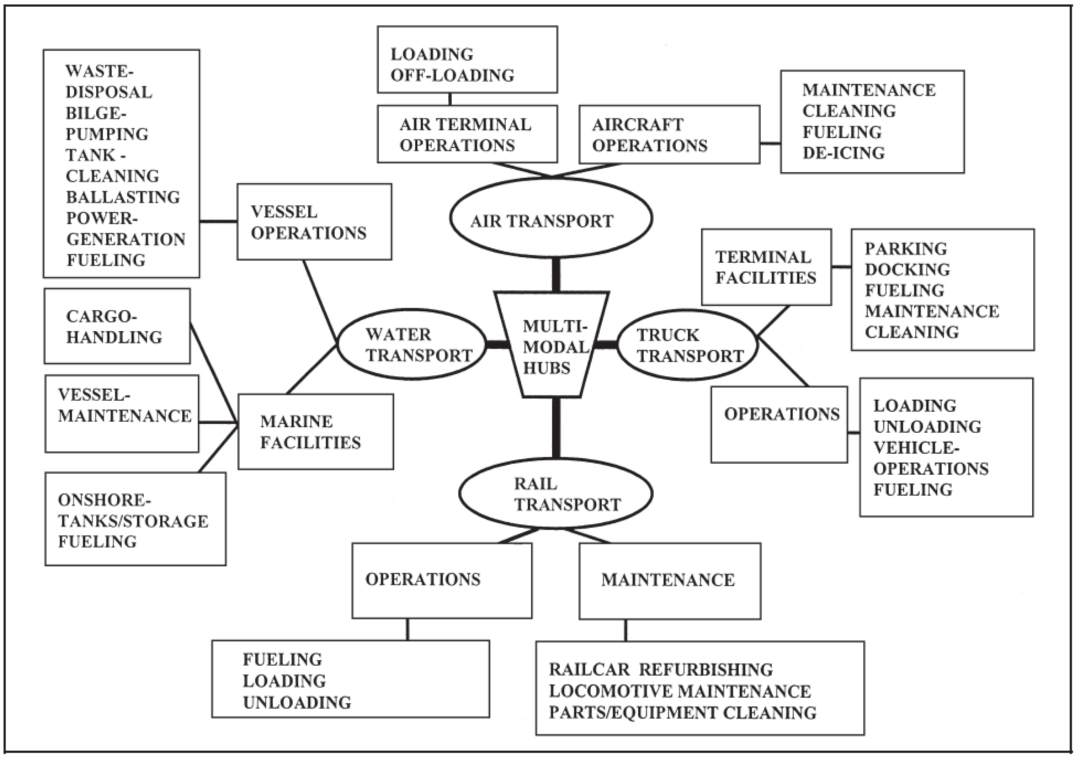
For example, from the origin/supplier to destinations/customers, the first step is to put the goods at the depot in the physical base. At this point, the commercial system indicates cost and delivery, while management and coordination processes involve packing products; the flow of information relates to

[1] Author, 2011

booking, and the freight forwarder takes responsibility for the freight. In the second step, when the road transporter carries the most liability, the physical base is transferred from road to rail transport; the commercial system shows packing, and management and coordination is in charge of container positioning, while the flow of information involves creating waybills. During the third step, when the rail transporter assumes responsibility, the physical base is in the rail terminal, and both the commercial system and the management and coordination system show inland movement from road to rail; and the flow of information involves creating invoices. In the fourth step, the rail terminals take full responsibility for the liability, and the physical base is in the sea trunk; the commercial system shows paper, which means that some paperwork must be handled to prepare for sea transport; management and coordination is dealing with terminal operations; and the flow of information is the manifest. The fifth step is when the sea carrier is responsible for the full liability, and the physical base is from seaport terminals to road or rail transporters; the commercial system shows port to port and paper work ready for inland movement; management and coordination is to schedule the routes; and the flow of information relates to delivery instruction. The final step is when full liability is taken by a freight forwarder again; the physical base is to depot goods in the distribution center; and the commercial system shows inland movement, the unpacking of containers, and cost and delivery for the final door-to-door service; management and coordination are also to schedule the routes, while the flow of information involves releasing the cargos.

The main idea of a multimodal transport system is the cooperation of different transport modes. Each mode is partly responsible for reducing the cost and improving the operation of the whole supply chain.

Figure 2. Components of multimodal transport

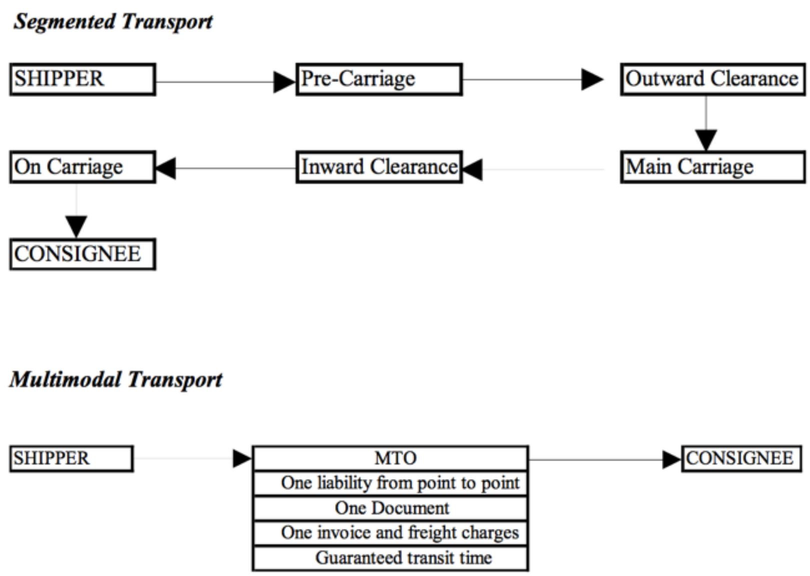


Source: Rodinelli et al., 2000

Figure 2 is an overview of a multimodal transportation system; it includes operations and other functions for all four modes of transport in that system. In the figure, the multimodal hub consists of air transport, truck transport, rail transport, and water transport. In the air transport section, the air terminal operations contain loading and off-loading process, and aircraft operations include maintenance, cleansing, fueling, and de-icing. In the truck transport section, the terminal facilities include parking, docking, fueling, maintenance, and cleansing, and operations include loading, unloading, vehicle operations, and fueling. In the rail transport section, operations include fueling, loading, and unloading, and maintenance includes railcar refurbishing, locomotive maintenance, and parts/equipment cleansing. In the water transport section, vessel operations include waste disposal, bilge pumping, cleaning, ballasting, power generation, and fueling, while marine facilities have cargo handling processes, vessel maintenance, and onshore tanks/storage fueling process. All these processes in the multimodal transport hubs are time consuming and require capital investment; therefore, the cost of money and time are distributed across the whole multimodal transport system if the goods are transported by two or more modes of transportation during the supply chain.

2.1.2 Segmented transport

Figure 3. ***Segmented transport vs Multimodal transport***



Source: Hayuth, 1987

According to Hayuth (1987), segmented transport is different from multimodal transport. Segmented transport starts from shippers; from there, the package is consolidated at the place of pre-carriage, then to outward clearance and main carriage, then to inward clearance, by carriage, and finally to the consignees. Multimodal transport starts from shippers; then, all the documents and packages (products) are consolidated at the place of the multimodal transport operator (MTO). With multimodal transport, there is only one liability from point to point, one document through the supply chain, one invoice, and one set of freight charges during the trade, and the total transit time is guaranteed.

2.1.3 Intermodal transport[2]

Intermodal freight transport is slightly different from multimodal transport. It consists of transporting containers from their origin to destinations without changing the content of the containers along the transport chain, which means that no handling work is required when changing transport modes (Crainic et al., 2007).

---

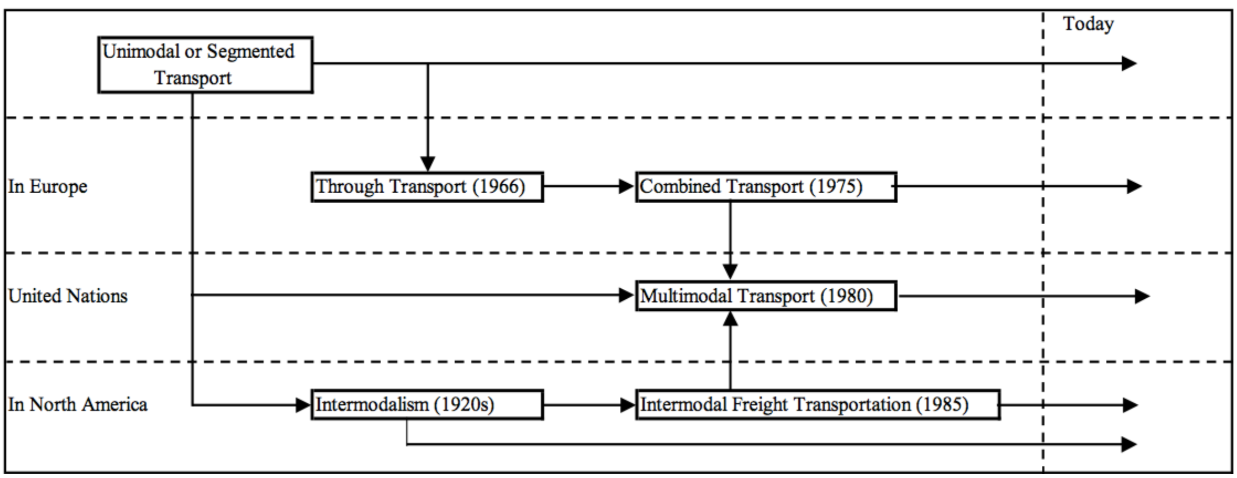
[2] Source: Ruth Baomiyong, 2000

But in the multimodal transport, there could exist some handling works such as loading and unloading the cargos from sea mode to rail mode.

2.1.4 Combined modal transport[3]

Combined modal transport is a form of intermodal transport that focuses on the efficiency of using multiple transport modes to ship products. According to the Commission of the European Communities (CEC, 2006), combined modal transport involves moving goods in one and the same loading unit, using two or more modes of transport, without handling the goods themselves when changing modes. The difference between combined transport and multimodal transport is that multimodal transport has MTOs to operate the process and satisfy customer requirements (service level and cost), whereas combined transport is designed only to maximize the total profit of the whole transport chain. For example, in combined transport, goods are transported by the cheaper modes of transport, such as rail, sea or inland waterways, for as long as possible, and by road and air transport for as short a time as possible. (Verweij, 2011)

Figure 4. ***Terminology evolution of transport terminology***



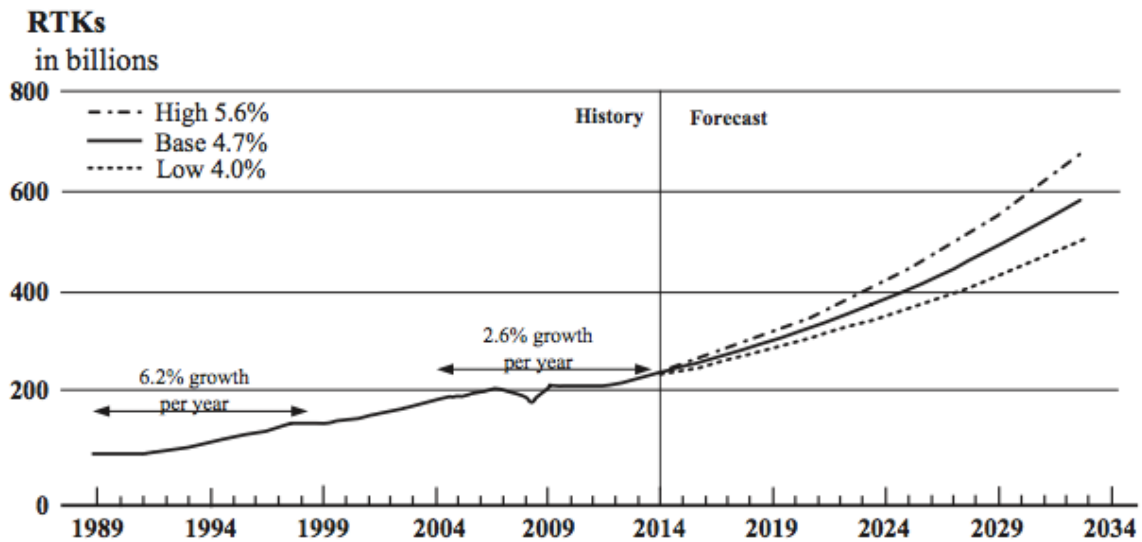
Source: Banomiyong, 2000

According to Banomiyong (2000), unimodal transport existed mostly in history. However, in 1920, North America started to refer to multimodal transport as intermodalism, and in 1966, Europe began to change it to "through transport," up until today. Europe has referred to multimodal transport as combined transport since 1975, while the United Nations have named it multimodal transport since 1980, and since 1985, North America have labelled it intermodal freight transport.

[3] Source: Ruth Baomiyong, 2000

2.1.5 Airway

Figure 5. Growth of world air cargo



Source: Feng et al., 2015

According to Feng et al. (2017), the trend of world air cargo, transported in revenue ton kilometer (RTK), kept rising at a growth rate of 6.2% per year since 1989, and after a fall in 2008 due to the world economic crisis, the air cargo industry continued to grow, but at a slower rate of 2.6% per year. Between the years 2014 and 2034, it is projected to grow according to figure 6. There are three possible situations: the high growth-rate situation is at 5.6% per year, the base growth-rate situation is at 4.7% per year, and the low growth-rate situation is at 4.0% per year.

Figure 6. Air cargo operations

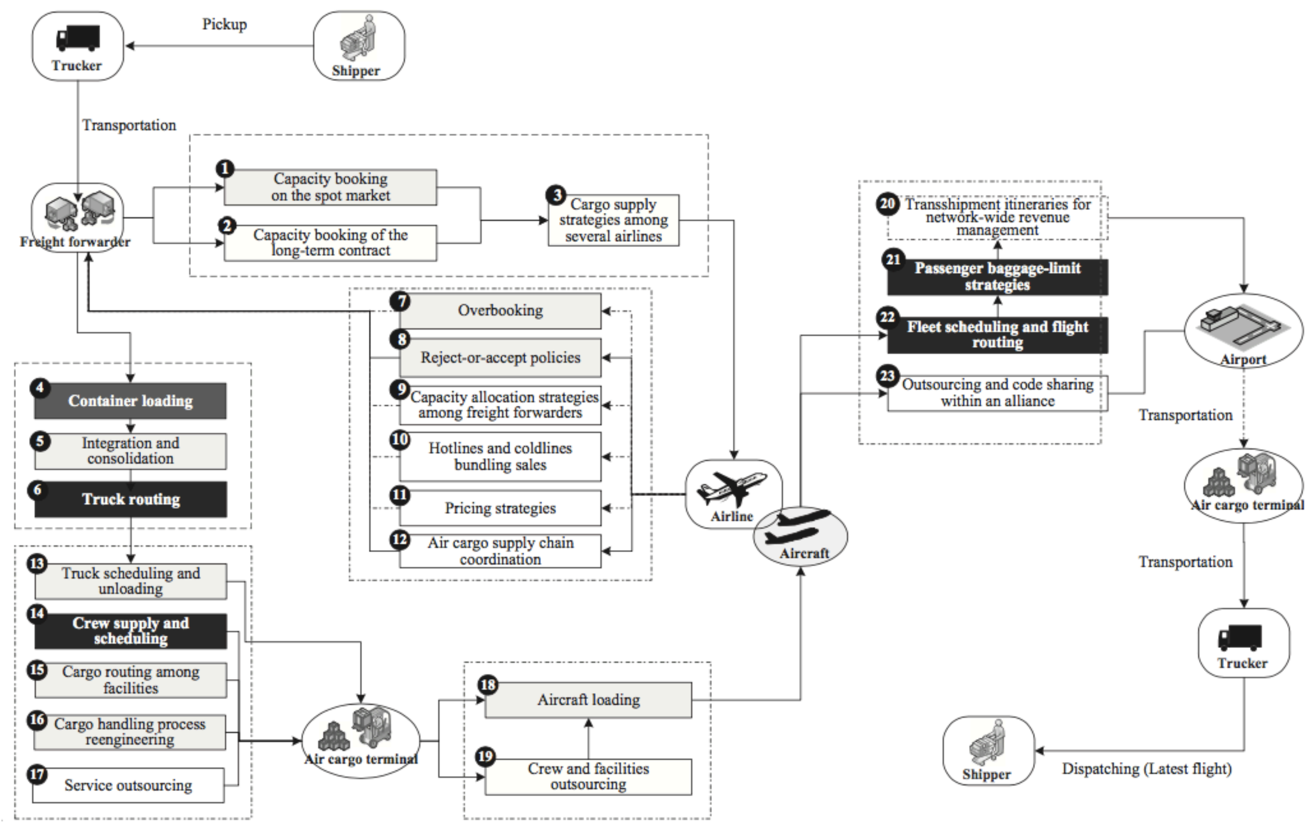


Fig. 4. Air cargo operations: process and the state of research.

Source: Feng et al., 2015

According to Feng et al. (2015), air cargo operations start from the shipper. The truckers will pick up the goods and transport them to the freight forwarders. Then, they will plan on capacity booking on the spot market and capacity booking of the long-term contract; freight forwarders will then implement cargo supply strategies across several airlines and make plans for container loading, integration and consolidation, and truck routing. After communicating with airline companies, freight forwarders will coordinate certain information, such as truck scheduling and unloading, crew supply and scheduling, and cargo routing among facilities, with air cargo terminals, and they will load the goods onto the aircraft to transport them to the destination airports. Finally, the trucker will pick up the goods from the air cargo terminals in the airports and deliver them to their final destinations.

The air transport sector has become a major tool for globalization in terms of economic and societal development (Reis et al., 2013). The world economy has thus been increasingly dependent on the air transport sector. Moreover, a growing percentage of goods, in terms of high value, are transported by air. Reis et al. (2013) also indicated that airports are now an essential multimodal interchange in multimodal transport networks.

Airports have not only acted as modern places, with a series of hotels and shops inside the facilities, but have also become the most important and influential means of transport for carrying both passengers and freight in metropolitan areas (Reis et al., 2013). There are plenty of these airports around the world, such as Frankfurt Main in Germany and Schiphol in the Netherlands. Overall, airway transport is becoming a major component of the multimodal transport system.

2.1.6 Railway

Due to the research done by Reis et al. (2013), rail terminals can be connected to the sea-port terminal by three typologies: (1) on-dock rail terminals (2) near-dock terminals, and (3) satellite terminals.

The first type, the on-dock terminal, involves moving containers from the dock to a railcar with its own facility. The second type, a near-dock terminal, means that freight delays will be reduced by using local road systems, and the gates of near-dock rail terminals will be cleared. The third type, a satellite terminal, means that the load center and the trans-modal terminal can be qualified as inland ports, which can be connected to sea-port terminals through rail shuttle and truck drayage services (Reis et al., 2013).

2.1.7 Road transport

According to Reis et al. (2013), road transport is the most frequently used transportation mode of the four (air, road, rail, and sea) modes so far because there are plenty of advantages to using road transport to convey goods. First, it is flexible to travel by road from almost any point to any other point. Second, it is compatible, for example, to transport goods from one country to another, since trucks can travel by road. Third, road transport is faster than any other mode of transport except air when traveling a short or medium distance. Finally, compared to air transport modes, transporting by truck (road) is much cheaper while still maintaining a relatively fast speed, though slower than air.

2.1.8 Maritime transport

According to Reis et al. (2013), port terminals are the most important infrastructure in the multimodal transport system with regard to traffic, space, and capital requirements. In the world, sea ports are always at the point of intersection of waterway and inland transport systems, such as railway transport. Ports are mostly divided into port area (maritime terminals) and hinterland (inland terminals). A rail terminal is another essential component of the overall sea-port terminal; it acts as a conjunction of inland and seaborne transport in the multimodal transport system. Reis et al. (2013) also implied that the container terminal, intermediate hub terminal, and barge terminal are three main terminals in sea-port terminals.

Containerization around the globe has changed the structure of sea ports. Those sea ports have to provide capital-intensive cranes and storage space for containers.

2.2 Why multimodal transport should be used

According to Lowe (2006), there are plenty of benefits of utilizing multimodal transport to move goods. First, it can reduce total costs over long distances, and sometimes, it could be faster in certain scenarios. Second, it can reduce road congestion because multimodal transport can reduce the total travel journey by truck.

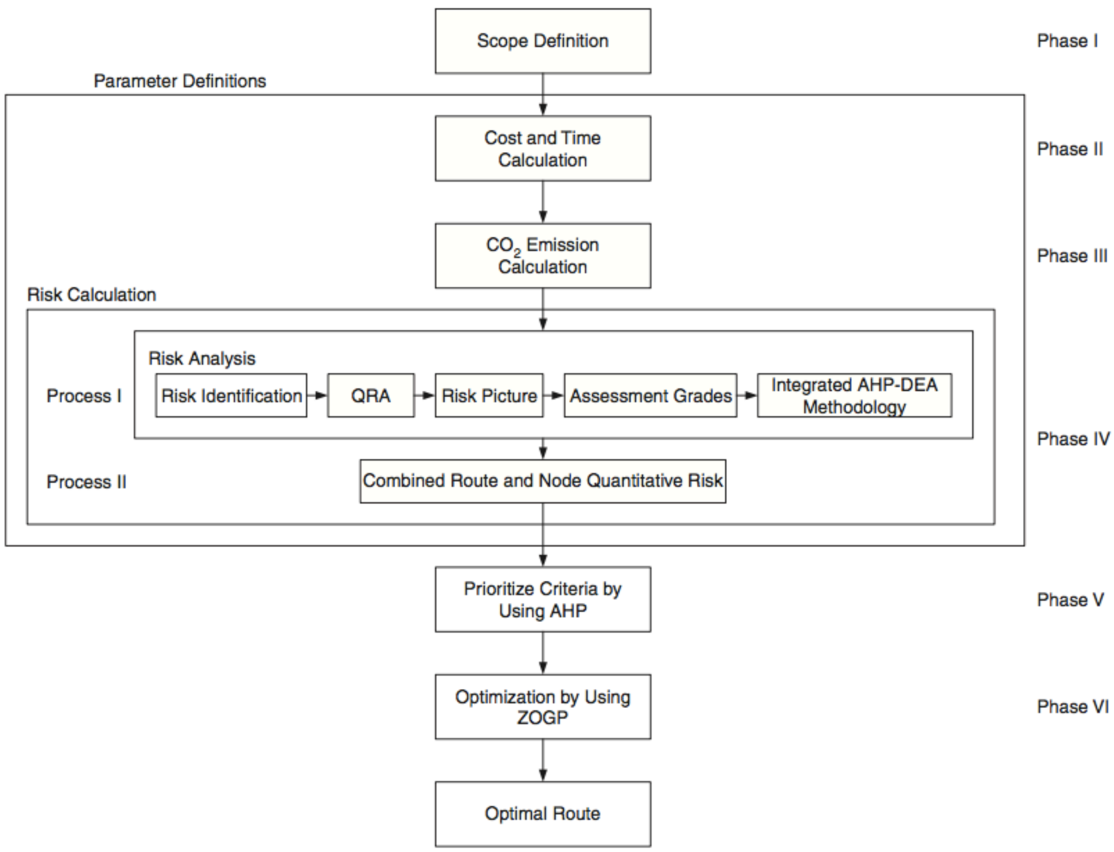
Yamada et al. (2009) illustrated that the multimodal transport network is able to support the economic development of countries, and it can reduce negative environmental impacts. Multimodal transport is also a crucial method for expanding the transport network in developing countries because most of these countries are still concentrating on the road-based freight transport network. Congo Hao et al. (2016) concluded that one mode of container transport cannot satisfy the needs of today's global supply chain; therefore, multimodal transport has emerged as a new and major means of transport that is widely recognized in the world. Multimodal transport can provide solutions to the challenge of cost minimization in logistics through reasonably designed routes and selected transport modes.

2.3 How multimode transport should be used

2.3.1 Multimodal transport in operational research

2.3.1.1 Route selection process

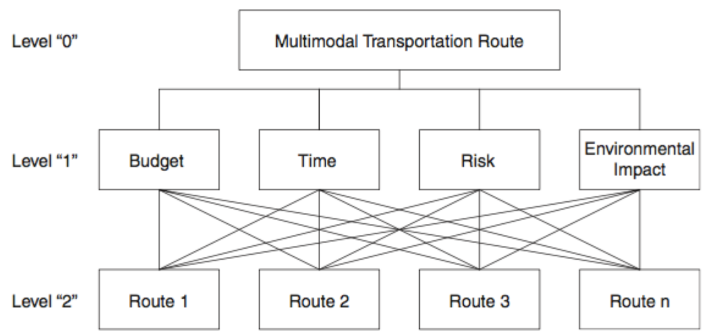
Figure 7. Conceptual framework for route selection in multimodal transport



Source: Kengpol et al., 2013

According to Kengpol et al. (2013), the optimal multimodal route selection should be processed under six steps. Step one is to decide on the scope range, for example, one must decide on the origin and destination from and to which to transport goods. The second step is to calculate cost and time under the cost and time model. Third, CO2 emissions must be calculated under the model of environmental control. The fourth step is to process a risk analysis, while the fifth step involves the prioritization of all routes by using an analytic hierarchy process (AHP), which is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology (Kengpol et al., 2013). Finally, the optimized route must be chosen by using zero-one goal programming (ZOGP). According to Kengpol et al. (2013), goal programming is one of the model which have been developed to deal with the multiple objectives decision-making problems. This model allows taking into account simultaneously many objectives while the decision-making is seeking the best solution from among a set of feasible solutions. The Zero-One goal programming means the decision model is formulated as 0-1, when the result is 1, then the decision suggestion should be true, otherwise the decision is not being made.

Figure 8. Structure for choosing a multimodal transport route



Source: Athakorn Kengpol and Sopida Tuammee et al., 2013

The figure above depicts the analytic hierarchy process (AHP) for route prioritization. Level "0" is the overall scenario of multimodal transport routes; level "1" contains the criteria of budget, time, risk, and environmental impact; and level "2" comprises the routes with the best outcomes of each criterion. The research we are conducting only considers the criteria of cost and time as well as the environmental impact.

2.3.2 Air and multimodal transport

2.3.2.1 Airfreight

According to Beuthe (2007), air transport was an important tool for the regional, national, and even global economy for the transportation of passengers as well as high-value and time-sensitive freight. Therefore, airfreight transport was a significant component for just-in-time (JIT) production systems. In particular, air cargo is increasingly essential for the service of the commercial and industrial sectors.

Table 1. Importance of airfreight markets in 2003

Table 3.6 Relative importance of the air freight markets in 2003 (% of freight tonne-km)

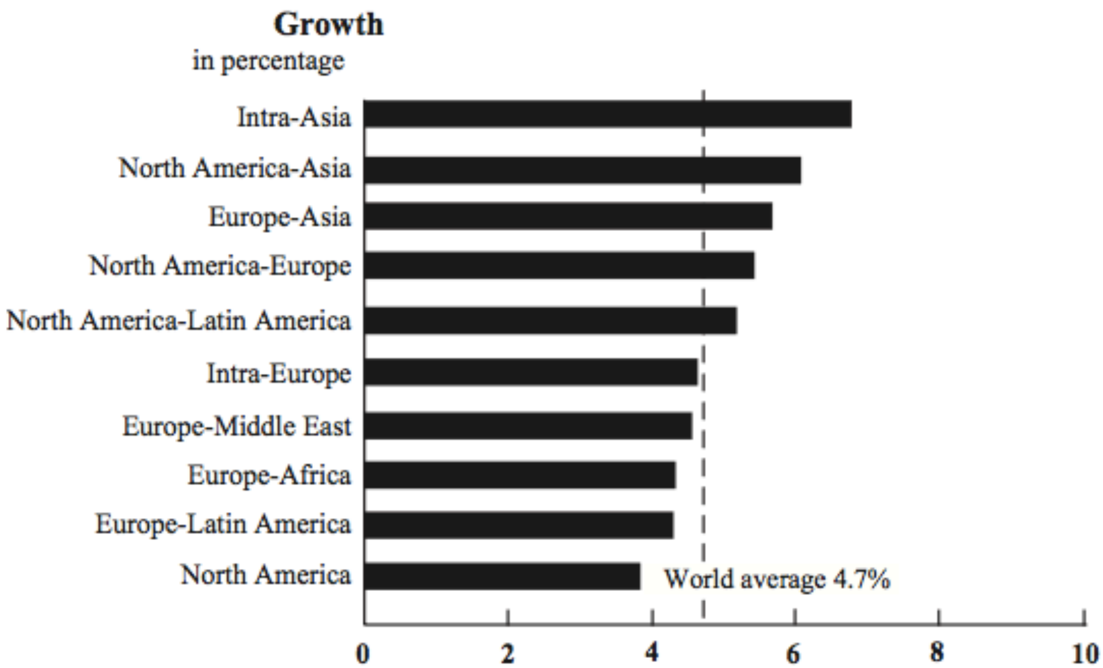
North America	11.5	North America to/from Latin America	3
Europe	0.5	Europe to/from North America	9.8
Asia	10.2	Asia to/from North America	26.2
Africa to/from Europe	2.7	Asia to/from Europe	19.8
Latin America to/from Europe	3.6	Middle East to/from Europe	2.8
Other flows	9.9		

Source: Airbus global market forecast (2004–2023).

Source: Beuthe, 2007

Table 3.6 demonstrates that the airfreight market in each region has a different relative importance. For example, the overall ranking of airfreight importance in North America, Europe, and Asia is first, second, and last respectively. The flows are ranked first from Asia to North America (and vice versa), second from Asia to Europe (and vice versa), then third from Europe to North America (and vice versa).

Figure 9. The world's leading air cargo markets



Source: Feng et al., 2015

According to Feng et al. (2015), which is a more recent reference, the world's top four air cargo markets are Intra-Asia at 7%, followed by North America-Asia, then Europe-Asia, which is ranked third, and North America-Europe was the fourth. Therefore, researching the three large regions, namely Asia, Europe, and North America, is significant enough for worldwide airfreight transport.

2.3.2.2 Air technologies

According to Johan Woxenius (1998), airfreighting developed rapidly in the world transport system during the 1990s. People were considering transporting parcels by air to reduce transport transit times; however, the potential to transport large quantities of goods was possible by applying the technology of lightweight air cargo or containers. Johan Woxenius (1998) also indicated that the transshipment equipment between rail and air could be developed. For example, the rollers should be equipped with airfreight planes on the floor, and the seats should be cleaned in order to load air containers with more spaces.

2.4 Gap in the current literature

The gap in the current literature is that few studies focused on air cargo in multimodal transportation systems. Most of the researches are concentrating on combinations of sea-rail and rail-road. Though there are some researches focusing on air-road combination in the literature, papers focusing on air-rail, air-sea in two modes combinations, three modes combinations, and four modes combinations are hard to find. Therefore, this thesis will make contributions to the air cargo in multimodal transportation systems, especially in the perspective of total transport cost and total transport time.

3 Methodology

3.1 Selection of cities for city pairs

Figure 10. World ship routes

Source: Dr. Jean-Paul Rodrigue, Hofstra University

The cities chosen as research objects were selected from the world's major ports and commercial cities. Figure 10 is the outlook of the world's major ports from which we found 13 cities in the region of Eurasia, namely Tokyo, Shanghai, Singapore, Mumbai, Istanbul, Athens, Rome, Madrid, Amsterdam, Hamburg, London, and Moscow, from east to west; eight cities in North America, which are Montreal, Halifax, New York, Miami, New Orleans, Los Angeles, Seattle, and Vancouver, from east to west; and two cities in Africa, namely Cairo and Cape Town, from North to South.

Of course, there are some missing ports in the selection list, such as Toronto in North America and Paris in France. As some major ports are near to each other, for example, Toronto is near Montreal and New York, and Paris is near the London Amsterdam ports, it is a technique strategy to reduce the number of combinations of cities and transport modes in the multimodal transport plan selection process. (Excel cannot calculate over 1 million combinations in a sheet.)

The three scenarios to be researched are Eurasia; North America; and cross continents among Eurasia, North America and Africa.

The city pairs were set for the situation of both short-distance and long-distance pairs in those three scenarios based on the short-distance criteria of a maximum distance of 8,000 kilometers, which means that if two city pairs are closer than 8,000 kilometers in a straight-line distance, then they are considered to be short-distance city pairs; otherwise, they are deemed as long-distance city pairs. For example, in Eurasia, we set the short-distance pairs as Shanghai-Singapore, Singapore-Shanghai, Mumbai-Istanbul, Istanbul-Mumbai, London-Amsterdam, and Amsterdam-London; the long-distance pairs are Shanghai-Amsterdam, Amsterdam-Shanghai, Singapore-London, London-Singapore, Tokyo-Hamburg, and Hamburg-Tokyo. In North America, we set the short-distance city pairs as Montreal-New York, New York-Montreal, New Orleans-Los Angeles, Los Angeles-New Orleans, Vancouver-Seattle, and Seattle-Vancouver; the long-distance city pairs are Montreal-Los Angeles, Los Angeles-Montreal, Miami-Vancouver, Vancouver-Miami, New York-Seattle, and Seattle-New York. For Eurasia, North America, and Africa combined, we set the city pairs as Shanghai-Montreal, Montreal-Shanghai, Singapore-Los Angeles, and Los Angeles-Singapore.

Table 2. Potential city selection for city pairs

Eurasia	**North America**	**Africa**
Tokyo	Montreal	Cairo
Shanghai	Halifax	Cape Town
Singapore	New York	
Mumbai	Miami	
Istanbul	New Orleans	
Athens	Los Angeles	
Rome	Seattle	
Madrid	Vancouver	
Amsterdam		
Hamburg		
London		
Moscow		

3.2 Scenarios of transport mode combinations

Table 3. Mode combination logic

AIR									
1 Mode	Two modes		Three modes			Four modes			
AIR	AIR	ROAD	AIR	ROAD	RAIL	AIR	ROAD	RAIL	SEA
	AIR	RAIL	AIR	ROAD	SEA	AIR	ROAD	SEA	RAIL
	AIR	SEA	AIR	RAIL	ROAD	AIR	RAIL	ROAD	SEA
	ROAD	AIR	AIR	RAIL	SEA	AIR	RAIL	SEA	ROAD
	RAIL	AIR	AIR	SEA	ROAD	AIR	SEA	ROAD	RAIL
	SEA	AIR	AIR	SEA	RAIL	AIR	SEA	RAIL	ROAD
			ROAD	AIR	RAIL	ROAD	AIR	RAIL	SEA
			ROAD	AIR	SEA	ROAD	AIR	SEA	RAIL
			ROAD	RAIL	AIR	ROAD	RAIL	AIR	SEA
			ROAD	SEA	AIR	ROAD	RAIL	SEA	AIR
			RAIL	AIR	ROAD	ROAD	SEA	AIR	RAIL
			RAIL	AIR	SEA	ROAD	SEA	RAIL	AIR
			RAIL	ROAD	AIR	RAIL	AIR	ROAD	SEA
			RAIL	SEA	AIR	RAIL	AIR	SEA	ROAD
			SEA	AIR	ROAD	RAIL	ROAD	AIR	SEA
			SEA	AIR	RAIL	RAIL	ROAD	SEA	AIR
			SEA	ROAD	AIR	RAIL	SEA	AIR	ROAD
			SEA	RAIL	AIR	RAIL	SEA	ROAD	AIR
						SEA	AIR	ROAD	RAIL
						SEA	AIR	RAIL	ROAD
						SEA	ROAD	AIR	RAIL
						SEA	ROAD	RAIL	AIR
						SEA	RAIL	AIR	ROAD
						SEA	RAIL	ROAD	AIR

ALL									
1 Mode	Two modes		Three modes			Four modes			
AIR	AIR	ROAD	AIR	ROAD	RAIL	AIR	ROAD	RAIL	SEA
ROAD	AIR	RAIL	AIR	ROAD	SEA	AIR	ROAD	SEA	RAIL
RAIL	AIR	SEA	AIR	RAIL	ROAD	AIR	RAIL	ROAD	SEA
SEA	ROAD	AIR	AIR	RAIL	SEA	AIR	RAIL	SEA	ROAD
	ROAD	RAIL	AIR	SEA	ROAD	AIR	SEA	ROAD	RAIL
	ROAD	SEA	AIR	SEA	RAIL	AIR	SEA	RAIL	ROAD
	RAIL	AIR	ROAD	AIR	RAIL	ROAD	AIR	RAIL	SEA
	RAIL	ROAD	ROAD	AIR	SEA	ROAD	AIR	SEA	RAIL
	RAIL	SEA	ROAD	RAIL	AIR	ROAD	RAIL	AIR	SEA
	SEA	AIR	ROAD	RAIL	SEA	ROAD	RAIL	SEA	AIR
	SEA	ROAD	ROAD	SEA	AIR	ROAD	SEA	AIR	RAIL
	SEA	RAIL	ROAD	SEA	RAIL	ROAD	SEA	RAIL	AIR
			RAIL	AIR	ROAD	RAIL	AIR	ROAD	SEA
			RAIL	AIR	SEA	RAIL	AIR	SEA	ROAD
			RAIL	ROAD	AIR	RAIL	ROAD	AIR	SEA
			RAIL	ROAD	SEA	RAIL	ROAD	SEA	AIR
			RAIL	SEA	AIR	RAIL	SEA	AIR	ROAD
			RAIL	SEA	ROAD	RAIL	SEA	ROAD	AIR
			SEA	AIR	ROAD	SEA	AIR	ROAD	RAIL
			SEA	AIR	RAIL	SEA	AIR	RAIL	ROAD
			SEA	ROAD	AIR	SEA	ROAD	AIR	RAIL
			SEA	ROAD	RAIL	SEA	ROAD	RAIL	AIR
			SEA	RAIL	AIR	SEA	RAIL	AIR	ROAD
			SEA	RAIL	ROAD	SEA	RAIL	ROAD	AIR

Table 3 above presents the logic of transport mode combinations. The scenarios were divided into two groups; one group, displayed in the left part of the table, must include an air transport mode, and the other group may not include this mode in the multimodal transport system. For example, the table on the left shows all the combinations where air transport mode is forced to be included. But the table on the right shows combinations where air transport mode is not necessarily included, but it may be. The main difference between the two tables is that there are more combinations in the second table. In the one mode transportation: road, rail and sea are added to the table; in the two modes combinations: road-rail; road-sea, and rail-sea combinations are added to the table; and in the three modes combinations: road-rail-sea are added to the table.

One constraint is that we did not include the scenarios of overlapping combinations, such as air-road-air-sea, which has two air modes; or air-road-sea-road, which has two road transport modes involved. The reason we have not included those scenarios is that the total number of scenarios without an overlap situation has already reached 1 million different combinations, and this is sufficient enough for the purpose of the thesis, which is to identify the existence of situations in which the air transport mode involved in multimodal transport is somewhat better than the air-unimodal transport mode or other combinations.

3.3 Differentiation of cargo size

In terms of the meanings of AKE and ASE cargo, they are codes with three alphabetic characters: the first letter indicates the unit load device (ULD) category, the second letter represents the base dimensions, and the last letter indicates the contour or compatibility with aircraft types. (See appendix 9)

Considering the differences in total transport costs and times due to the differences in cargo sizes, we divided the scenario into heavy cargo (ASE-33 Cu.M, 11,340 kg) and light cargo (AKE-4.3 Cu.M, 1,588 kg). See appendix 9 for further details. The reason why we decided to use these two cargos for comparison is that AKE cargo can be a good representative of small shipments with a weight of 1588kg per cargo, and ASE cargo can be a good representative of large shipments with a weight of11340kg per cargo, about 10 times that of an AKE cargo.

Table 4. Air cargo selection for the research

	AKE cargo (small cargo)	**ASE cargo (large cargo)**
Dimension	**L153cm*W200cm*H162cm**	**L604cm*W243cm*H243cm**
Internal volume	**4.3 Cu.M**	**33 Cu.M**
Maximum gross weight	**1,588 kg**	**11,340 kg**

Table 4 lists the summary of the two selected cargos from various air cargos that the International Air Transport Association (IATA) and the Airports Council International (ACI) named. The reason we chose these two cargos as standardized light and heavy types for the research is because they vary in both volume and weight; other criteria are not considered in the research. In the table, the dimension of L means length, W means width and H means height; Internal volume of Cu.M means cubic meter and the maximum gross weight means the maximum weight in kilogram to be loaded in one cargo.

Table 5. Overall scenarios of city pairs

AKE/ASE Cargo—with air		**AKE/ASE Cargo—air not required**	
Short distance		**Short distance**	
Eurasia	Shanghai-Singapore	**Eurasia**	Shanghai-Singapore
	Singapore-Shanghai		Singapore-Shanghai
	Mumbai-Istanbul		Mumbai-Istanbul
	Istanbul-Mumbai		Istanbul-Mumbai
	London-Amsterdam		London-Amsterdam
	Amsterdam-London		Amsterdam-London
North America	Montreal-New York	**North America**	Montreal-New York
	New York-Montreal		New York-Montreal
	New Orleans-Los Angeles		New Orleans-Los Angeles
	Los Angeles-New Orleans		Los Angeles-New Orleans
	Vancouver-Seattle		Vancouver-Seattle
	Seattle-Vancouver		Seattle-Vancouver
Long distance		**Long distance**	
Eurasia	Shanghai-Amsterdam	**Eurasia**	Shanghai-Amsterdam
	Amsterdam-Shanghai		Amsterdam-Shanghai
	Singapore-London		Singapore-London
	London-Singapore		London-Singapore
	Tokyo-Hamburg		Tokyo-Hamburg
	Hamburg-Tokyo		Hamburg-Tokyo
North America	Montreal-Los Angeles	**North America**	Montreal-Los Angeles
	Los Angeles-Montreal		Los Angeles-Montreal
	Miami - Vancouver		Miami - Vancouver
	Vancouver - Miami		Vancouver-Miami
	New York-Seattle		New York-Seattle
	and Seattle-New York		and Seattle-New York
Eurasia, North America, Africa	Shanghai-Montreal	**Eurasia, North America, Africa**	Shanghai-Montreal
	Montreal-Shanghai		Montreal-Shanghai
	Singapore-Los Angeles		Singapore-Los Angeles
	Los Angeles-Singapore		Los Angeles-Singapore

3.4 Differentiation of product value

The value of the product is another factor to be considered because it could have an impact on the product holding cost, thereby influencing the total transport cost. We began by analyzing scenarios of low-value products with high-speed transport requirements, such as perishables and fast-changing, low-value fashion items, which have set at $10/kg. In the data analysis section, we conduct a sensitivity analysis to test the influence of product value on total cost, varying from $10/kg to $1,500/kg.

Table 6. Products we are researching

	Low-value products	High-value products
Product value range	Start from $10/kg	To be tested in sensitivity analysis
Product attributes	Demand high speed	
Product examples	e.g. Low-value fashion items, and low-value perishable products.	e.g. Electronic devices and jewelry.

The reason why we chose these two values is that we want to see the changes in decision making when the specific value of products changes when carrying those products from the same origins to destinations. Decision changes according to specific values are analyzed in different scenarios in the sensitivity analysis part.

3.5 Optimal itinerary selection

The methodology involves the use of quantitative methods to calculate the total cost and total transport time of different transport mode combinations for the selected city pairs. Then, in Excel, we used "Filter Function-Ascending" to choose the plans that cost the least in the total cost section and the highest speed plan in the total transport time section. We also chose three alternative plans with lower costs in the highest speed section.

3.6 Interviews for thesis results validation

We have conducted six interviews with transportation companies to test the thesis results in terms of optimal itineraries selection: Four of the interviewees are freight forwarders, one is a large railway company in Canada, and another is a consulting company in transportation.

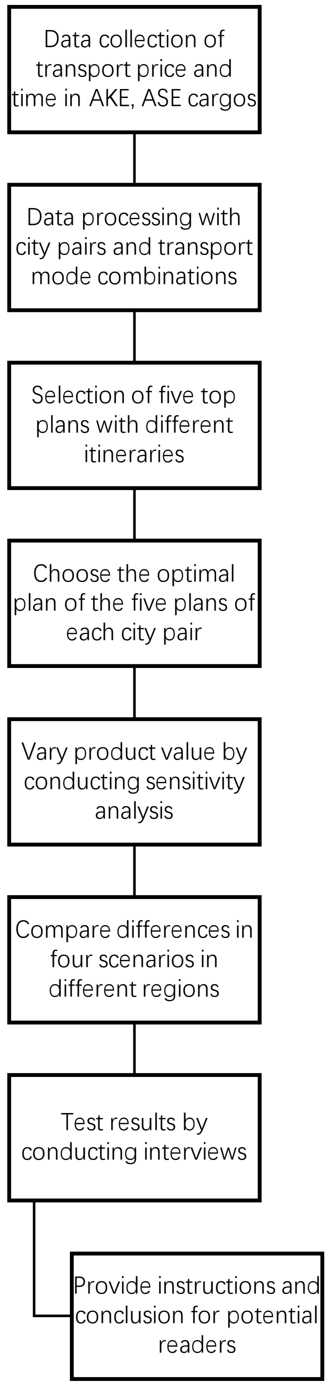
All of the interviewees have experiences with multimodal transportation, therefore their opinions of our thesis results in terms of optimal routes selection are important. Also, due to some data errors and unavailability in secondary database, their opinions are of great significance as well to check the accuracy of the data we collected from the websites, . Most of the data we have collected are from secondary databases; some data regarding rail transportation in the North America region are calculated based on an assumption of ratio between air and rail in terms of transportation price and total transportation time.

The interviews were also very useful to fill in the gap between theoretical data analysis and the practical business world.

The interviews were conducted in a semi-structured form. The questionnaire is presented in appendix 8.

3.7 Logic of the thesis

Figure 11. Flow chart of the thesis logic

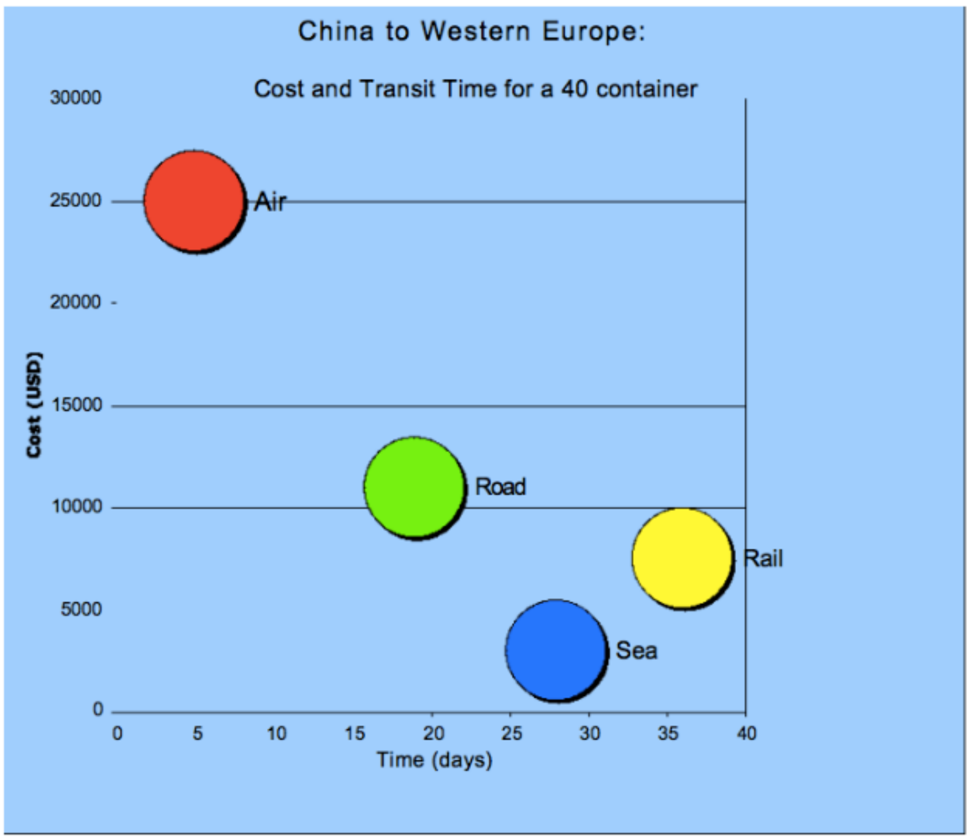


4 Data collection

4.1 Data source

All the data for transport price and time, including the air, road, railway, and maritime transport modes, were collected from the following websites: freightos.com and worldfreightrates.com. We collected the data of AKE (4.3 Cu.M, 1,588 kg) air cargo as small or light cargo transportation, and ASE (33 Cu.M, 11,340 kg) air cargo as large or heavy cargo transportation.

Figure 12. Correlation between the price and time of the four transport modes



Source: U.S. Chamber of Commerce, 2006

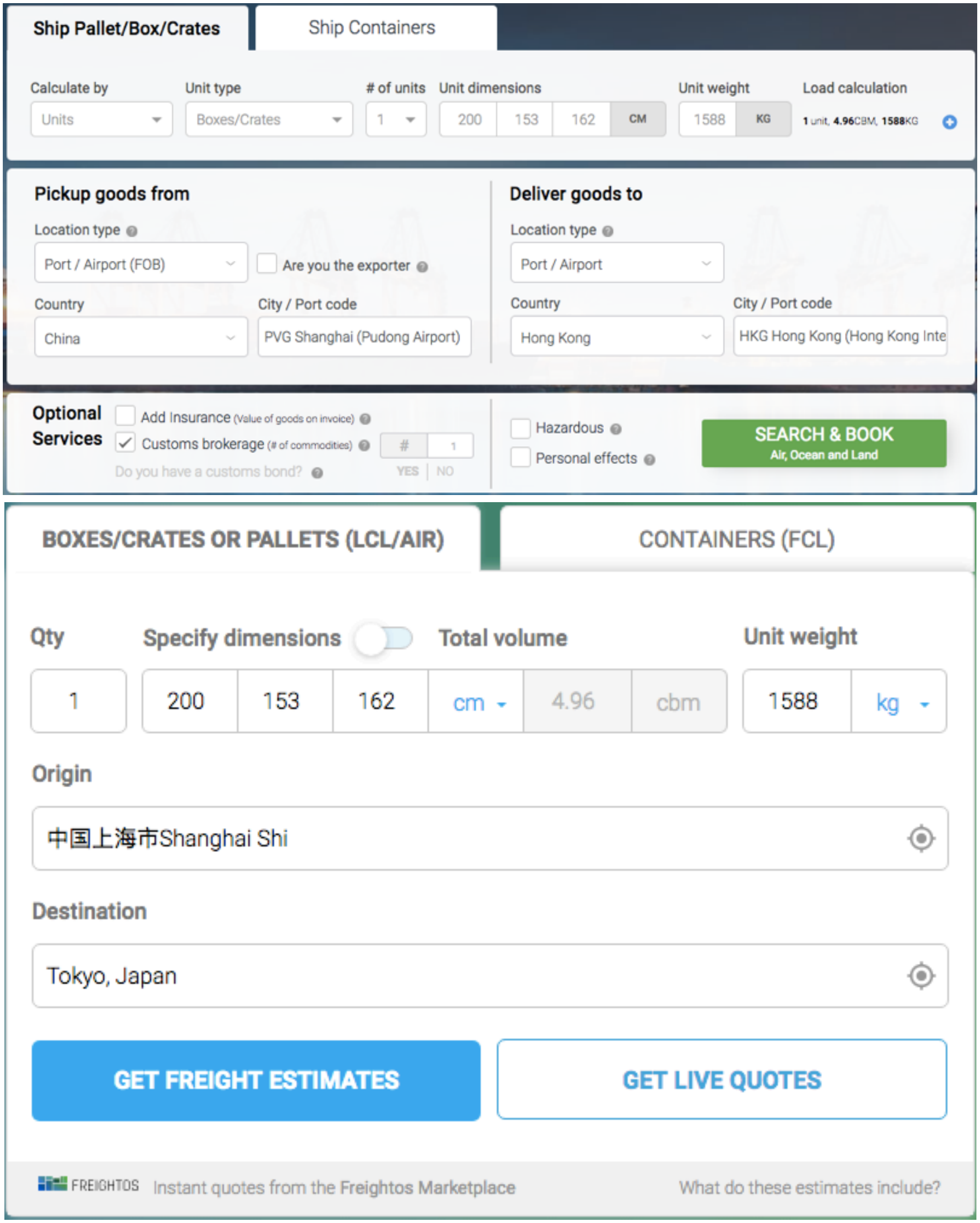
The figure above illustrates that freight with a 40-foot container transported from China to Western Europe by air, road, railway, or sea is distributed in the cost-time axis. The coordinate of the air mode is (5, 25,000), which means that transporting a 40-foot container from China to Western Europe by air takes 5 days and costs 25,000 U.S. dollars. Furthermore, the coordinate for roads is (18, 11,000), rail (36, 6,000), and sea (28, 3,000).

Therefore, the mathematical relationship between price and time for the four transport modes can be calculated. For example, the price for road transportation is 11000/25000 = 0.44 of the air mode in US dollar per container, while the price for rail is 6000/25000 = 0.25 of the air mode, and the sea mode is 3000/25000 = 0.12 of the air mode. Furthermore, the transit time for road transportation is 18/5 = 3.6 times that of the air mode, the transit time for rail is 36/5 = 7.2 times that of the air mode, and the transit time via sea is 28/5 = 5.6 times that of the air mode.

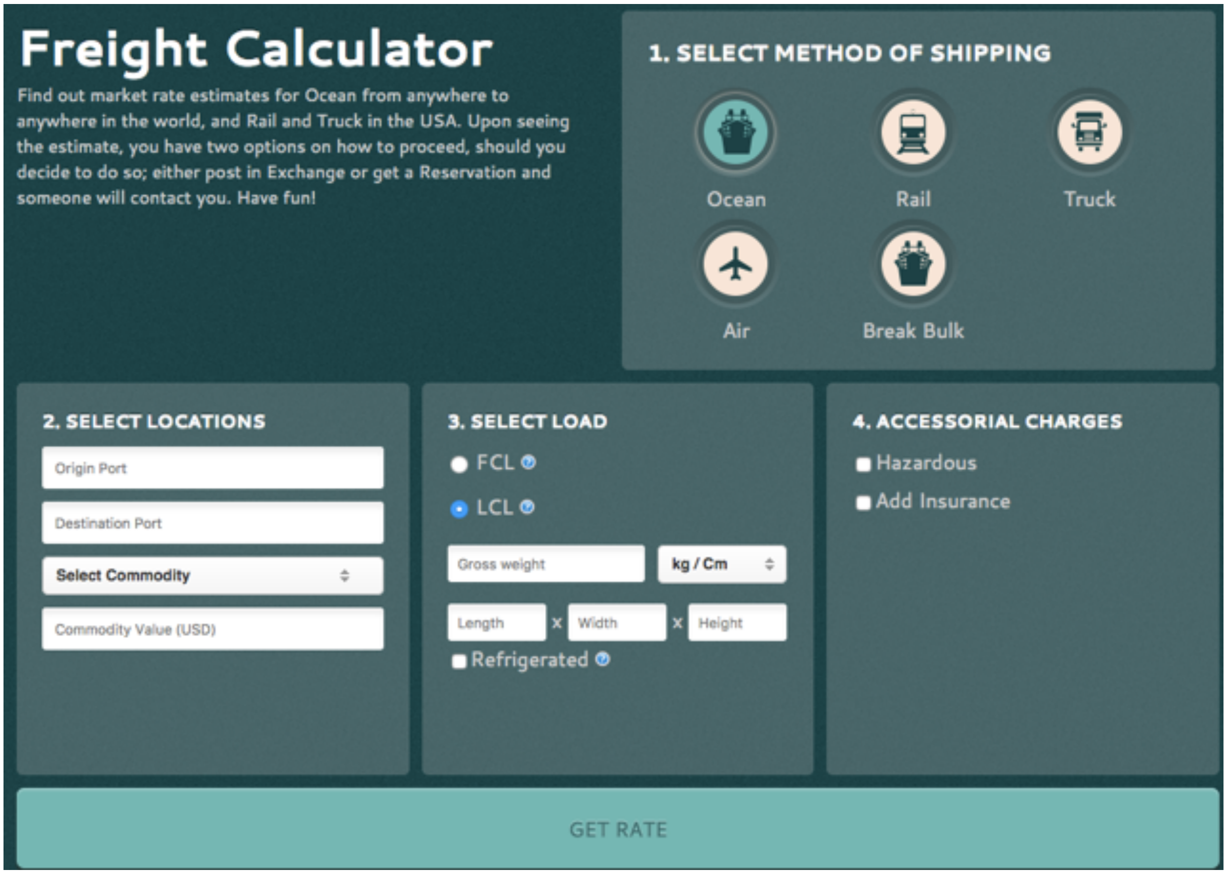
In principle, all the data should be collected from the existing websites (freightos.com and worldfreightrates.com). However, due to the unavailability of some data, such as railway modes in some Eurasia areas and North American city pairs, we made an assumption by using the ratio of railway to air (from the U.S. Chamber of Commerce, 2006) to calculate the price and time of the railway mode for 20% of the city pairs.

We should also take into account the fact that some cities are not reachable with one or many modes. For example, the city of Moscow could not be reached by sea mode, which is a limitation for this thesis research.

Figure 13. *Freight price search engine*



Source: Freightos.com



Source: Worldfreightrates.com

The figure above is a set of search engines from freightos.com and worldfreightrates.com. We set the dimension and weight for the AKE and ASE cargo standard. Then, we collected data regarding price and transit time for each transport mode (air, road, rail, and sea). All the dimensions and weight standards were set the same for the four transport modes when using search engines. Then, we began to gather the data into an Excel sheet, indicating cargo type, transport modes, and the quoting companies that are usually freight forwarders.

Table 7 below is a snapshot of the data sample for the AKE cargo's air transport mode. The table header contains, inter alia, the following information: origin and destination, the transport modes, cargo types, quoting companies, average prices, and average transit times for transporting each unit (AKE cargo) between its origin and destination.

Overall, the data collected for AKE cargos were from May 1st to 15th, 2017, and for ASE cargos, they were from June 1st to 10th, 2017. The seasonality of price and time are not taken into consideration, which is another limitation of the thesis.

4.2 Data arrangement

Table 7. Sample for the AKE cargo Air mode data

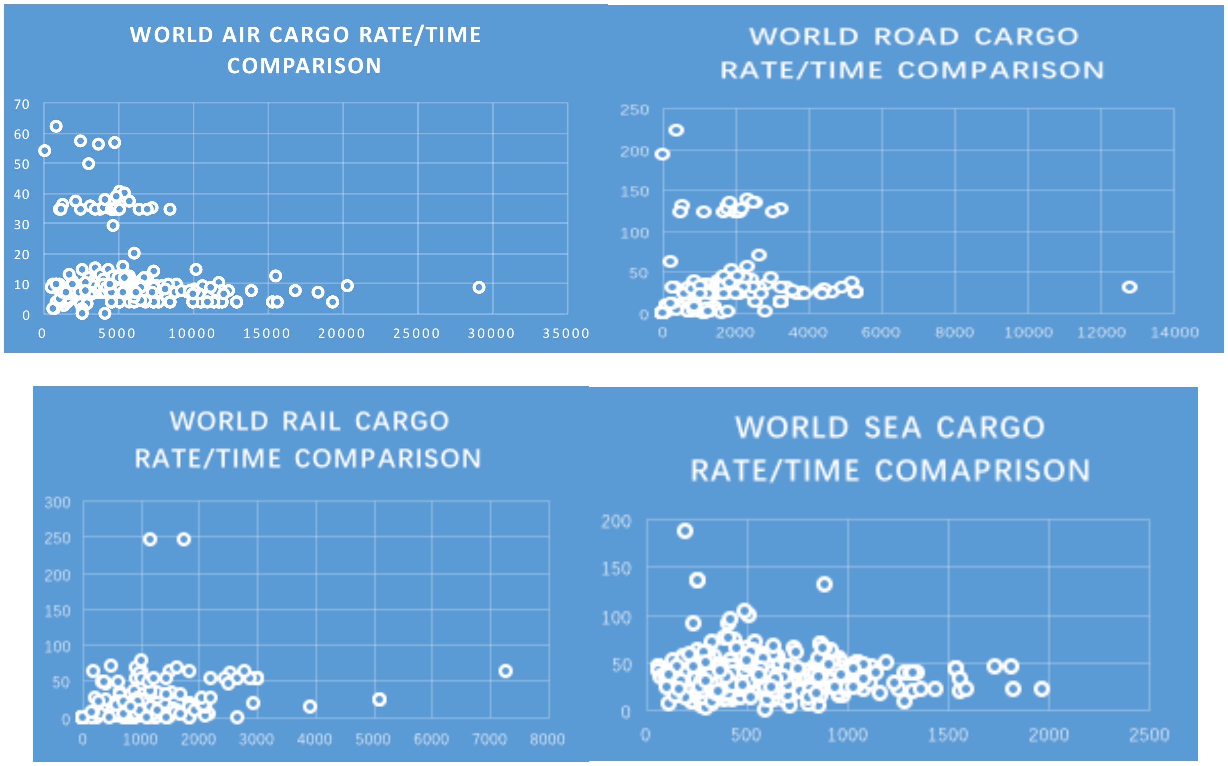
Origin	Destination	Mode of trasnport	Cargo type	Quote from which freight forwarder	Quantity	Price min (US$)	Price max (US$)	Average price	Time min (Day)	Time max (Day)	Average time
New York	Miami	Air cargo	AKE (4.3 Cu.M, 1588kg)	Archgate	1			1283			3
New York	New Orleans	Air cargo	AKE (4.3 Cu.M, 1588kg)	Archgate	1			1128			4
New York	Los Angeles	Air cargo	AKE (4.3 Cu.M, 1588kg)	Freightos rate estimate	1	1077	4043	2560	13	17	15
New York	Seatle	Air cargo	AKE (4.3 Cu.M, 1588kg)	Archgate	1			1487			6
New York	Montreal	Air cargo	AKE (4.3 Cu.M, 1588kg)	Archgate	1			918			3
New York	Vancouver	Air cargo	AKE (4.3 Cu.M, 1588kg)	Archgate	1			1808			6
New York	Halifax	Air cargo	AKE (4.3 Cu.M, 1588kg)	Archgate	1			1942			5
New York	London	Air cargo	AKE (4.3 Cu.M, 1588kg)	Primorus Worldwide	1			5076	3	5	4
New York	Amsterdam	Air cargo	AKE (4.3 Cu.M, 1588kg)	Access Air	1			2452	2	5	3.5
New York	Frankfurt	Air cargo	AKE (4.3 Cu.M, 1588kg)	Access Air	1			2452	2	5	3.5
New York	Italy	Air cargo	AKE (4.3 Cu.M, 1588kg)	Primorus Worldwide	1			5076	3	5	4
New York	Greece	Air cargo	AKE (4.3 Cu.M, 1588kg)	Primorus Worldwide	1			7351	3	5	4
New York	Turkey	Air cargo	AKE (4.3 Cu.M, 1588kg)	Primorus Worldwide	1			11728	3	5	4
New York	Spain	Air cargo	AKE (4.3 Cu.M, 1588kg)	Primorus Worldwide	1			5986	3	5	4
New York	Shanghai	Air cargo	AKE (4.3 Cu.M, 1588kg)	Freightos rate estimate	1	6032	8626	7329	13	15	14
New York	Moscow	Air cargo	AKE (4.3 Cu.M, 1588kg)	Primorus Worldwide	1			19255	3	5	4
New York	Mumbai	Air cargo	AKE (4.3 Cu.M, 1588kg)	Primorus Worldwide	1			11903	3	5	4
New York	Bangladesh	Air cargo	AKE (4.3 Cu.M, 1588kg)	Primorus Worldwide	1			11378	3	5	4
New York	Singapore	Air cargo	AKE (4.3 Cu.M, 1588kg)	Access Air	1			2928	2	5	3.5
New York	Tokyo	Air cargo	AKE (4.3 Cu.M, 1588kg)	Freightos rate estimate	1	4422	6700	5561	6	7	6.5
New York	Capetown	Air cargo	AKE (4.3 Cu.M, 1588kg)	Primorus Worldwide	1			7632	3	5	4
New York	Cairo	Air cargo	AKE (4.3 Cu.M, 1588kg)	Primorus Worldwide	1			10502	3	5	4
Miami	New York	Air cargo	AKE (4.3 Cu.M, 1588kg)	Archgate	1			1341			3
Miami	New Orleans	Air cargo	AKE (4.3 Cu.M, 1588kg)	Archgate	1			960			3
Miami	Los Angeles	Air cargo	AKE (4.3 Cu.M, 1588kg)	Archgate	1			1399			5
Miami	Seatle	Air cargo	AKE (4.3 Cu.M, 1588kg)	Global Forwarding Enterprises LLC	1			649			10
Miami	Montreal	Air cargo	AKE (4.3 Cu.M, 1588kg)	Archgate	1			1519			4
Miami	Vancouver	Air cargo	AKE (4.3 Cu.M, 1588kg)	Archgate	1			1849			6
Miami	Halifax	Air cargo	AKE (4.3 Cu.M, 1588kg)	Archgate	1			2085			6
Miami	London	Air cargo	AKE (4.3 Cu.M, 1588kg)	Freight Right	1			2483	8	10	9
Miami	Amsterdam	Air cargo	AKE (4.3 Cu.M, 1588kg)	Primorus Worldwide	1			6826	3	5	4
Miami	Frankfurt	Air cargo	AKE (4.3 Cu.M, 1588kg)	Primorus Worldwide	1			5076	3	5	4
Miami	Italy	Air cargo	AKE (4.3 Cu.M, 1588kg)	Primorus Worldwide	1			5076	3	5	4
Miami	Greece	Air cargo	AKE (4.3 Cu.M, 1588kg)	Primorus Worldwide	1			7351	3	5	4
Miami	Turkey	Air cargo	AKE (4.3 Cu.M, 1588kg)	Primorus Worldwide	1			11728	3	5	4
Miami	Spain	Air cargo	AKE (4.3 Cu.M, 1588kg)	Primorus Worldwide	1			5986	3	5	4
Miami	Shanghai	Air cargo	AKE (4.3 Cu.M, 1588kg)	Primorus Worldwide	1			10502	3	5	4
Miami	Moscow	Air cargo	AKE (4.3 Cu.M, 1588kg)	Primorus Worldwide	1			19255	3	5	4
Miami	Mumbai	Air cargo	AKE (4.3 Cu.M, 1588kg)	Primorus Worldwide	1			11903	3	5	4
Miami	Bangladesh	Air cargo	AKE (4.3 Cu.M, 1588kg)	Primorus Worldwide	1			11378	3	5	4
Miami	Singapore	Air cargo	AKE (4.3 Cu.M, 1588kg)	Freightos rate estimate	1	4710	8210	6460	10	12	11
Miami	Tokyo	Air cargo	AKE (4.3 Cu.M, 1588kg)	Primorus Worldwide	1			7632	3	5	4
Miami	Capetown	Air cargo	AKE (4.3 Cu.M, 1588kg)	Primorus Worldwide	1			15299	3	5	4

Air Sea Road Rail

Source: Adapted from freightos.com, Worldfreightrates.com, 2017

After the data searching and processing, the transport data of price and time for AKE and ASE cargos were gathered. Figure 14 contains charts that were plotted with the collected data for each cargo type and each transport mode.

Figure 14. The AKE transport price (USD/Cargo—horizontal axis) and time (Days—vertical axis) correlation in terms of transport modes

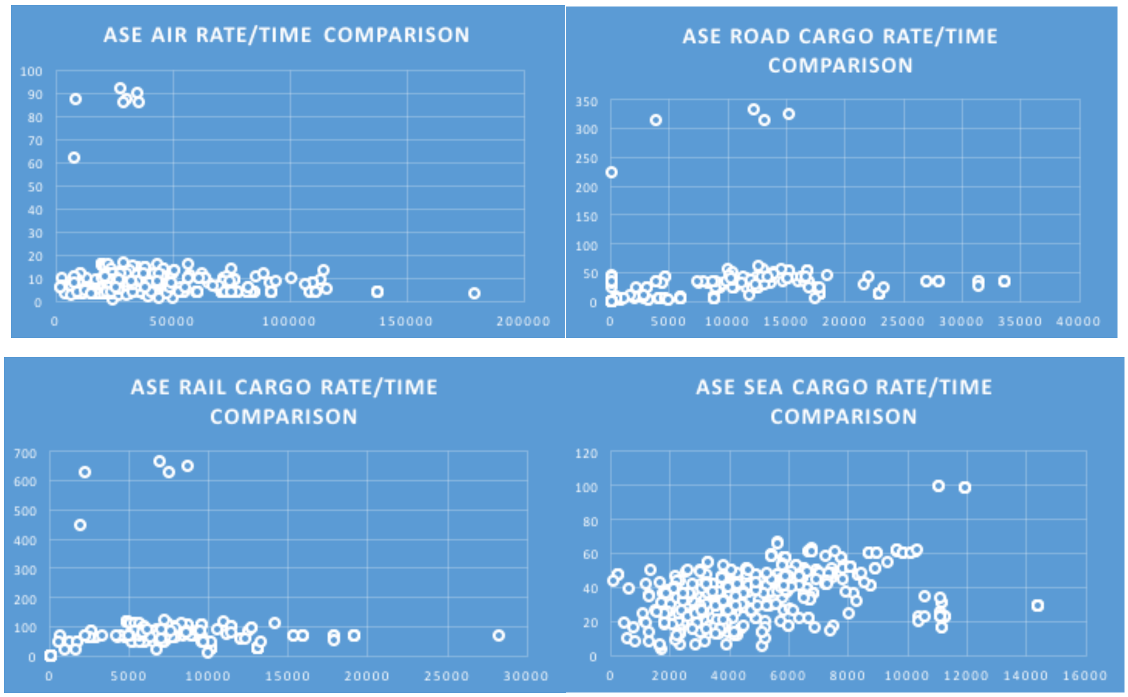


Source: Adapted from freightos.com, Worldfreightrates.com, 2017

Figure 14 illustrates the distribution of the transport price and time for air, road, rail, and sea modes for transporting AKE cargo. The horizontal axis is the transport price, and the vertical axis is the transport time. We found that the air mode is aggregated in the range of (5,000, 10), where 5,000 represents $5,000/AKE cargo, and 10 represents 10 days. The road mode is aggregated in the range of (2,000, 20), rail is in the range of (1,000, 40), and sea is around (500, 50). The correlations between price and time for air and other transport modes are similar to the proportion in the earlier figure 4; only one nuance exists in the proportion of rail speed to airspeed, which could be the development of modern trains, which are trains with faster speeds.

From the table, we can see a big picture of differences in the four transport modes (Air, road, rail and sea) in terms of average transport price and transport transit time to ship a single AKE air cargo. Obviously, the air mode is the fastest while the most expensive one among the four, then comes road, rail and sea. Also, from the tables, there exists some outliers of each mode, and those outliers are due to be the accuracy of the secondary database and the assumption we made according to U.S. Chamber of Commerce (2006) to calculate unavailable data.

Figure 15. The ASE transport price (USD/Cargo—horizontal axis) and time (Days—vertical axis) correlation in terms of transport modes



Source: Adapted from freightos.com, Worldfreightrates.com, 2017

Figure 15 depicts the price and time correlation of four transport modes when transporting ASE air cargo around the world. The air mode is aggregated around the range of ($50,000, 10days), the road mode is aggregated at the dot of (15,000, 30), the rail mode is at the range of (10,000, 80), and the sea mode is around (4,000, 50). The correlation between price and time is also similar to the results in figure 4.

Furthermore, the large cargo (ASE) is, on average, 10 times the price of the small air cargo (AKE) for all the modes, and transport time via rail is longer. The reason is that shipping a large cargo can include more handling cost and time, such as loading and unloading the cargos, and the total weight of cargo is much heavier than the small cargos, therefore the total transportation cost is higher.

In the ASE cargo section, there are also some outliers shown in each table, and the reason is the same as for the small cargo section, which is the accuracy of secondary data base and the assumption we made to calculate unavailable data.

4.3 Data processing

Table 8. Part of price and time data of transporting AKE cargo by all modes

	ORIGINS	DESTINATIONS	AVERAGE PRICE	AVERAGE TIME	INVENTORY HOLDING COST
NEWYORKMIAMIAIR	NEWYORK	MIAMI	1283	3	26.10
NEWYORKNEWORLEANSAIR	NEWYORK	NEWORLEANS	1128	4	34.81
NEWYORKLOSANGELESAIR	NEWYORK	LOSANGELES	2560	15	130.52
NEWYORKSEATTLEAIR	NEWYORK	SEATTLE	1487	6	52.21
NEWYORKMONTREALAIR	NEWYORK	MONTREAL	918	3	26.10
NEWYORKVANCOUVERAIR	NEWYORK	VANCOUVER	1808	6	52.21
NEWYORKHALIFAXAIR	NEWYORK	HALIFAX	1942	5	43.51
NEWYORKLONDONAIR	NEWYORK	LONDON	5076	4	34.81
NEWYORKAMSTERDAMAIR	NEWYORK	AMSTERDAM	2452	3.5	30.45
NEWYORKHAMBURGAIR	NEWYORK	HAMBURG	2452	3.5	30.45
NEWYORKROMEAIR	NEWYORK	ROME	5076	4	34.81
NEWYORKATHENSAIR	NEWYORK	ATHENS	7351	4	34.81
NEWYORKISTANBULAIR	NEWYORK	ISTANBUL	11728	4	34.81
NEWYORKMADRIDAIR	NEWYORK	MADRID	5986	4	34.81
NEWYORKSHANGHAIAIR	NEWYORK	SHANGHAI	7329	14	121.82
NEWYORKMOSCOWAIR	NEWYORK	MOSCOW	19255	4	34.81
NEWYORKMUMBAIAIR	NEWYORK	MUMBAI	11903	4	34.81
NEWYORKBANGLADESHAIR	NEWYORK	BANGLADESH	11378	4	34.81
NEWYORKSINGAPOREAIR	NEWYORK	SINGAPORE	2928	3.5	30.45
NEWYORKTOKYOAIR	NEWYORK	TOKYO	5561	6.5	56.56
NEWYORKCAPETOWNAIR	NEWYORK	CAPETOWN	7632	4	34.81
NEWYORKCAIROAIR	NEWYORK	CAIRO	10502	4	34.81

The data in the Table 8 were arranged after the initial collection. The first column lists the new definitions from Excel in order to facilitate the value lookup in combination form (presented in table 8). Column 2 contains the origin cities—in this table, the origin cities are all New York; column 3 lists the destination cities for the city pair; column 4 presents the average transporting price for all four transport modes; column 5 indicates the average transport time for all four transport modes; and column 6 presents the total inventory cost described below (with transit time only).

We assumed that the holding cost for holding one unit of product in the warehouse for a year is 20% of the product value. We calculated the product value from $10/kg. So, to take the first city pair—New York and Miami—as an example, the inventory holding cost is 3d/365d * 1,588 kg * $10/kg * 20% = $26.1.

Table 9. Assumption of delay time between two transport modes' transfer

			DELAY TIME
AIRROADDELAY	AIR	ROAD	1.00
AIRRAILDELAY	AIR	RAIL	1.00
AIRSEADELAY	AIR	SEA	2.00
ROADAIRDELAY	ROAD	AIR	1.00
ROADRAILDELAY	ROAD	RAIL	1.00
ROADSEADELAY	ROAD	SEA	2.00
RAILAIRDELAY	RAIL	AIR	1.00
RAILROADDELAY	RAIL	ROAD	1.00
RAILSEADELAY	RAIL	SEA	2.00
SEAAIRDELAY	SEA	AIR	2.00
SEAROADDELAY	SEA	ROAD	2.00
SEARAILDELAY	SEA	RAIL	2.00

The table above presents the assumption of the delay time when transferring between two transport modes in a multimodal transport system. Air-road, air-rail, and road-rail transfers are performed in one day, while air-sea, road-sea, and rail-sea transfers generally take two days.

The reason why we chose those values as modal change time delays is according to an interview conducted with a freight forwarding company, Delmar Cargo.

Table 10.Part of the transport mode and city pair combinations

ORIGIN	DESTINATION	MODE NUMBER	MODE1	MODE2	MODE3	MODE4	TRANSIT CITY1	TRANSIT CITY2	TRANSIT CITY3	TRANSIT CITY4	TRANSIT CITY5
SINAGPORE	SHANGHAI	1.00	AIR				SINGAPORE	SHANGHAI			
		2.00	AIR	ROAD			SINGAPORE	BANGLADESH	SHANGHAI		
		2.00	AIR	ROAD			SINGAPORE	MUMBAI	SHANGHAI		
		2.00	AIR	ROAD			SINGAPORE	ISTANBUL	SHANGHAI		
		2.00	AIR	ROAD			SINGAPORE	ATHENS	SHANGHAI		
		2.00	AIR	ROAD			SINGAPORE	ROME	SHANGHAI		
		2.00	AIR	ROAD			SINGAPORE	MADRID	SHANGHAI		
		2.00	AIR	ROAD			SINGAPORE	AMSTERDAM	SHANGHAI		
		2.00	AIR	ROAD			SINGAPORE	HAMBURG	SHANGHAI		
		2.00	AIR	ROAD			SINGAPORE	LONDON	SHANGHAI		
		2.00	AIR	ROAD			SINGAPORE	MOSCOW	SHANGHAI		
		2.00	AIR	ROAD			SINGAPORE	TOKYO	SHANGHAI		

1.00	PRICE1	2.00	PRICE2	3.00	PRICE3	4.00	PRICE4	TOTAL PRICE
SINGAPORESHANGHAIAIR	1465.50							1465.50
SINGAPOREBANGLADESHAIR	5138.00	BANGLADESHSHANGHAIROAD	822.00					5960.00
SINGAPOREMUMBAIAIR	3282.00	MUMBAISHANGHAIROAD	822.00					4104.00
SINGAPOREISTANBULAIR	8102.00	ISTANBULSHANGHAIROAD	1608.42					9710.42
SINGAPOREATHENSAIR	6703.50	ATHENSSHANGHAIROAD	1776.50					8480.00
SINGAPOREROMEAIR	5656.50	ROMESHANGHAIROAD	2031.92					7688.42
SINGAPOREMADRIDAIR	4659.00	MADRIDSHANGHAIROAD	2628.78					7287.78
SINGAPOREAMSTERDAMAIR	6113.50	AMSTERDAMSHANGHAIROAD	620.62					6734.12
SINGAPOREHAMBURGAIR	4589.50	HAMBURGSHANGHAIROAD	552.20					5141.70
SINGAPORELONDONAIR	5066.50	LONDONSHANGHAIROAD	315.92					5382.42
SINGAPOREMOSCOWAIR	8778.50	MOSCOWSHANGHAIROAD	1679.92					10458.42
SINGAPORETOKYOAIR	4306.50	TOKYOSHANGHAIROAD	#DIV/0!					#DIV/0!

	TRANSIT TIME1		TRANSIT TIME2		TRANSIT TIME3		TRANSIT TIME4	TOTAL TRANSIT TIME
SINGAPORESHANGHAIAIR	7.00							7.00
SINGAPOREBANGLADESHAIR	10.50	BANGLADESHSHANGHAIROAD	6.00					16.50
SINGAPOREMUMBAIAIR	9.50	MUMBAISHANGHAIROAD	9.00					18.50
SINGAPOREISTANBULAIR	8.00	ISTANBULSHANGHAIROAD	34.20					42.20
SINGAPOREATHENSAIR	12.00	ATHENSSHANGHAIROAD	32.40					44.40
SINGAPOREROMEAIR	37.50	ROMESHANGHAIROAD	124.20					161.70
SINGAPOREMADRIDAIR	12.50	MADRIDSHANGHAIROAD	32.40					44.90
SINGAPOREAMSTERDAMAIR	7.00	AMSTERDAMSHANGHAIROAD	25.20					32.20
SINGAPOREHAMBURGAIR	7.00	HAMBURGSHANGHAIROAD	25.20					32.20
SINGAPORELONDONAIR	12.00	LONDONSHANGHAIROAD	32.40					44.40
SINGAPOREMOSCOWAIR	7.00	MOSCOWSHANGHAIROAD	30.60					37.60
SINGAPORETOKYOAIR	7.00	TOKYOSHANGHAIROAD	#DIV/0!					#DIV/0!

1.00	DELAY TIME1	2.00	DELAY TIME2	3.00	DELAY TIME3	TOTAL DELAY TIME	TOTAL DELAY HOLDING COST
						0.00	0.00
AIRROADDELAY	1.00					1.00	8.70
AIRROADDELAY	1.00					1.00	8.70
AIRROADDELAY	1.00					1.00	8.70
AIRROADDELAY	1.00					1.00	8.70
AIRROADDELAY	1.00					1.00	8.70
AIRROADDELAY	1.00					1.00	8.70
AIRROADDELAY	1.00					1.00	8.70
AIRROADDELAY	1.00					1.00	8.70
AIRROADDELAY	1.00					1.00	8.70
AIRROADDELAY	1.00					1.00	8.70
AIRROADDELAY	1.00					1.00	8.70

	HOLDING COST1		HOLDING COST2		HOLDING COST3		HOLDING COST4	TOTAL HOLDING COST
SINGAPORESHANGHAIAIR	60.91							60.91
SINGAPOREBANGLADESHAIR	91.36	BANGLADESHSHANGHAIROAD	52.21					143.57
SINGAPOREMUMBAIAIR	82.66	MUMBAISHANGHAIROAD	78.31					160.98
SINGAPOREISTANBULAIR	69.61	ISTANBULSHANGHAIROAD	297.59					367.20
SINGAPOREATHENSAIR	104.42	ATHENSSHANGHAIROAD	281.92					386.34
SINGAPOREROMEAIR	326.30	ROMESHANGHAIROAD	1080.71					1407.01
SINGAPOREMADRIDAIR	108.77	MADRIDSHANGHAIROAD	281.92					390.69
SINGAPOREAMSTERDAMAIR	60.91	AMSTERDAMSHANGHAIROAD	219.27					280.18
SINGAPOREHAMBURGAIR	60.91	HAMBURGSHANGHAIROAD	219.27					280.18
SINGAPORELONDONAIR	104.42	LONDONSHANGHAIROAD	281.92					386.34
SINGAPOREMOSCOWAIR	60.91	MOSCOWSHANGHAIROAD	266.26					327.17
SINGAPORETOKYOAIR	60.91	TOKYOSHANGHAIROAD	#DIV/0!					#DIV/0!

Table 10 lists the basic data process of the city pair and transport mode combinations. The first and second columns present the original origins and destinations respectively; column 3 is the mode number; column 4 to column 7 contain the mode name, such as air mode and road mode; and column 5 to column 10 consist of the transit city names when using a multimodal transport system. The following four table excerpts use the Excel function "VLOOKUP" to match the value of the transport price and time between each city pair in table 6, then, to calculate the total transport cost and total transport time.

The total transport cost includes the pure transport price of each city pair with transport modes in the multimodal transport combination, the holding cost during the transit time, and the holding cost during the delay time. The total transport time includes the pure transport transit time between each city pair with transport modes in the multimodal transport transfer, and the delay time of each transport mode transfer.

Table 11. Ways in which to choose optimal plans for lowest cost, highest speed, and alternatives 1, 2, and 3—(AKE with air)

ORIGIN	DESTINATION	MODE1	MODE2	MODE3	MODE4	TRANSIT CITY1	TRANSIT CITY2	TRANSIT CITY3	TRANSIT CITY4	TRANSIT CITY5	TOTAL PRICE	TOTAL TRANSIT TIME	TOTAL DELAY TIME	TOTAL DELAY HOLDING COST	TOTAL HOLDING COST	TOTAL COST	TOTAL TRANSPORT TIME
SHANGHAI	MONTREAL	SEA	AIR			SHANGHAI	NEWYORK	MONTREAL			1330.50	43.50	2.00	17.40	378.51	1726.41	45.50
		ROAD	SEA	AIR		SHANGHAI	SINGAPORE	NEWYORK	MONTREAL		1683.00	60.00	4.00	34.81	522.08	2239.89	64.00
		SEA	AIR	RAIL		SHANGHAI	NEWYORK	NEWORLEANS	MONTREAL		1924.25	51.26	3.00	26.10	446.02	2396.37	54.26
		AIR	SEA			SHANGHAI	SINGAPORE	MONTREAL			1989.50	46.50	2.00	17.40	404.61	2411.52	48.50
		AIR	SEA	ROAD		SHANGHAI	SINGAPORE	VANCOUVER	MONTREAL		2051.00	46.50	4.00	34.81	404.61	2490.42	50.50
		ROAD	SEA	AIR	RAIL	SHANGHAI	SINGAPORE	SEATTLE	VANCOUVER	MONTREAL	1930.25	60.30	5.00	43.51	524.69	2498.45	65.30
		ROAD	SEA	AIR	RAIL	SHANGHAI	SINGAPORE	NEWORLEANS	MIAMI	MONTREAL	1897.75	65.81	5.00	43.51	572.66	2513.92	70.81
		SEA	AIR	RAIL		SHANGHAI	NEWYORK	MIAMI	MONTREAL		2075.25	50.31	3.00	26.10	437.79	2539.14	53.31
		ROAD	SEA	AIR		SHANGHAI	BANGLADESH	NEWYORK	MONTREAL		2114.00	45.50	4.00	34.81	395.91	2544.72	49.50

ORIGIN	DESTINATION	MODE1	MODE2	MODE3	MODE4	TRANSIT CITY1	TRANSIT CITY2	TRANSIT CITY3	TRANSIT CITY4	TRANSIT CITY5	TOTAL PRICE	TOTAL TRANSIT TIME	TOTAL DELAY TIME	TOTAL DELAY HOLDING COST	TOTAL HOLDING COST	TOTAL COST	TOTAL TRANSPORT TIME
SHANGHAI	MONTREAL	AIR	RAIL			SHANGHAI	NEWYORK	MONTREAL			7037.50	6.04	1.00	8.70	52.57	7098.77	7.04
		AIR				SHANGHAI	MONTREAL				13803.00	7.50	0.00	0.00	65.26	13868.26	7.50
		AIR	ROAD			SHANGHAI	HALIFAX	MONTREAL			14513.00	10.50	1.00	8.70	91.36	14613.07	11.50
		AIR	RAIL			SHANGHAI	HALIFAX	MONTREAL			14297.38	10.72	1.00	8.70	93.25	14399.33	11.72
		AIR	RAIL			SHANGHAI	NEWORLEANS	MONTREAL			11260.75	10.76	1.00	8.70	93.61	11363.06	11.76
		AIR	RAIL			SHANGHAI	MIAMI	MONTREAL			11256.75	10.81	1.00	8.70	94.08	11359.53	11.81
		AIR	ROAD	RAIL		SHANGHAI	MIAMI	NEWYORK	MONTREAL		11824.00	11.04	2.00	17.40	96.08	11937.48	13.04

ORIGIN	DESTINATION	MODE1	MODE2	MODE3	MODE4	TRANSIT CITY1	TRANSIT CITY2	TRANSIT CITY3	TRANSIT CITY4	TRANSIT CITY5	TOTAL PRICE	TOTAL TRANSIT TIME	TOTAL DELAY TIME	TOTAL DELAY HOLDING COST	TOTAL HOLDING COST	TOTAL COST	TOTAL TRANSPORT TIME
SHANGHAI	MONTREAL	AIR	RAIL			SHANGHAI	NEWYORK	MONTREAL			7037.50	6.04	1.00	8.70	52.57	7098.77	7.04
		AIR				SHANGHAI	MONTREAL				13803.00	7.50	0.00	0.00	65.26	13868.26	7.50
		AIR	ROAD			SHANGHAI	HALIFAX	MONTREAL			14513.00	10.50	1.00	8.70	91.36	14613.07	11.50
		AIR	RAIL			SHANGHAI	HALIFAX	MONTREAL			14297.38	10.72	1.00	8.70	93.25	14399.33	11.72
		AIR	RAIL			SHANGHAI	NEWORLEANS	MONTREAL			11260.75	10.76	1.00	8.70	93.61	11363.06	11.76
		AIR	RAIL			SHANGHAI	MIAMI	MONTREAL			11256.75	10.81	1.00	8.70	94.08	11359.53	11.81
		AIR	ROAD	RAIL		SHANGHAI	MIAMI	NEWYORK	MONTREAL		11824.00	11.04	2.00	17.40	96.08	11937.48	13.04
		AIR	ROAD	RAIL		SHANGHAI	NEWORLEANS	NEWYORK	MONTREAL		11824.00	11.04	2.00	17.40	96.08	11937.48	13.04
		AIR	RAIL	ROAD		SHANGHAI	NEWYORK	HALIFAX	MONTREAL		8003.50	11.11	2.00	17.40	96.66	8117.56	13.11
		AIR	RAIL	ROAD		SHANGHAI	SEATTLE	VANCOUVER	MONTREAL		11295.00	11.60	2.00	17.40	100.90	11413.30	13.60
		ROAD	AIR			SHANGHAI	BANGLADESH	MONTREAL			7541.50	13.50	1.00	8.70	117.47	7667.67	14.50
		AIR	ROAD	RAIL		SHANGHAI	SEATTLE	NEWYORK	MONTREAL		12472.50	13.04	2.00	17.40	113.48	12603.38	15.04
		AIR	ROAD			SHANGHAI	VANCOUVER	MONTREAL			14084.00	14.50	1.00	8.70	126.17	14218.87	15.50
		AIR	ROAD	RAIL		SHANGHAI	LOSANGELES	NEWYORK	MONTREAL		8053.50	13.54	2.00	17.40	117.83	8188.73	15.54

City pairs	Plans	Transit cities				Price-$	Delay-d	Total cost-$	Cost/kg	Total time-d	Modes Air	Road	Rail	Sea	Sum
SH-MTL	Lowest cost	SH-NYC	NYC-MTL			$1,330.50	2	$1,726.41	$1.09	45.50	1			1	2
		SEA	AIR												
		$412.50	$918.00												
		40.5d	3d												
	Highest speed	SH-NYC	NYC-MTL			$7,037.50	1	$7,098.77	$4.47	7.04	1		1		2
		AIR	RAIL												
		$6,808.00	$229.50												
		4.5d	1.54d												
	Alternative 1	SH-NYC	NYC-HLF	HLF-MTL		$8,003.50	2	$8,117.56	$5.11	13.11	1	1	1		3
		AIR	RAIL	ROAD											
		$6,808.00	$485.50	$710.00											
		4.5d	3.6d	3d											
	Alternative 2	SH-BGD	BGD-MTL			$7,541.50	1	$7,667.67	$4.83	14.50	1	1			2
		ROAD	AIR												
		$825.00	$6,716.50												
		6d	7.5d												
	Alternative 3	SH-LA	LA-NYC	NYC-MTL		$8,053.50	2	$8,188.73	$5.16	15.54	1	1	1		3
		AIR	ROAD	RAIL											
		$6,458.00	$1,366.00	$229.50											
		4.5d	7.5d	1.5d											

The table above presents the logic for choosing the top five plans with the lowest cost, highest speed, and alternatives 1, 2 and 3. We have included the screen shot of AKE with an air combination as an example.

The first table is the result of using Excel's "Ascending" function in the total cost section—the first column, marked as a red frame, is the plan for the lowest cost The second table was formed after using Excel's

“Ascending” function in the total transport time section—the first column, marked as a red frame, is the plan for the lowest transit time; the third table was also formed after using the “Ascending” function in Excel, and the three alternative plans were chosen as low transit time while displaying low cost among the high-speed options; The fourth table is a summary of the top five plans for the Eurasia city pair of Shanghai-Singapore, and of those five plans, we chose the optimal plan as the one with the lowest cost and highest speed. For example, the plan with red frames, the lowest-cost plan, was chosen as the optimal plan for the Shanghai-Singapore city pair—it calls for shipping products from Shanghai to Singapore by air with a total cost of $1,657 and a total transport time of 6.5 days. However, we found that the lowest-cost alternative is not always the best option, because sometimes when the shipping price is too low, which are mostly shipping by sea, the total transit time will be long, thus having a direct impact on holding cost.

In the last table, the first column lists the names of the city pairs. The second column contains the five selected plans for each city pair: the lowest-cost plan, the highest-speed plan, and three alternative plans with multimodal transport options. The third column indicates the transit cities between the origins and destinations with transport price and time for each transit, and the fourth to eighth columns present the total transport price, total delayed time (total multimodal transfer time), total cost including holding cost, cost per kilogram, and total transport time respectively. Finally, the last column is a summary of the transport modes that each plan used.

4.4 Interviews for data validation

Interviews will be taken to test not only the research results, but also the accuracy of data we have collected from the secondary database. The test includes the assumptions we made on calculating unavailable data, and the reasonability of the data. For example, if the data of transportation time are too long by air, we have to doubt whether the data we collected are reasonable. In addition, we have to know why those information errors happen. The answers will be displayed after the interviews.

5 Discussion and analysis of results

5.1 Economic perspective

5.1.1 Results of optimal plans of city pairs—product value at $10/kg

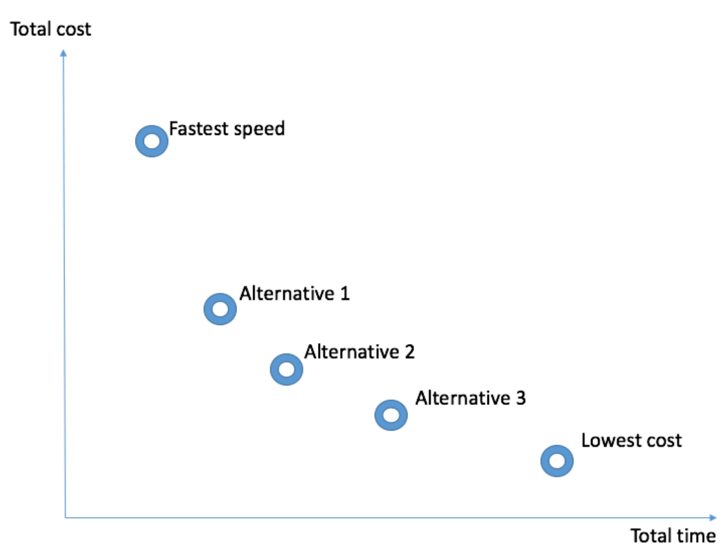
5.1.1.1 Scenario 1: AKE cargo—with air (AKE cargo, 4.3 Cu.M, 1,588 kg)

In this section, we analyze the differences in transporting a small cargo—AKE air cargo—from city to city, demonstrating the five best selected plans from the city pairs' combinations. Those five top plans are depicted by the sequence of the lowest-cost plan, including the delay cost and the warehouse holding cost in terms of transporting time; then the highest speed plan; and the three alternative plans with modest transporting times and costs. We chose the best solutions out of the five plans for each city pair using common-sense logic, taking into account both criteria of total cost and total transport time —the red frames marked in the Excel screenshots are the chosen solutions. The yellow highlighted areas are total cost and total transport time, which are marked for easy comparison.

Overall, we divided the scenarios into short distance and long distance; In the short-distance scenario, there are situations in the eastern regions, middle regions, and western regions, such as a combination of Shanghai and Singapore in the eastern region of the Eurasia continent. In the long-distance scenario, there are situations involving travelling from the east side of the continent to the west and from the west side to the east.

The transportation mode combinations include the air mode for each situation in this section in order to observe the economic influence of air cargo (by airplane) in the multimodal transportation system.

Figure 16 Tradeoff between cost and time among 5 plans



5.1.1.1.1 Eurasia

5.1.1.1.1.1 Short distance

To take the western region in Eurasia as an example (see the table below), for the city pair of London to Amsterdam, we have chosen alternative 1 as the optimal plan out of the five options. This plan involves travelling from London to Moscow by air at a price of $524.5 and for a time period of 9 days, and then, from Moscow to Amsterdam by road at a price of $978.34 and a time of 2 days. However, we can see that the total transport time is 12 days instead of 11 days; this is because there is a 1-day delay in terms of transferring from the air mode to the road mode. When we compare the best solution to the lowest-cost plan, the lowest-cost plan is $803.03 with 20 transport days—travelling by air from London to Moscow at a price of $524.50 and a time of 9 days; then, from Moscow to Amsterdam by sea at a rate of $104.5 and a time of 9 days, and including the 2-day delay of transferring from the air to the maritime transport mode brings the total time to 20 days.

The reason for choosing alternative 1 is that it is much faster than the lowest-cost plan and still cheaper than a direct flight from London to Amsterdam.

Table 12 Scenario 1-Eurasia-short distance

City pairs	Plans	Transit cities			Price-$	Delay-d	Total cost-$	Cost/kg	Total time-d	Modes				
										Air	Road	Rail	Sea	Sum
SH-SGP	Lowest cost	SH-SGP AIR 1601.00 6.5d			1601.00	0.00	1657.00	1.04	6.50	1.00				1.00
SH-SGP	Highest speed	SH-SGP AIR 1601.00 6.5d			1601.00	0.00	1657.00	1.04	6.50	1.00				1.00
SH-SGP	Alternative 1	SH-BGD ROAD 825.00 6d	BGD-SGP AIR 3917.00 10.5d		4742.00	1.00	4894.27	3.08	17.50	1.00	1.00			2.00
SH-SGP	Alternative 2	SH-TKY SEA 602.50 6d	TKY-SGP AIR 1193.50 10.5d		2516.00	2.00	2724.83	1.72	24.00	1.00			1.00	2.00
SH-SGP	Alternative 3	SH-MB ROAD 825.00 9d	MB-BGD RAIL 682.75 5.59d	BGD-SGP AIR 3917.00 10.5d	5424.75	2.00	5660.45	3.56	27.09	1.00	1.00	1.00		3.00
SGP-SH	Lowest cost	SGP-LD SEA 420.00 28d	LD-SH AIR 718.00 9d		1138.00	2.00	1477.35	0.93	39.00	1.00			1.00	2.00
SGP-SH	Highest speed	SGP-SH AIR 1465.50 7d			1465.50	0.00	1526.41	0.96	7.00	1.00				1.00
SGP-SH	Alternative 1	SGP-BGD ROAD 822.00 5.5d	BGD-SH AIR 3944.00 7.5d		4766.00	1.00	4887.82	3.08	14.00	1.00	1.00			2.00
SGP-SH	Alternative 2	SGP-BGD RAIL 1284.50 10.6d	BGD-SH AIR 3944.00 7.5d		5228.50	1.00	5395.02	3.40	19.14	1.00		1.00		2.00
SGP-SH	Alternative 3	SGP-MB AIR 3282.00 9.5d	MB-SH ROAD 822.00 9d		4104.00	1.00	4273.68	2.69	19.50	1.00	1.00			2.00
MB-ISTB	Lowest cost	MB-LD SEA 426.00 37.5d	LD-MSC AIR 524.50 9d	MSC-ISTB ROAD 692.50 3.5d	1643.00	3.00	2104.17	1.33	53.00	1.00	1.00		1.00	3.00
MB-ISTB	Highest speed	MB-ISTB AIR 4577.00 10.5d			4577.00	0.00	4668.36	2.94	10.50	1.00				1.00
MB-ISTB	Alternative 1	MB-ATHS AIR 2304.00 9.5d	ATHS-ISTB RAIL 1118.00 3.8d		3422.00	1.00	3546.50	2.23	14.30	1.00		1.00		2.00
MB-ISTB	Alternative 2	MB-HMB AIR 3808.50 9.5d	HMB-ISTB RAIL 1302.88 7.8d		5111.38	1.00	5271.15	3.32	18.36	1.00		1.00		2.00
MB-ISTB	Alternative 3	MB-AMSD AIR 2444.00 9.5d	AMSD-ISTB RAIL 867.75 8.46d		3311.75	1.00	3476.75	2.19	18.96	1.00		1.00		2.00
ISTB-MB	Lowest cost	ISTB-SGP AIR 773.50 62d	SGP-MB ROAD 822.00 7.5d		1595.50	1.00	2208.95	1.39	70.50	1.00	1.00			2.00
ISTB-MB	Highest speed	ISTB-MB AIR 3883.00 11.5d			3883.00	0.00	3983.07	2.51	11.50	1.00				1.00
ISTB-MB	Alternative 1	ISTB-BGD AIR 3776.00 9.5d	BGD-MB ROAD 822.00 5d		4598.00	1.00	4732.87	2.98	15.50	1.00	1.00			2.00
ISTB-MB	Alternative 2	ISTB-BGD AIR 3776.00 9.5d	BGD-MB RAIL 1033.38 5.58d		4809.38	1.00	4949.36	3.12	16.09	1.00		1.00		2.00
ISTB-MB	Alternative 3	ISTB-MSC ROAD 692.50 3.5d	MSC-MB AIR 4007.00 12d		4699.50	1.00	4843.07	3.05	16.50	1.00	1.00			2.00
LD-AMSD	Lowest cost	LD-MSC AIR 524.50 9d	MSC-AMSD SEA 104.50 9d		629.00	2.00	803.03	0.51	20.00	1.00			1.00	2.00
LD-AMSD	Highest speed	LD-AMSD AIR 2794.50 9d			2794.50	0.00	2872.81	1.81	9.00	1.00				1.00
LD-AMSD	Alternative 1	LD-MSC AIR 524.50 9d	MSC-AMSTD ROAD 978.34 2d		1502.84	1.00	1607.26	1.01	12.00	1.00	1.00			2.00
LD-AMSD	Alternative 2	LD-MSC AIR 524.50 9d	MSC-AMSD RAIL 555.88 6.18d		1080.38	1.00	1221.19	0.77	16.20	1.00		1.00		2.00
LD-AMSD	Alternative 3	LD-ATHS AIR 727.50 9d	ATHS-AMSD RAIL 826.00 6.3d		1553.50	1.00	1696.17	1.07	16.40	1.00		1.00		2.00
AMSD-LD	Lowest cost	AMSD-SH AIR 1410.50 7d	SH-LD SEA 461.00 39.5d		1871.50	2.00	2293.52	1.44	48.50	1.00			1.00	2.00
AMSD-LD	Highest speed	AMSD-LD AIR 2865.00 9d			2865.00	0.00	2943.31	1.85	9.00	1.00				1.00
AMSD-LD	Alternative 1	AMSD-HMB AIR 3179.50 7d	HMB-LD RAIL 947.88 2.07d		4127.38	1.00	4215.04	2.65	10.08	1.00		1.00		2.00
AMSD-LD	Alternative 2	AMSD-HMB SEA 590.50 2.5d	HMB-LD AIR 3791.50 9d		4382.00	2.00	4499.47	2.83	13.50	1.00			1.00	2.00
AMSD-LD	Alternative 3	AMSD-ATHS AIR 3098.50 7d	ATHS-LD RAIL 882.75 7.04d		3981.25	1.00	4112.17	2.59	15.05	1.00		1.00		2.00

5.1.1.1.1.2 Long distance

In the long-distance section in the Eurasia region (see the table below), we observe some differences: the red frames (our logically chosen optimal plans) are not always marked as the highest-speed plan; instead, they are sometimes alternatives with multimodal combinations. For example, from Shanghai to Amsterdam, it is no longer possible to travel by air directly; instead, travel must be done from Shanghai to Bangladesh by road at a price of $825 and a time of 6 days, and then, from Bangladesh to Amsterdam by air at a price of $2,730.5 and a time of 7 days. The total transport cost is thus $3,677.32, and the total transport time is 14 days. Although air transport should be maximum 2 days, the data we collected included all the handling processes, customs brokerage time and some errors due to accuracy of the secondary database.

However, from the lowest-cost plan, it is evident that the total transport cost is $2,043.3, and the total transport time is 57.68 days. Since we are researching products with high-speed requirements, 57.68 days is considered to be too long to transport the goods.

Looking at the plan with the highest speed, the total transport cost is $11,999.26, and the total transport time is 7.5 days. Although this transport time is 6.5 days less than that of the alternative 1 plan, the total cost is $11,999.26, which is $9,268.76 (11999.26-2730.50=9268.76) more than the alternative 1 plan. If we use the plan of alternative 1, we can transport four times more goods than with the air mode. Therefore, the optimal plan is alternative 1, which is cheap enough while maintaining the high transport speed.

Table 13 Scenario 1 -Eurasia - long distance

City pairs	Plans	Transit cities				Price-$	Delay-d	Total cost-$	Cost/kg	Total time-d	Modes				
											Air	Road	Rail	Sea	Sum
SH-AMSD	Lowest cost	SH-LD	LD-MSC	MSC-AMSD		1541.38	3.00	2043.30	1.29	57.68	1.00		1.00	1.00	3.00
		SEA	AIR	RAIL											
		461.00	524.50	555.88											
		39.5d	9d	6.2d											
	Highest speed	SH-AMSD				11934.00	0.00	11999.26	7.56	7.50	1.00				1.00
		AIR													
		11934.00													
		7.50													
	Alternative 1	SH-HMB	HMB-AMSD			9582.63	1.00	9665.87	6.09	9.57	1.00		1.00		2.00
		AIR	RAIL												
		8718.00	864.63												
		7.5d	1.06d												
	Alternative 2	SH-BGD	BGD-AMSD			3555.50	1.00	3677.32	2.32	14.00	1.00	1.00			2.00
		ROAD	AIR												
		825.00	2730.50												
		6d	7d												
	Alternative 3	SH-BGD	BGD-AMSD			5395.63	2.00	5535.43	3.49	16.07	1.00	1.00	1.00		3.00
		ROAD	AIR	RAIL											
		825.00	3706.00	864.63											
		6d	7d	1.06d											
SGP-LD	Lowest cost	SGP-SH	SH-LD			1926.50	2.00	2348.52	1.48	48.50	1.00			1.00	2.00
		AIR	SEA												
		1465.50	461.00												
		7d	39.5d												
	Highest speed	SGP-AMSD	AMSD-LD			6829.75	1.00	6908.24	4.35	9.02	1.00		1.00		2.00
		AIR	RAIL												
		6113.50	716.25												
		7d	1.02d												
	Alternative 1	SGP-HMB	HMB-LD			5537.38	1.00	5625.04	3.54	10.08	1.00		1.00		2.00
		AIR	RAIL												
		4589.50	947.88												
		7d	2.07d												
	Alternative 2	SGP-LD				5066.50	0.00	5170.92	3.26	12.00	1.00				1.00
		AIR													
		5066.50													
		12d													
	Alternative 3	SGP-BGD	BGD-AMSD	AMSD-LD		4268.75	2.00	4403.80	2.77	15.52	1.00	1.00	1.00		3.00
		ROAD	AIR	RAIL											
		822.00	2730.50	716.25											
		5.5d	7d	1.02d											
TKY-HMB	Lowest cost	TKY-SGP	SGP-HMB			2390.00	2.00	2738.05	1.72	40.00	1.00			1.00	2.00
		AIR	SEA												
		1913.50	476.50												
		10d	28d												
	Highest speed	TKY-HMB				4448.50	0.00	4509.41	2.84	7.00	1.00				1.00
		AIR													
		4448.50													
		7.00													
	Alternative 1	TKY-AMSD	AMSD-HMB			3140.88	1.00	3219.77	2.03	9.07	1.00		1.00		2.00
		AIR	RAIL												
		2346.00	794.88												
		7d	1.06d												
	Alternative 2	TKY-AMSD	AMSD-HMB			2936.50	2.00	3036.57	1.91	11.50	1.00			1.00	2.00
		AIR	SEA												
		2346.00	590.50												
		7d	2.5d												
	Alternative 3	TKY-AMSD	AMSD-LD	LD-HMB		3912.75	3.00	4060.85	2.56	17.02	1.00		1.00	1.00	3.00
		AIR	RAIL	SEA											
		2346.00	716.25	850.50											
		7d	1.02d	6d											
AMSD-SH	Lowest cost	AMSD-LD	LD-SH			993.50	2.00	1141.42	0.72	17.00	1.00			1.00	2.00
		SEA	AIR												
		275.50	718.00												
		6d	9d												
	Highest speed	AMSD-SH				1410.50	0.00	1471.41	0.93	7.00	1.00				1.00
		AIR													
		1410.50													
		7d													
	Alternative 1	AMSD-HMB	HMB-SH			2049.88	1.00	2128.77	1.34	9.07	1.00		1.00		2.00
		RAIL	AIR												
		794.88	1255.00												
		1.06d	7d												
	Alternative 2	AMSD-LD	LD-SH			1434.25	1.00	1530.15	0.96	11.02	1.00		1.00		2.00
		RAIL	AIR												
		716.25	718.00												
		1.02d	9d												
	Alternative 3	AMSD-HMB	HMB-SH			1845.50	2.00	1945.57	1.23	11.50	1.00			1.00	2.00
		SEA	AIR												
		590.50	1255.00												
		2.5d	7d												
LD-SGP	Lowest cost	LD-SH	SH-SGP			782.00	1.00	956.03	0.60	20.00	1.00	1.00			2.00
		AIR	ROAD												
		718.00	64.00												
		9d	10d												
	Highest speed	LD-SGP				2576.50	0.00	2707.02	1.70	15.00	1.00				1.00
		AIR													
		2576.50													
		15d													
	Alternative 1	LD-BGD	GD-SGP			1604.00	1.00	1738.87	1.10	15.50	1.00	1.00			2.00
		AIR	ROAD												
		1548.50	55.50												
		9d	5.5d												
	Alternative 2	LD-AMSD	AMSD-SH	SH-SGP		2173.13	2.00	2350.56	1.48	20.39	1.00	1.00	1.00		3.00
		RAIL	AIR	ROAD											
		698.63	1410.50	64.00											
		1.39d	7d	10d											
	Alternative 3	LD-BGD	BGD-SGP			2527.75	1.00	2707.36	1.70	20.64	1.00		1.00		2.00
		AIR	RAIL												
		1548.50	979.25												
		9d	10.6d												
HMB-TKY	Lowest cost	HMB-SH	SH-TKY			1857.50	2.00	2040.23	1.28	21.00	1.00			1.00	2.00
		AIR	SEA												
		1255.00	602.50												
		7d	12d												
	Highest speed	HMB-TKY				3502.00	0.00	3562.91	2.24	7.00	1.00				1.00
		AIR													
		3502.00													
		7d													
	Alternative 1	HOM-AMSD	AMSD-TKY			5367.13	1.00	5450.37	3.43	9.57	1.00		1.00		2.00
		RAIL	AIR												
		864.63	4502.50												
		1.06d	7.5d												
	Alternative 2	HMB-AMSD	AMSD-TKY			4799.00	2.00	4916.47	3.10	13.50	1.00			1.00	2.00
		SEA	AIR												
		296.50	4502.50												
		4d	7.5d												
	Alternative 3	HMB-MSC	MSC-TKY			3209.63	1.00	3337.25	2.10	14.67	1.00		1.00		2.00
		RAIL	AIR												
		1366.13	1843.50												
		5.17d	8.5d												

Overall, short-distance city pairs in Eurasia mostly use the fastest speed plans—air only; however, there are two exceptions to using the alternative plan, one of which is discussed in the next subsection.

By intuition, long-distance city pairs are more likely to use the alternative plans with multimodal transport ideas. No optimal plan is depicted in the highest-speed section; all plans are either alternatives or the lowest-cost plans. Therefore, the short-distance city pairs do not find the multimodal transport system appealing, while the long-distance city pairs are more likely to use this system to reduce total costs and retain high speeds of transportation.

5.1.1.1.2 North America

5.1.1.1.2.1 Short distance

The optimal plans for short-distance city pairs in North America demonstrate similar characteristics to the optimal plans in Eurasia—they are mostly situated in the highest-speed plans, which are air-only plans.

Two exceptions exist in the short-distance optimal plans. One of them is the city pair of Vancouver to Seattle, whose optimal plan is alternative 1. The itinerary is to travel from Vancouver to Los Angeles by rail at a price of $1,826 and a time of 5.3 days, and then, from Los Angeles to Seattle by air at a price of $755 and a time of 2 days. The total cost is thus $2,653.51, and the total transport time is 8.33 days, instead of $7,338.81 and 4 days respectively in the highest-speed plan. The reason the alternative 1 plan is better is because the price is much lower than that of the highest-speed plan, and the transport time is only 3 days longer.

Table 14 Scenario 1 -North America - Short distance

City pairs	Plans	Transit cities				Price-$	Delay-d	Total cost-$	Cost/kg	Total time-d	Modes Air	Road	Rail	Sea	Sum
MTL-NYC	Lowest cost	MTL-MIA SEA $146.50 16.5d	MIA-NYC AIR $1,341.00 3d			$1,487.50	2	$1,674.58	$1.05	21.50	1			1	2
	Highest speed	MTL-NYC AIR $7,304.00 4d				$7,304.00	0	$7,338.81	$4.62	4.00	1				1
	Alternative 1	MTL-HLF AIR $1,977.50 7d	HLF-NYC RAIL $1,826.00 3.6d			$3,803.50	1	$3,904.54	$2.46	11.61	1		1		2
	Alternative 2	MTL-NOL RAIL $1,826.00 11.05d	NOL-NYC AIR $1,341.00 3d			$3,167.00	1	$3,297.99	$2.08	15.05	1		1		2
	Alternative 3	MTL-MIA RAIL $1,826.00 11.2d	MIA-NYC AIR $1,341.00 3d			$3,167.00	1	$3,299.44	$2.08	15.22	1		1		2
NYC-MTL	Lowest cost	NYC-MTL AIR $918.00 3d				$918.00	0	$944.10	$0.59	3.00	1				1
	Highest speed	NYC-MTL AIR $918.00 3d				$918.00	0	$944.10	$0.59	3.00	1				1
	Alternative 1	NYC-HLF AIR $1,942.00 5d	HLF-MTL ROAD $710.00 3d			$2,652.00	1	$2,730.31	$1.72	9.00	1	1			2
	Alternative 2	NYC-MIA AIR $1,283.00 3d	MIA-NYC RAIL $379.75 6.8d			$1,662.75	1	$1,756.83	$1.11	10.81	1		1		2
	Alternative 3	NYC-NOL AIR $1,128.00 4d	NOL-MTL RAIL $383.75 6.75d			$1,511.75	1	$1,614.06	$1.02	11.76	1		1		2
NOL-LA	Lowest cost	NOL-LA AIR $1,161.00 4d				$1,161.00	0	$1,195.81	$0.75	4.00	1				1
	Highest speed	NOL-LA AIR $1,161.00 4d				$1,161.00	0	$1,195.81	$0.75	4.00	1				1
	Alternative 1	NOL-STL ROAD $1,366.00 5.5d	STL-LA AIR $631.00 2d			$1,997.00	1	$2,070.96	$1.30	8.50	1	1			2
	Alternative 2	NOL-MIA RAIL $618.00 3.5d	MIA-LA AIR $1,399.00 5d			$2,017.00	1	$2,100.50	$1.32	9.60	1		1		2
	Alternative 3	NOL-STL AIR $1,323.00 5d	STL-LA RAIL $550.50 4.7d			$1,873.50	1	$1,966.93	$1.24	10.74	1		1		2
LA-NOL	Lowest cost	LA-NOL AIR $865.00 4d				$865.00	0	$899.81	$0.57	4.00	1				1
	Highest speed	LA-NOL AIR $865.00 4d				$865.00	0	$899.81	$0.57	4.00	1				1
	Alternative 1	LA-MIA AIR $1,103.00 5d	MIA-NOL RAIL $471.00 3.6d			$1,574.00	1	$1,657.61	$1.04	9.61	1		1		2
	Alternative 2	LA-STL RAIL $811.50 4.7d	STL-NOL AIR $1,027.00 5d			$1,838.50	1	$1,931.86	$1.22	10.73	1		1		2
	Alternative 3	LA-STL ROAD $742.00 5.5d	STL-NOL AIR $1,027.00 5d			$1,769.00	1	$1,869.07	$1.18	11.50	1	1			2
VCV-STL	Lowest cost	VCV-MTL ROAD $281.00 7d	MTL-MIA SEA $146.50 16.5d	MIA-STL AIR $649.00 10d		$1,076.50	4	$1,402.80	$0.88	37.50	1	1		1	2
	Highest speed	VCV-STL AIR $7,304.00 4d				$7,304.00	0	$7,338.81	$4.62	4.00	1				1
	Alternative 1	VCV-LA RAIL $1,826.00 5.3d	LA-STL AIR $755.00 2d			$2,581.00	1	$2,653.51	$1.67	8.33	1		1		2
	Alternative 2	VCV-LA RAIL $1,826.00 5.33d	LA-NOL AIR $865.00 4d	NOL-STL ROAD $1,366.00 5.5d		$4,057.00	2	$4,203.47	$2.65	16.83	1	1	1		3
	Alternative 3	VCV-MTL ROAD $281.00 7d	MTL-NYC RAIL $1,826.00 2.48d	NYC-STL AIR $1,487.00 6d		$3,594.00	2	$3,746.13	$2.36	17.48	1	1	1		3
STL-VCV	Lowest cost	STL-VCV AIR $548.00 2d				$548.00	0	$565.40	$0.36	2.00	1				1
	Highest speed	STL-VCV AIR $548.00 2d				$548.00	0	$565.40	$0.36	2.00	1				1
	Alternative 1	STL-LA AIR $631.00 2d	LA-VCV RAIL $1,417.75 5.3d			$2,048.75	1	$2,121.15	$1.34	8.32	1		1		2
	Alternative 2	STL-NOL ROAD $1,366.00 5.5d	NOL-VCV AIR $1,567.00 5d			$2,933.00	1	$3,033.07	$1.91	11.50	1	1			2
	Alternative 3	STL-MTL AIR $2,272.00 7d	MTL-VCV ROAD $397.00 7d			$2,669.00	1	$2,799.52	$1.76	15.00	1	1			2

5.1.1.1.2.2 Long distance

In the long-distance section in the North America region, to transport AKE cargo, five optimal plans out of six city pairs are situated in the lowest-cost plan and the alternative plans, and only one optimal plan is that of the highest speed.

To elaborate, the optimal plan for the highest speed for the New-York-to-Seattle city pair is to travel from New York to Seattle by air; the total cost of the highest speed is $1,539, and the total transport time is 6 days. The second optimal plan for this city pair is the alternative 1 plan, which is to travel from New York to Los Angeles by road at a price of $905 and a time of 7.5 days, and then, from Los Angeles to Seattle at a price of $755 and a time of 2 days; the total cost is $1,751.86, and the total transport time is 10.5 days, including the total transit time and total delay (transport modal transfer time). The difference is not large; therefore, the alternative plan may have potential when transporting products in AKE cargo with a multimodal transport system.

Table 15 Scenario 1 -North America - Long distance

City pairs	Plans	Transit cities				Price-$	Delay-d	Total cost-$	Cost/kg	Total time-d	Modes				
											Air	Road	Rail	Sea	Sum
MTL-LA	Lowest cost	MTL-MIA	MIA-STL	STL-LA		$1,346.00	3	$1,643.91	$1.04	34.24	1		1	1	3
		SEA	AIR	RAIL											
		$146.50	$649.00	$550.50											
		16.5d	10d	4.7d											
	Highest speed	MTL-LA				$7,304.00	0	$7,338.81	$4.62	4.00	1				1
		AIR													
		$7,304.00													
		4d													
	Alternative 1	MTL-VCV	VCV-STL	STL-LA		$2,854.00	2	$2,954.90	$1.86	11.60	1	1	1		3
		ROAD	RAIL	AIR											
		$397.00	$1,826.00	$631.00											
		7d	0.59d	2d											
	Alternative 2	MTL-VCV	VCV-LA			$3,891.00	1	$4,007.02	$2.52	13.33	1		1		2
		AIR	RAIL												
		$2,065.00	$1,826.00												
		7d	5.3d												
	Alternative 3	MTL-NYC	NYC-NOL	NOL-LA		$3,704.50	2	$3,826.17	$2.41	13.98	1	1	1		3
		RAIL	ROAD	AIR											
		$1,826.00	$717.50	$1,161.00											
		2.4d	5.5d	4d											
MIA-VCV	Lowest cost	MIA-STL	STL-VCV			$786.00	1	$886.90	$0.56	11.60	1		1		2
		AIR	RAIL												
		$649.00	$137.00												
		10d	0.59d												
	Highest speed	MIA-VCV				$1,849.00	0	$1,901.21	$1.20	6.00	1				1
		AIR													
		$1,849.00													
		6d													
	Alternative 1	MIA-NOL	NOL-VCV			$2,038.00	1	$2,121.61	$1.34	9.61	1		1		2
		RAIL	AIR												
		$471.00	$1,567.00												
		3.6d	5d												
	Alternative 2	MIA-STL	STL-VCV			$1,914.00	1	$2,009.72	$1.27	11.00	1	1			2
		ROAD	AIR												
		$1,366.00	$548.00												
		8d	2d												
	Alternative 3	MIA-NOL	NOL-STL	STL-VCV		$2,463.00	2	$2,559.55	$1.61	11.10	1	1	1		3
		AIR	ROAD	RAIL											
		$960.00	$1,366.00	$137.00											
		3d	5.5d	0.59d											
NYC-STL	Lowest cost	NYC-MIA	MIA-STL			$795.00	2	$1,064.74	$0.67	31.00	1			1	2
		SEA	AIR												
		$146.00	$649.00												
		19d	10d												
	Highest speed	NYC-STL				$1,487.00	0	$1,539.21	$0.97	6.00	1				1
		AIR													
		$1,487.00													
		6d													
	Alternative 1	NYC-LA	LA-STL			$1,660.50	1	$1,751.86	$1.10	10.50	1	1			2
		ROAD	AIR												
		$905.50	$755.00												
		$7.50	$2.00												
	Alternative 2	NYC-NOL	NOL-STL			$2,040.50	1	$2,140.57	$1.35	11.50	1	1			2
		ROAD	AIR												
		$717.50	$1,323.00												
		$5.50	$5.00												
	Alternative 3	NYC-NOL	NOL-STL			$1,928.00	1	$2,028.61	$1.28	11.56	1		1		2
		RAIL	AIR												
		$605.00	$1,323.00												
		$5.56	$5.00												
LA-MTL	Lowest cost	LA-STL	STL-VCV	VCV-MTL		$1,173.00	2	$1,273.90	$0.80	11.60	1	1	1		3
		AIR	RAIL	ROAD											
		$755.00	$137.00	$281.00											
		2d	0.59d	7d											
	Highest speed	LA-MTL				$5,671.00	0	$5,705.81	$3.59	4.00	1				1
		AIR													
		$5,671.00													
		4d													
	Alternative 1	LA-NOL	NOL-MTL			$2,901.00	1	$2,992.36	$1.88	10.50	1	1			2
		ROAD	AIR												
		$1,366.00	$1,535.00												
		5.5d	4d												
	Alternative 2	LA-STL	STL-MTL			$1,173.00	2	$1,273.90	$0.80	11.60	1	1	1		3
		AIR	RAIL	ROAD											
		$755.00	$137.00	$281.00											
		2d	0.59d	7d											
	Alternative 3	LA-NOL	NOL-MTL			$1,248.75	1	$1,351.06	$0.85	11.76	1		1		2
		AIR	RAIL												
		$865.00	$383.75												
		4d	6.75d												
VCV-MIA	Lowest cost	VCV-NOL	NOL-MIA			$1,169.50	2	$1,608.92	$1.01	50.50	1			1	2
		SEA	AIR												
		$416.50	$753.00												
		$46.50	$2.00												
	Highest speed	VCV-MIA				$7,304.00	0	$7,338.81	$4.62	4.00	1				1
		AIR													
		$7,304.00													
		4d													
	Alternative 1	VCV-STL	STL-NOL	NOL-MIA		$3,945.00	2	$4,032.85	$2.54	10.10	1	1	1		3
		RAIL	ROAD	AIR											
		$1,826.00	$1,366.00	$753.00											
		0.59d	5.5d	2d											
	Alternative 2	VCV-NOL	NOL-MIA			$2,929.00	1	$3,027.62	$1.91	11.33	1		1		2
		RAIL	AIR												
		$1,826.00	$1,103.00												
		5.3d	5d												
	Alternative 3	VCV-STL	STL-MIA			$2,602.00	1	$2,702.90	$1.70	11.60	1		1		2
		RAIL	AIR												
		$1,826.00	$776.00												
		0.59d	10d												
STL-NYC	Lowest cost	STL-NYC				$1,056.00	0	$1,143.01	$0.72	10.00	1				1
		AIR													
		$1,056.00													
		10d													
	Highest speed	STL-VCV	VCV-NYC			$7,441.00	1	$7,489.69	$4.72	5.60	1		1		2
		RAIL	AIR												
		$1,056.00													
		10d													
	Alternative 1	STL-NOL	NOL-NYC			$2,707.00	1	$2,789.66	$1.76	9.50	1	1			2
		ROAD	AIR												
		$1,366.00	$1,341.00												
		5.5d	3d												
	Alternative 2	STL-NOL	NOL-NYC			$1,779.50	1	$1,878.99	$1.18	11.43	1		1		2
		AIR	RAIL												
		$1,027.00	$752.50												
		5d	5.4d												
	Alternative 3	STL-NOL	NOL-NYC			$1,744.50	1	$1,844.57	$1.16	11.50	1	1			2
		AIR	ROAD												
		$1,027.00	$717.50												
		5d	5.5d												

5.1.1.1.3 Eurasia, North America, and Africa combined

5.1.1.1.3.1 Long distance

The city pairs to crossover Eurasia, North America, and Africa are all considered to be long-distance city pairs. We observe that there is a half-half situation for the optimal highest-speed plan and the optimal alternative plans.

Optimal plans involving the highest speed are from Shanghai to Montreal and from Los Angeles to Singapore, while the optimal alternative plans are from Montreal to Shanghai and from Singapore to Los Angeles. However, a closer look reveals that the highest-speed plan of the Shanghai-to-Montreal city pair is not travelled by air mode only, it is also a multimodal transport method. The itinerary is to travel from Shanghai to New York by air at a price of $6,808 and a time of 4.5 days, and then, from New York to Montreal by rail at a price of $229 and a time of 1.54 days. Although there is a 1-day delay because of the multimodal transport transfer time, overall, the transport time is 7.04 days, while the Shanghai-Montreal direct flight is 7.5 days with a price of $13,803. Therefore, the plan with the fastest speed is not the air-only plan but the plan with a multimodal method, and at the same time, the total cost is much less than that of the air-only plan (presented in the following table and named as “air only”)

Table 16 Scenario 1 – Eurasia & North America& Africa - long distance

City pairs	Plans	Transit cities				Price-$	Delay-d	Total cost-$	Cost/kg	Total time-d	Modes				
											Air	Road	Rail	Sea	Sum
SH-MTL	Lowest cost	SH-NYC	NYC-MTL			$1,330.50	2	$1,726.41	$1.09	45.50	1			1	2
		SEA	AIR												
		$412.50	$918.00												
		40.5d	3d												
	Highest speed	SH-NYC	NYC-MTL			$7,037.50	1	$7,098.77	$4.47	7.04	1		1		2
		AIR	RAIL												
		$6,808.00	$229.50												
		4.5d	1.54d												
	Alternative 1	SH-NYC	NYC-HLF	HLF-MTL		$8,003.50	2	$8,117.56	$5.11	13.11	1	1	1		3
		AIR	RAIL	ROAD											
		$6,808.00	$485.50	$710.00											
		4.5d	3.6d	3d											
	Alternative 2	SH-BGD	BGD-MTL			$7,541.50	1	$7,667.67	$4.83	14.50	1	1			2
		ROAD	AIR												
		$825.00	$6,716.50												
		6d	7.5d												
	Alternative 3	SH-LA	LA-NYC	NYC-MTL		$8,053.50	2	$8,188.73	$5.16	15.54	1	1	1		3
		AIR	ROAD	RAIL											
		$6,458.00	$1,366.00	$229.50											
		4.5d	7.5d	1.5d											
SGP-LA	Lowest cost	SGP-AMSD	AMSD-LA			$1,144.50	2	$1,518.66	$0.96	43.00	1			1	2
		SEA	AIR												
		$337.00	$807.50												
		31d	10d												
	Highest speed	SGP-SH	SH-LA			$7,280.00	1	$7,388.77	$4.65	12.50	1	1			2
		ROAD	AIR												
		$822.00	$6,458.00												
		7d	4.5d												
	Alternative 1	SGP-LA				$1,646.50	0	$1,759.62	$1.11	13.00	1				1
		AIR													
		$1,646.50													
		13d													
	Alternative 2	SGP-BGD	BGD-LA			$6,348.50	1	$6,496.42	$4.09	17.00	1	1			2
		ROAD	AIR												
		$822.00	$5,526.50												
		5.5d	10.5d												
	Alternative 3	SGP-BGD	BGD-STL	STL-LA		$6,769.50	2	$6,941.24	$4.37	19.74	1	1	1		3
		ROAD	AIR	RAIL											
		$822.00	$5,397.00	$550.50											
		5.5d	7.5d	4.7d											
MTL-SH	Lowest cost	MTL-LD	LD-SH			$1,074.00	2	$1,313.29	$0.83	27.50	1			1	2
		SEA	AIR												
		$356.00	$718.00												
		16.5d	9d												
	Highest speed	MTL-SH				$4,586.00	0	$4,651.26	$2.93	7.50	1				1
		AIR													
		$4,586.00													
		7.5d													
	Alternative 1	MTL-SGP	SGP-SH			$3,350.50	1	$3,437.51	$2.16	10.00	1	1			2
		AIR	ROAD												
		$2,528.50	$822.00												
		2d	7d												
	Alternative 2	MTL-VCV	VCV-SH			$4,611.50	1	$4,742.02	$2.99	15.00	1	1			2
		ROAD	AIR												
		$397.00	$4,214.50												
		7d	7d												
	Alternative 3	MTL-SGP	SGP-BDG	BGD-SH		$4,635.00	2	$4,814.57	$3.03	20.64	1	1	1		3
		AIR	RAIL	ROAD											
		$2,528.50	$1,284.50	$822.00											
		2d	10.6d	6d											
LA-SGP	Lowest cost	LA-STL	STL-SGP			$939.00	2	$1,465.43	$0.92	60.50	1			1	2
		AIR	SEA												
		$755.00	$184.00												
		$2.00	$56.50												
	Highest speed	LA-SGP				$2,928.00	0	$2,958.45	$1.86	3.50	1				1
		AIR													
		$2,928.00													
		3.50													
	Alternative 1	LA-VCV	VCV-SGP			$3,946.25	1	$4,014.30	$2.53	7.82	1		1		2
		RAIL	AIR												
		$1,417.75	$2,528.50												
		$5.32	$1.50												
	Alternative 2	LA-STL	STL-VCV	VCV-SGP		$3,407.50	2	$3,491.00	$2.20	9.60	1	1	1		3
		ROAD	RAIL	AIR											
		$742.00	$137.00	$2,528.50											
		$5.50	$0.60	$1.50											
	Alternative 3	LA-NYC	NYC-SGP			$4,294.00	1	$4,398.42	$2.77	12.00	1	1			2
		ROAD	AIR												
		$1,366.00	$2,928.00												
		$7.50	$3.50												

5.1.1.2 Scenario 2. ASE—with Air (ASE cargo, 33 Cu.M, 11,340 kg)

Scenario 2 involves transporting one ASE (heavy) cargo from origin to destination in three different regions. However, in all the results, the air transport mode is required, for example, in the multimodal transport method, there is always the inclusion of the air mode in the transport mode combination between each city pair's itineraries.

5.1.1.2.1 Eurasia

5.1.1.2.1.1 Short distance

In the following table, we see that the only two optimal plans are highest-speed plans; others are either lowest-cost plans or alternative plans. Therefore, we can conclude that the transportation of ASE (large) cargos between the short-distance city pairs does not favor air modes. This is because transporting large cargo by air is quite expensive, even though it is fast. We should thus examine more plans to consider the transport cost and total transport time.

For example, in the city pair of Singapore to Shanghai, the total cost of travelling by air is $45,627, and the total transport time is 11.5 days, while the plan of alternative 2 is to transport goods from Singapore to Mumbai by air, and then, from Mumbai to Shanghai by road, with a total cost of $35,171 and a total time of 22.5 days.

Therefore, the total volume of air cargo could have an impact on the selection of optimal itinerary plans because large cargo could cost much more than small cargo when transported by air only, even if the two origins and destinations are close. Alternative plans—the plans of multimodal transport methods—could be a suitable choice to reduce transport costs and maintain high-quality service levels (high transport speed) when transporting low-value products ($10/kg) that are time sensitive.

Table 17 Scenario 2 -Eurasia - Short distance

City pairs	Plans	Transit cities				Price-$	Delay-d	Total cost-$	Cost/kg	Total time-d	Modes				
											Air	Road	Rail	Sea	Sum
SH-SGP	Lowest cost	SH-ISTB	ISTB-SGP			11466.50	2.00	18270.50	1.61	109.50	1.00			1.00	2.00
		SEA	AIR												
		3729.00	7737.50												
		45.5d	62d												
	Highest speed	SH-SGP				19754.50	0.00	20375.87	1.80	10.00	1.00				1.00
		AIR													
		19754.50													
		10d													
	Alternative 1	SH-HMB	HMB-SGP			47141.48	1.00	48148.10	4.25	16.20	1.00	1.00			2.00
		ROAD	AIR												
		17453.48	29688.00												
		7.2d	8d												
	Alternative 2	SH-BGD	BGD-SGP			43943.50	1.00	45372.65	4.00	23.00	1.00	1.00			2.00
		AIR	ROAD												
		43507.50	436.00												
		16.5d	5.5d												
	Alternative 3	SH-HMB	HMB-SGP			39604.75	1.00	41058.76	3.62	23.40	1.00		1.00		2.00
		RAIL	AIR												
		9916.75	29688.00												
		14.4d	8d												
SGP-SH	Lowest cost	SGP-RM	RM-MD	MD-SH		11051.00	3.00	14872.42	1.31	61.50	1.00	1.00		1.00	3.00
		AIR	ROAD	SEA											
		8626.00	790.00	1635.00											
		10.00	5.00	43.50											
	Highest speed	SGP-SH				45627.00	0.00	46341.58	4.09	11.50	1.00				1.00
		AIR													
		45627.00													
		11.5d													
	Alternative 1	SGP-MB	MB-SH			51738.50	1.00	53105.51	4.68	22.00	1.00	1.00			2.00
		ROAD	AIR												
		5959.00	45779.50												
		7d	14d												
	Alternative 2	SGP-MB	MB-SG			33773.50	1.00	35171.58	3.10	22.50	1.00	1.00			2.00
		AIR	ROAD												
		27814.50	5959.00												
		12.5d	9d												
	Alternative 3	SGP-HMB	HMB-SH			41100.00	2.00	43430.14	3.83	37.50	1.00			1.00	2.00
		SEA	AIR												
		2831.00	38269.00												
		25.5d	10d												
MB-ISTB	Lowest cost	MB-SGP	SGP-RM	RM-ISTB		11382.50	3.00	13308.75	1.17	31.00	1.00	1.00		1.00	3.00
		ROAD	AIR	SEA											
		514.00	8626.00	2242.50											
		7.50	10.00	10.50											
	Highest speed	MB-ISTB				71450.00	0.00	72071.37	6.36	10.00	1.00				1.00
		AIR													
		71450.00													
		10d													
	Alternative 1	MB-RM	RM-ISTB			19040.00	2.00	20407.01	1.80	22.00	1.00			1.00	2.00
		AIR	SEA												
		16797.50	2242.50												
		9.5d	10.5d												
	Alternative 2	MB-HMB	HMB-IST			21609.00	2.00	23317.77	2.06	27.50	1.00			1.00	2.00
		AIR	SEA												
		17952.50	3656.50												
		9.5d	16d												
	Alternative 3	MB-BGD	BGD-RM	RM-ISTB		16827.50	3.00	18598.40	1.64	28.50	1.00	1.00		1.00	3.00
		ROAD	AIR	SEA											
		5959.00	8626.00	2242.50											
		5d	10d	10.5d											
ISTB-MB	Lowest cost	ISTB-AMSD	AMSD-MB			7214.33	2.00	10071.53	0.89	45.98	1.00			1.00	2.00
		AIR	SEA												
		3770.83	3443.50												
		3.48	40.50												
	Highest speed	ISTB-MB				27092.00	0.00	27744.44	2.45	10.50	1.00				1.00
		AIR													
		27092.00													
		10.5d													
	Alternative 1	ISTB-AMSD	ASMD-MB			27938.17	1.00	29462.74	2.60	24.54	1.00	1.00			2.00
		ROAD	AIR												
		1659.17	26279.00												
		12.5d	11d												
	Alternative 2	ISTB-MD	MD-MB			24465.50	2.00	26205.34	2.31	28.00	1.00			1.00	2.00
		SEA	AIR												
		2979.00	21486.50												
		14d	12d												
	Alternative 3	ISTB-LD	LD-MB			26746.50	2.00	28641.68	2.53	30.50	1.00			1.00	2.00
		SEA	AIR												
		4158.00	22588.50												
		12.5d	16d												
LD-AMSD	Lowest cost	LD-ISTB	ISTB-AMSD			6618.83	2.00	8015.81	0.71	22.48	1.00			1.00	2.00
		SEA	AIR												
		2848.00	3770.83												
		17.00	3.48												
	Highest speed	LD-AMSD				27797.00	0.00	28356.23	2.50	9.00	1.00				1.00
		AIR													
		27797.00													
		9d													
	Alternative 1	LD-HMB	HMB-AMSD			27116.50	2.00	28017.49	2.47	14.50	1.00			1.00	2.00
		AIR	SEA												
		25417.00	1699.50												
		9d	3.5d												
	Alternative 2	LD-ISTB	ISTB-AMSD			6618.83	2.00	8015.81	0.71	22.48	1.00			1.00	2.00
		SEA	AIR												
		2848.00	3770.83												
		17d	3.4d												
	Alternative 3	LD-MSC	MSC-ISTB	ISTB-AMSD		11558.83	3.00	13328.63	1.18	28.48	1.00	1.00		1.00	3.00
		SEA	ROAD	AIR											
		2848.00	4940.00	3770.83											
		18.5d	3.5d	3.4d											
AMSD-LD	Lowest cost		HAMBURG			7773.00	2.00	9295.36	0.82	24.50	1.00			1.00	2.00
		AIR	SEA												
		4934.00	2839.00												
		7.00	15.50												
	Highest speed	AMSD-LD				21739.00	0.00	22298.23	1.97	9.00	1.00				1.00
		AIR													
		21739.00													
		9d													
	Alternative 1	AMSD-RM	RM-LD			23399.00	2.00	24393.19	2.15	16.00	1.00			1.00	2.00
		AIR	SEA												
		21083.50	2315.50												
		7d	7d												
	Alternative 2	AMSD-MD	MD-RM	RM-LD		26844.00	3.00	28211.01	2.49	22.00	1.00	1.00		1.00	3.00
		AIR	ROAD	SEA											
		23738.50	790.00	2315.50											
		7d	5d	7d											
	Alternative 3	AMSD-HMB	HMB-LD			7773.00	2.00	9295.36	0.82	24.50	1.00			1.00	2.00
		AIR	SEA												
		4934.00	2839.00												
		7d	15.5d												

5.1.1.2.1.2 Long distance

The optimal plans regarding long-distance for transporting ASE cargo in the Eurasia region are mostly alternatives and lowest-cost plans. Only two of them are highest-speed plans.

The highest-speed plans, as optimal plans, are both in the west-to-east region, which is from Amsterdam to Shanghai and from London to Singapore.

Table 18 Scenario 2 -Eurasia - Long distance

City pairs	Plans	Transit cities				Price-$	Delay-d	Total cost-$	Cost/kg	Total time-d	Modes				
											Air	Road	Rail	Sea	Sum
SH-AMSD	Lowest cost	SH-ISTB	ISTB-AMSD			7499.83	2.00	10667.71	0.94	50.98	1.00			1.00	2.00
		SEA	AIR												
		3729.00	3770.83												
		45.5d	3.4d												
	Highest speed	SH-HMB	HMB-AMSD			41366.50	2.00	41832.53	3.69	7.50	1.00			1.00	2.00
		AIR	SEA												
		39667.00	1699.50												
		2d	3.5d												
	Alternative 1	SH-MB	MB-AMSD			26291.50	1.00	27503.17	2.43	19.50	1.00	1.00			2.00
		ROAD	AIR												
		5959.00	20332.50												
		9d	9.5d												
	Alternative 2	SH-LD	LD-AMSD			37573.00	2.00	39095.36	3.45	24.50	1.00			1.00	2.00
		AIR	SEA												
		37030.50	542.50												
		12d	10.5d												
	Alternative 3	SH-MB	MB-HMB	HMB-AMSD		25611.00	3.00	27164.42	2.40	25.00	1.00	1.00		1.00	3.00
		ROAD	AIR	SEA											
		5959.00	17952.50	1699.50											
		9d	9.5d	3.5d											
SGP-LD	Lowest cost	SGP-RM	RM-LD			10941.50	2.00	12122.10	1.07	19.00	1.00			1.00	2.00
		AIR	SEA												
		8626.00	2315.50												
		10.00	7.00												
	Highest speed	SGP-LD				30271.50	0.00	31017.14	2.74	12.00	1.00				1.00
		AIR													
		30271.50													
		12d													
	Alternative 1	SGP-RM	RM-LD			10941.50	2.00	12122.10	1.07	19.00	1.00			1.00	2.00
		AIR	SEA												
		8626.00	2315.50												
		10d	7d												
	Alternative 2	SGP-BGD	BGD-RM	RM-LD		16900.50	3.00	18484.99	1.63	25.50	1.00	1.00		1.00	3.00
		ROAD	AIR	SEA											
		5959.00	8626.00	2315.50											
		5.5d	10d	7d											
	Alternative 3	SGP-MB	MB-RM	RM-LD		25072.00	3.00	26718.63	2.36	26.50	1.00	1.00		1.00	3.00
		ROAD	AIR	SEA											
		5959.00	16797.50	2315.50											
		7d	9.5d	7d											
TKY-HMB	Lowest cost	TKY-AMSD	AMSD-HMB			8203.00	2.00	11030.23	0.97	45.50	1.00			1.00	2.00
		SEA	AIR												
		3269.00	4934.00												
		36.5d	7d												
	Highest speed	TYK-HMB				66965.00	0.00	67399.96	5.94	7.00	1.00				1.00
		AIR													
		66965.00													
		7d													
	Alternative 1	TKY-RM	RM-HMB			34405.00	2.00	35803.08	3.16	22.50	1.00			1.00	2.00
		AIR	SEA												
		29299.00	5106.00												
		7d	13.5d												
	Alternative 2	TKY-RM	RM-MD	MD-HMB		35183.50	3.00	36954.40	3.26	28.50	1.00	1.00		1.00	3.00
		AIR	ROAD	SEA											
		29299.00	790.00	5094.50											
		7d	5d	13.5d											
	Alternative 3	TKY-SH	SH-HMB			42687.50	2.00	44551.61	3.93	30.00	1.00			1.00	2.00
		SEA	AIR												
		3020.50	39667.00												
		26d	2d												
AMSD-SH	Lowest cost	AMSD-HMB	HMB-SH			7080.00	2.00	10559.67	0.93	56.00	1.00			1.00	2.00
		AIR	SEA												
		4934.00	2146.00												
		7d	47d												
	Highest speed	AMSD-SH				36219.50	0.00	36840.87	3.25	10.00	1.00				1.00
		AIR													
		36219.50													
		10d													
	Alternative 1	AMSD-SGP	SGP-SH			32819.00	1.00	33782.12	2.98	15.50	1.00	1.00			2.00
		AIR	ROAD												
		26860.00	5959.00												
		7.5d	7d												
	Alternative 2	AMSD-MB	MB-SH			32238.00	1.00	33542.88	2.96	21.00	1.00	1.00			2.00
		AIR	ROAD												
		26279.00	5959.00												
		11d	9d												
	Alternative 3	AMSD-SGP	SGP-SH			29857.50	2.00	32063.36	2.83	35.50	1.00			1.00	2.00
		AIR	SEA												
		26860.00	2997.50												
		7.5d	26d												
LD-SGP	Lowest cost	LD-ISTB	ISTB-SGP			10585.50	2.00	15618.60	1.38	81.00	1.00			1.00	2.00
		SEA	AIR												
		2848.00	7737.50												
		17d	62d												
	Highest speed	LD-SGP				26797.00	0.00	27449.44	2.42	10.50	1.00				1.00
		AIR													
		26797.00													
		10.5d													
	Alternative 1	LD-HMB	HMB-SGP			34755.50	2.00	35718.62	3.15	15.50	1.00			1.00	2.00
		SEA	AIR												
		5067.50	29688.00												
		5.5d	8d												
	Alternative 2	LD-AMSD	AMSD-SGP			27402.50	2.00	28645.24	2.53	20.00	1.00			1.00	2.00
		SEA	AIR												
		542.50	26860.00												
		10.5d	7.5d												
	Alternative 3	LD-MB	MB-SGP			23102.50	1.00	24624.86	2.17	24.50	1.00	1.00			2.00
		AIR	ROAD												
		22588.50	514.00												
		16d	7.5d												
HMB-TKY	Lowest cost	HMB-MD	MD-RM	RM-TKY		10611.88	3.00	16875.28	1.49	100.80	1.00		1.00	1.00	3.00
		RAIL	AIR	SEA											
		5950.38	2335.00	2326.50											
		46.8d	7d	44d											
	Highest speed	HMB-TKY				44700.50	0.00	45135.46	3.98	7.00	1.00				1.00
		AIR													
		44700.50													
		7d													
	Alternative 1	HMB-RM	RM-MD	MD-TKY		35611.00	3.00	36978.01	3.26	22.00	1.00	1.00		1.00	3.00
		SEA	ROAD	AIR											
		2847.50	790.00	31973.50											
		7d	5d	7d											
	Alternative 2	HMB-MD	MD-TKY			36413.00	2.00	38059.63	3.36	26.50	1.00			1.00	2.00
		SEA	AIR												
		4439.50	31973.50												
		17.5d	7d												
	Alternative 3	HMB-ISTB	ISTB-TKY			39252.50	2.00	40899.13	3.61	26.50	1.00			1.00	2.00
		SEA	AIR												
		3656.50	35596.00												
		16d	8.5d												

One city pair's (Shanghai-Amsterdam) highest-speed plan does not utilize unimodal air transportation but rather a combination of two different transport modes to transport ASE cargos.

The highest-speed plan uses the itinerary from Shanghai to Hamburg by air at a price of $39,667, with a transit time of 2 days, and then, from Hamburg to Amsterdam by sea at q price of $1,699.5 and a time of 3.5 days. The total cost of the highest-speed plan is $27,503 and the total transport time is 7.5 days. However, the direct airline between Shanghai and Amsterdam is at a total cost of $20,375 and a time of 10 days. Even though the cost is much lower than the highest-speed plan, the transport time is 2.5 days slower.

5.1.1.2.2 North America

5.1.1.2.2.1 Short distance

The short-distance transport situation in North America is similar to that in the Eurasia region. Two highest-speed plans are chosen as optimal plans: from New Orleans to Los Angeles and from Los Angeles to New Orleans. Both are situated in the middle area of North America.

The rest of the optimal plans (red frames) are alternative plans. For example, in the eastern area, for the city pair of Montreal to New York, the optimal plan is alternative 1; the itinerary is indicated as going from Montreal to Halifax by air at a price of $9,667 and a time of 9 days, and then, from Halifax to New York by road at a price of $22,952 and a time of 14.4 days. We may deem it unreasonable to transport products by such a combination, and we may consider whether the best itinerary might be to transport goods from Montreal to New York by road only. This possible itinerary is illustrated in scenario 4, which involves ASE cargo for which air transport is not required.

Table 19 Scenario 2 -North America - Short distance

City pairs	Plans	Transit cities		Price-$	Delay-d	Total cost-$	Cost/kg	Total time-d	Modes				
									Air	Road	Rail	Sea	Sum
MTL-NYC	Lowest cost	MTL-HLF	HLF-NYC	$16,455.00	2	$19,437.58	$1.71	48.00	1	0	0	1	2
		AIR	SEA										
		$9,667.00	$6,788.00										
		$9.00	$37.00										
	Highest speed	MTL-NYC		$52,164.00	0	$52,412.55	$4.62	4.00	1	0	0	0	1
		AIR											
		$52,164.00											
		4d											
	Alternative 1	MTL-HLF	HLF-NYC	$32,619.16	1	$34,135.30	$3.01	24.40	1	1	0	0	2
		AIR	ROAD										
		$9,667.00	$22,952.16										
		9d	14.4d										
	Alternative 2	MTL-LA	LA-NYC	$43,284.16	1	$45,204.19	$3.99	30.90	1	1	0	0	2
		ROAD	AIR										
		$22,952.16	$20,332.00										
		14.4d	15.5d										
	Alternative 3	MTL-STL	STL-NYC	$43,284.16	1	$45,204.19	$3.99	30.90	1	1	0	0	2
		ROAD	AIR										
		$22,952.16	$20,332.00										
		14.4d	15.5d										
NYC-MTL	Lowest cost	NYC-VCV	VCV-MTL	$11,808.00	2	$15,474.08	$1.36	59.00	1	0	0	1	2
		SEA	AIR										
		$254.50	$11,553.50										
		$48.00	$9.00										
	Highest speed	NYC-MTL		$40,500.00	0	$40,748.55	$3.59	4.00	1	0	0	0	1
		AIR											
		$40,500.00											
		4d											
	Alternative 1	NYC-HLF	HLF-MTL	$27,487.00	1	$29,003.14	$2.56	24.40	1	1	0	0	2
		ROAD	AIR										
		$17,820.00	$9,667.00										
		14.4d	9d										
	Alternative 2	NYC-VCV	VCV-MTL	$29,373.50	1	$30,889.64	$2.72	24.40	1	1	0	0	2
		ROAD	AIR										
		$17,820.00	$11,553.50										
		14.4d	9d										
	Alternative 3	NYC-HLF	HLF-MTL	$20,892.00	2	$23,035.73	$2.03	34.50	1	0	0	1	2
		SEA	AIR										
		$11,225.00	$9,667.00										
		23.5d	9d										
NOL-LA	Lowest cost	NOL-LA		$20,387.00	0	$21,350.12	$1.88	15.50	1	0	0	0	1
		AIR											
		$20,387.00											
		15.5d											
	Highest speed	NOL-LA		$20,387.00	0	$21,350.12	$1.88	15.50	1	0	0	0	1
		AIR											
		$20,387.00											
		15.5d											
	Alternative 1	NOL-MIA	MIA-LA	$24,486.00	1	$25,853.01	$2.28	22.00	1	1	0	0	2
		ROAD	AIR										
		$4,099.00	$20,387.00										
		5.5d	15.5d										
	Alternative 2	NOL-NYC	NYC-LA	$24,486.00	1	$25,853.01	$2.28	22.00	1	1	0	0	2
		ROAD	AIR										
		$4,099.00	$20,387.00										
		5.5d	15.5d										
	Alternative 3	NOL-STL	STL-LA	$24,962.50	1	$26,329.51	$2.32	22.00	1	1	0	0	2
		AIR	ROAD										
		$20,387.00	$4,575.50										
		15.5d	5.5d										
LA-NOL	Lowest cost	LA-NOL		$20,332.00	0	$21,295.12	$1.88	15.50	1	0	0	0	1
		AIR											
		$20,332.00											
		15.5d											
	Highest speed	LA-NOL		$20,332.00	0	$21,295.12	$1.88	15.50	1	0	0	0	1
		AIR											
		$20,332.00											
		15.5d											
	Alternative 1	LA-MIA	MIA-NOL	$24,431.00	1	$25,798.01	$2.27	22.00	1	1	0	0	2
		AIR	ROAD										
		$20,332.00	$4,099.00										
		15.5d	5.5d										
	Alternative 2	LA-NYC	NYC-NOL	$24,431.00	1	$25,798.01	$2.27	22.00	1	1	0	0	2
		AIR	ROAD										
		$20,332.00	$4,099.00										
		15.5d	5.5d										
	Alternative 3	LA-STL	STL-NOL	$24,907.50	1	$26,274.51	$2.32	22.00	1	1	0	0	2
		ROAD	AIR										
		$4,575.50	$20,332.00										
		5.5d	15.5d										
VCV-STL	Lowest cost	VCV-MTL	MTL-STL	$24,594.50	1	$27,005.42	$2.38	38.80	1	0	1	0	2
		AIR	RAIL										
		$11,553.50	$13,041.00										
		9d	28.8d										
	Highest speed	VCV-STL		$52,164.00	0	$52,412.55	$4.62	4.00	1	0	0	0	1
		AIR											
		$52,164.00											
		4d											
	Alternative 1	VCV-MTL	MTL-STL	$34,505.66	1	$36,021.80	$3.18	24.40	1	1	0	0	2
		AIR	ROAD										
		$11,553.50	$22,952.16										
		9d	14.4d										
	Alternative 2	VCV-HLF	HLF-STL	$34,505.66	1	$36,021.80	$3.18	24.40	1	1	0	0	2
		AIR	ROAD										
		$11,553.50	$22,952.16										
		9d	14.4d										
	Alternative 3	VCV-NOL	NOL-STL	$43,339.16	1	$45,259.19	$3.99	30.90	1	1	0	0	2
		ROAD	AIR										
		$22,952.16	$20,387.00										
		14.4d	15.5d										
STL-VCV	Lowest cost	STL-MTL	MTL-VCV	$17,609.50	2	$20,498.87	$1.81	46.50	1	0	0	1	2
		SEA	AIR										
		$6,515.00	$11,094.50										
		$35.50	$9.00										
	Highest speed	STL-VCV		$40,500.00	0	$40,748.55	$3.59	4.00	1	0	0	0	1
		AIR											
		$40,500.00											
		4d											
	Alternative 1	STL-MTL	MTL-VCV	$28,914.50	1	$30,430.64	$2.68	24.40	1	1	0	0	2
		ROAD	AIR										
		$17,820.00	$11,094.50										
		$14.40	$9.00										
	Alternative 2	STL-HLF	HLF-VCV	$28,914.50	1	$30,430.64	$2.68	24.40	1	1	0	0	2
		ROAD	AIR										
		$17,820.00	$11,094.50										
		$14.40	$9.00										
	Alternative 3	STL-MTL	MTL-VCV	$21,219.50	1	$23,630.42	$2.08	38.80	1	0	1	0	2
		RAIL	AIR										
		$10,125.00	$11,094.50										
		$28.80	$9.00										

5.1.1.2.2.2 Long distance

The long-distance outcomes are similar to those of the short-distance optimal plans. Two of the six city pairs adopt highest-speed plans as their best itineraries. The rest of them utilize alternative plans as their optimal solutions.

The two city pairs that choose highest speed as their optimal plans are New York-Seattle and Seattle-New York. We compare the result to the result of scenario 1—AKE cargo with air. The difference is that in scenario 1, from Seattle to New York, the optimal plan chosen out of the five options was the lowest-cost plan—travel from Seattle to New York by air only—however, the highest-speed plan was to travel from Seattle to Vancouver by rail, and then fly to New York from Vancouver. The lowest-cost plan and the highest-speed plan use different itineraries. However, in scenario 2—ASE cargo with air—the lowest-cost plan and the highest-speed plan are the same: to transport goods from Seattle to New York by air.

Table 20. Scenario 2: North America—short distance

City pairs	Plans	Transit cities				Price-$	Delay-d	Total cost-$	Cost/kg	Total time-d	Modes				
											Air	Road	Rail	Sea	Sum
MTL-LA	Lowest cost	MTL-HLF	HLF-LA			$22,708.00	1	$25,118.92	$2.22	38.80	1	0	1	0	2
		AIR	RAIL												
		$9,667.00	$13,041.00												
		9d	28.8d												
	Highest speed	MTL-LA				$52,164.00	0	$52,412.55	$4.62	4.00	1	0	0	0	1
		AIR													
		$52,164.00													
		4d													
	Alternative 1	MTL-HLF	HLF-LA			$32,619.16	1	$34,135.30	$3.01	24.40	1	1	0	0	2
		AIR	ROAD												
		$9,667.00	$22,952.16												
		9d	14.4d												
	Alternative 2	MTL-VCV	VCV-LA			$34,046.66	1	$35,562.80	$3.14	24.40	1	1	0	0	2
		AIR	ROAD												
		$11,094.50	$22,952.16												
		9d	14.4d												
	Alternative 3	MTL-MIA	MIA-LA			$43,339.16	1	$45,259.19	$3.99	30.90	1	1	0	0	2
		ROAD	AIR												
		$22,952.16	$20,387.00												
		14.4d	15.5d												
MIA-VCV	Lowest cost	MIA-MTL	MTL-VCV			$15,010.00	2	$17,557.62	$1.55	41.00	1	0	0	1	2
		SEA	AIR												
		$3,915.50	$11,094.50												
		30d	9d												
	Highest speed	MIA-VCV				$40,500.00	0	$40,748.55	$3.59	4.00	1	0	0	0	1
		AIR													
		$40,500.00													
		4d													
	Alternative 1	MIA-HLF	HLF-VCV			$28,914.50	1	$30,430.64	$2.68	24.40	1	1	0	0	2
		ROAD	AIR												
		$17,820.00	$11,094.50												
		14.4d	9d												
	Alternative 2	MIA-MTL	MTL-VCV			$28,914.50	1	$30,430.64	$2.68	24.40	1	1	0	0	2
		ROAD	AIR												
		$17,820.00	$11,094.50												
		14.4d	9d												
	Alternative 3	MIA-HLF	HLF-VCV			$22,319.50	2	$24,463.23	$2.16	34.50	1	0	0	1	2
		SEA	AIR												
		$11,225.00	$11,094.50												
		23.5d	9d												
NYC-STL	Lowest cost	NYC-STL				$20,387.00	0	$21,350.12	$1.88	15.50	1	0	0	0	1
		AIR													
		$20,387.00													
		15d													
	Highest speed	NYC-STL				$20,387.00	0	$21,350.12	$1.88	15.50	1	0	0	0	1
		AIR													
		$20,387.00													
		15d													
	Alternative 1	NYC-NOL	NOL-STL			$24,486.00	1	$25,853.01	$2.28	22.00	1	1	0	0	2
		ROAD	AIR												
		$4,099.00	$20,387.00												
		5.5d	15.5d												
	Alternative 2	NYC-MIA	MIA-STL			$24,486.00	1	$25,853.01	$2.28	22.00	1	1	0	0	2
		ROAD	AIR												
		$4,099.00	$20,387.00												
		5.5d	15.5d												
	Alternative 3	NYV-LA	LA-STL			$24,962.50	1	$26,329.51	$2.32	22.00	1	1	0	0	2
		AIR	ROAD												
		$20,387.00	$4,575.50												
		15.5d	5.5d												
LA-MTL	Lowest cost	LA-VCV	VCV-MTL			$16,413.50	2	$18,488.88	$1.63	33.40	1	0	0	1	2
		SEA	AIR												
		$4,860.00	$11,553.50												
		22.4d	9d												
	Highest speed	LA-MTL				$40,500.00	0	$40,748.55	$3.59	4.00	1	0	0	0	1
		AIR													
		$40,500.00													
		4d													
	Alternative 1	LA-HLF	HLF-MTL			$27,487.00	1	$29,003.14	$2.56	24.40	1	1	0	0	2
		ROAD	AIR												
		$17,820.00	$9,667.00												
		14.4d	9d												
	Alternative 2	LA-VCV	VCV-MTL			$29,373.50	1	$30,889.64	$2.72	24.40	1	1	0	0	2
		ROAD	AIR												
		$17,820.00	$11,553.50												
		14.4d	9d												
	Alternative 3	LA-MIA	MIA-MTL			$38,152.00	1	$40,072.03	$3.53	30.90	1	1	0	0	2
		AIR	ROAD												
		$20,332.00	$17,820.00												
		15.5d	14.4d												
VCV-MIA	Lowest cost	VCV-MTL	MTL-MIA			$15,467.50	2	$18,015.12	$1.59	41.00	1	0	0	1	2
		AIR	SEA												
		$11,553.50	$3,914.00												
		9d	30d												
	Highest speed	VCV-MIA				$52,164.00	0	$52,412.55	$4.62	4.00	1	0	0	0	1
		AIR													
		$52,164.00													
		4d													
	Alternative 1	VCV-HLF	HLF-MIA			$34,505.66	1	$36,021.80	$3.18	24.40	1	1	0	0	2
		AIR	ROAD												
		$11,553.50	$22,952.16												
		9d	14.4d												
	Alternative 2	VCV-MTL	MTL-MIA			$34,505.66	1	$36,021.80	$3.18	24.40	1	1	0	0	2
		AIR	ROAD												
		$11,553.50	$22,952.16												
		9d	14.4d												
	Alternative 3	VCV-HLF	HLF-MIA			$24,594.50	1	$27,005.42	$2.38	38.80	1	0	1	0	2
		AIR	RAIL												
		$11,553.50	$13,041.00												
		9d	28.8d												
STL-NYC	Lowest cost	STL-NYC				$20,332.00	0	$21,295.12	$1.88	15.50	1	0	0	0	1
		AIR													
		$20,332.00													
		15.5d													
	Highest speed	STL-NYC				$20,332.00	0	$21,295.12	$1.88	15.50	1	0	0	0	1
		AIR													
		$20,332.00													
		15.5d													
	Alternative 1	STL-NOL	NOL-NYC			$24,431.00	1	$25,798.01	$2.27	22.00	1	1	0	0	2
		AIR	ROAD												
		$20,332.00	$4,099.00												
		$15.50	$5.50												
	Alternative 2	STL-MIA	MIA-NYC			$24,431.00	1	$25,798.01	$2.27	22.00	1	1	0	0	2
		AIR	ROAD												
		$20,332.00	$4,099.00												
		$15.50	$5.50												
	Alternative 3	STL-LA	LA-NYC			$24,907.50	1	$26,274.51	$2.32	22.00	1	1	0	0	2
		ROAD	AIR												
		$4,575.50	$20,332.00												
		$5.50	$15.50												

5.1.1.2.3 Eurasia, North America, and Africa

5.1.1.2.3.1 Long distance

The situation in Eurasia, North America, and Africa's cross-continent transportation is slightly different from that in the AKE cargo scenario. In scenario 1, two of the optimal plans are highest-speed plans. However, in scenario 2, all optimal plans between city pairs are either lowest-cost plans or alternative plans.

The reason they do not choose highest-speed plans as their optimal plans is that highest-speed plans in the first scenario are all transported by air, and the price to transport them by air is high. Furthermore, since the product value is relatively low, the product holding cost during the transport time and delay time is not that significant, and we thus choose other alternative plans and lowest-cost plans to reduce the total transport cost and to maintain a relatively high transport speed.

Table 21. Scenario 2: Eurasia, North America, and Africa—long distance

City pairs	Plans	Transit cities				Price-$	Delay-d	Total cost-$	Cost/kg	Total time-d	Modes				
											Air	Road	Rail	Sea	Sum
SH-MTL	Lowest cost	SH-SGP	SGP-RM	RM-MTL		$12,399.50	3	$14,916.05	$1.32	40.50	1	1	0	1	3
		ROAD	AIR	SEA											
		$1,058.50	$8,626.00	$2,715.00											
		7d	10d	20.5d											
	Highest speed	SH-MTL				$62,484.50	0	$63,230.14	$5.58	12.00	1	0	0	0	1
		AIR													
		$62,484.50													
		12d													
	Alternative 1	SH-VCV	VCV-MTL			$36,243.50	1	$37,113.42	$3.27	14.00	1	1	0	0	2
		AIR	ROAD												
		$34,241.00	$2,002.50												
		6d	7d												
	Alternative 2	SH-MB	MB-MTL			$34,568.50	1	$35,873.38	$3.16	21.00	1	1	0	0	2
		ROAD	AIR												
		$5,959.00	$28,609.50												
		9d	11d												
	Alternative 3	SH-HMB	HMB-MTL			$43,005.00	2	$44,372.01	$3.91	22.00	1	0	0	1	2
		AIR	SEA												
		$39,667.00	$3,338.00												
		2d	18d												
SGP-LA	Lowest cost	SGP-RM	RM-LA			$15,578.50	2	$19,337.79	$1.71	60.50	1	0	0	1	2
		AIR	SEA												
		$8,626.00	$6,952.50												
		10d	48.5d												
	Highest speed	SGP-LA				$43,298.00	0	$43,813.96	$3.86	8.30	1	0	0	0	1
		AIR													
		$43,298.00													
		8.3d													
	Alternative 1	SGP-MB	MB-LA			$38,785.00	1	$39,530.64	$3.49	12.00	1	1	0	0	2
		ROAD	AIR												
		$5,959.00	$32,826.00												
		7d	4d												
	Alternative 2	SGP=HMB	HMB-LA			$34,923.00	2	$36,880.32	$3.25	31.50	1	0	0	1	2
		SEA	AIR												
		$2,831.00	$32,092.00												
		25.5d	4d												
	Alternative 3	SGP-RM	RM-LA			$33,765.50	2	$35,753.88	$3.15	32.00	1	0	0	1	2
		SEA	AIR												
		$1,673.50	$32,092.00												
		26d	4d												
MTL-SH	Lowest cost	MTL-HLF	HLF-SH			$15,784.00	2	$19,201.53	$1.69	55.00	1	0	0	1	2
		AIR	SEA												
		$9,667.00	$6,117.00												
		9d	44d												
	Highest speed	MTL-SH				$34,349.00	0	$35,063.58	$3.09	11.50	1	0	0	0	1
		AIR													
		$34,349.00													
		11.5d													
	Alternative 1	MTL-HLF	HLF-SH			$37,587.50	1	$38,550.62	$3.40	15.50	1	1	0	0	2
		ROAD	AIR												
		$3,238.50	$34,349.00												
		3d	11.5d												
	Alternative 2	MTL-SGP	SGP-SH			$29,833.00	1	$30,858.26	$2.72	16.50	1	1	0	0	2
		AIR	ROAD												
		$23,874.00	$5,959.00												
		8.5d	7d												
	Alternative 3	MTL-SGP	SGP-SH			$26,871.50	2	$29,139.50	$2.57	36.50	1	0	0	1	2
		AIR	SEA												
		$23,874.00	$2,997.50												
		8.5d	26d												
LA-SGP	Lowest cost	LA-MB	MB-SGP			$12,429.00	1	$13,174.64	$1.16	12.00	1	1	0	0	2
		AIR	ROAD												
		$11,915.00	$514.00												
		3.5d	7.5d												
	Highest speed	LA-SGP				$20,482.00	0	$20,699.48	$1.83	3.50	1	0	0	0	1
		AIR													
		$20,482.00													
		3.5d													
	Alternative 1	LA-BGD	BGD-SGP			$29,990.00	1	$30,611.37	$2.70	10.00	1	1	0	0	2
		AIR	ROAD												
		$29,554.00	$436.00												
		3.5d	5.5d												
	Alternative 2	LA-NYC	NYC-SGP			$29,233.00	1	$29,978.64	$2.64	12.00	1	1	0	0	2
		ROAD	AIR												
		$8,751.00	$20,482.00												
		7.5d	3.5d												
	Alternative 3	LA-MB	MB-SGP			$13,060.50	2	$14,644.99	$1.29	25.50	1	0	0	1	2
		AIR	SEA												
		$11,915.00	$1,145.50												
		3.5d	20d												

5.1.1.3 Scenario 3. AKE—air not required (AKE cargo, 4.3 Cu.M, 1,588 kg)

This section introduces a scenario for the transportation of one small cargo with all possible situations in which the air mode is not required, for example, the combination of road and rail in the two-mode combination, and to transport from origins to destinations by road only, which means that the air transport mode is no longer a necessary option.

5.1.1.3.1 Eurasia

5.1.1.3.1.1 Short distance

In this section, we can see that there are only two best solutions from the highest-speed plans. The rest are lowest-cost plans and alternative plans. The situation is different from that of scenario 1—AKE with air, where optimal plans were almost all highest-speed plans.

For example, when we compare the optimal plan for the Shanghai-to-Singapore city pair to the highest-speed plan, we find that the best itinerary is from Shanghai to Singapore by road, with a price of $64 and a transit time of 10 days; the total cost of $151.01 and the total transport time of 10 days are because there is no delay/modal transfer time. However, the highest-speed plan is from Shanghai to Singapore by air at a price of $1,657.56 and a speed of 6.5 days. We find that even though the speed of the optimal plan is 3.5 days slower than that of the highest-speed plan, the total cost is $1,505.05 lower.

Table 22 Scenario 3 - Eurasia - Short distance

City pairs	Plans	Transit cities				Price-$	Delay-d	Total cost-$	Cost/kg	Total time-d	Modes				
											Air	Road	Rail	Sea	Sum
SH-SGP	Lowest cost	SH-SGP				64.00		151.01	0.10	10.00	0.00	1.00	0.00	0.00	1.00
		ROAD													
		64.00													
		10d													
	Highest speed	SH-SGP				1601.00	0.00	1657.56	1.04	6.50	1.00	0.00	0.00	0.00	1.00
		AIR													
		1601.00													
		6.5d													
	Alternative 1	SH-SGP				147.00	0.00	299.27	0.19	17.50	0.00	0.00	0.00	1.00	1.00
		SEA													
		147.00													
		17.50													
	Alternative 2	SH-BGD	BGD-SGP			1168.00	2.00	1402.94	0.88	27.00	0.00	1.00	0.00	1.00	2.00
		ROAD	SEA												
		825.00	343.00												
		6.00	19.00												
	Alternative 3	SH-BGD	BGD-SGP			413.50	2.00	674.54	0.42	30.00	0.00	1.00	0.00	1.00	2.00
		SEA	ROAD												
		358.00	55.50												
		22.50	5.50												
SGP-SH	Lowest cost	SGP-SH				366.38		804.92	0.51	50.40	0.00	0.00	1.00	0.00	1.00
		RAIL													
		366.38													
		50.4d													
	Highest speed	SGP-SH				1465.50	0.00	1526.41	0.96	7.00	1.00	0.00	0.00	0.00	1.00
		AIR													
		1465.50													
		7d													
	Alternative 1	SGP-SH				822.00	0.00	882.91	0.56	7.00	0.00	1.00	0.00	0.00	1.00
		ROAD													
		822.00													
		7d													
	Alternative 2	SGP-BGD	BGD-SH			1338.00	2.00	1529.43	0.96	22.00	0.00	1.00	0.00	1.00	2.00
		SEA	ROAD												
		516.00	822.00												
		14d	6d												
	Alternative 3	SGP-MB	MB-SH			1642.50	1.00	1870.73	1.18	26.23	0.00	1.00	1.00	0.00	2.00
		RAIL	ROAD												
		820.50	822.00												
		16.2d	9d												
MB-ISTB	Lowest cost	MB-ISTB				829.00		1181.41	0.74	40.50	0.00	0.00	0.00	1.00	1.00
		SEA													
		829.00													
		40.50													
	Highest speed	MB-ISTB				4577.00	0.00	4668.36	2.94	10.50	1.00	0.00	0.00	0.00	1.00
		AIR													
		4577.00													
		10.5d													
	Alternative 1	MB-ISTB				1144.25		1269.59	0.80	14.40	0.00	0.00	1.00	0.00	1.00
		RAIL													
		1144.25													
		14.4d													
	Alternative 2	MB-MSC	MSC-ISTB			2484.50	1.00	2628.22	1.66	16.52	0.00	1.00	1.00	0.00	2.00
		ROAD	RAIL												
		825.00	1659.50												
		9d	6.5d												
	Alternative 3	MB-MSC	MSC-ISTB			1628.00	2.00	1802.03	1.13	20.00	0.00	1.00	0.00	1.00	2.00
		ROAD	SEA												
		825.00	803.00												
		9d	9d												
ISTB-MB	Lowest cost	ISTB-MB				970.75	0.00	1096.09	0.69	14.40	0.00	0.00	1.00	0.00	1.00
		RAIL													
		970.75													
		14d													
	Highest speed	ISTB-MB				3883.00	0.00	3983.07	2.51	11.50	1.00	0.00	0.00	0.00	1.00
		AIR													
		3883.00													
		11.5d													
	Alternative 1	ISTB-BGD	BGD-MB			4598.00	1.00	4732.87	2.98	15.50	1.00	1.00	0.00	0.00	2.00
		AIR	ROAD												
		3776.00	822.00												
		9.5d	5d												
	Alternative 2	ISTB-SH	SH-MB			4480.50	1.00	4650.18	2.93	19.50	1.00	1.00	0.00	0.00	2.00
		AIR	ROAD												
		3655.50	825.00												
		9.5d	9d												
	Alternative 3	ISTB-MSC	MSC-MB			4720.00	2.00	4898.38	3.08	20.50	1.00	0.00	0.00	1.00	2.00
		SEA	AIR												
		713.00	4007.00												
		6.5d	12d												
LD-AMSD	Lowest cost	LD-MSC	MSC-AMSD			235.63	2.00	396.17	0.25	18.45	0.00	0.00	1.00	1.00	2.00
		RAIL	SEA												
		131.13	104.50												
		7.45d	9d												
	Highest speed	LD-AMSD				698.63	0.00	710.73	0.45	1.39	0.00	0.00	1.00	0.00	1.00
		RAIL													
		698.63													
		1.39d													
	Alternative 1	LD-HMB	HMB-AMSD			1301.88	2.00	1374.97	0.87	8.40	0.00	0.00	1.00	1.00	2.00
		RAIL	SEA												
		1005.38	296.50												
		2.4d	4d												
	Alternative 2	LD-HMB	HMB-AMSD			1715.13	2.00	1794.02	1.13	9.07	0.00	0.00	1.00	1.00	2.00
		SEA	RAIL												
		850.50	864.63												
		6d	1.06d												
	Alternative 3	LD-MSC	MSC-AMSD			1109.47	1.00	1200.39	0.76	10.45	0.00	1.00	1.00	0.00	2.00
		RAIL	ROAD												
		131.13	978.34												
		7.45d	2d												
AMSD-LD	Lowest cost	AMSD-LD				275.50	0.00	327.71	0.21	6.00	0.00	0.00	0.00	1.00	1.00
		SEA													
		275.50													
		6d													
	Highest speed	AMSD-LD				716.25	0.00	725.13	0.46	1.02	0.00	0.00	1.00	0.00	1.00
		RAIL													
		716.25													
		1.02d													
	Alternative 1	AMSD-HMB	HMB-LD			1538.38	2.00	1595.59	1.00	6.58	0.00	0.00	1.00	1.00	2.00
		SEA	RAIL												
		590.50	947.88												
		2.5d	2.07d												
	Alternative 2	AMSD-LD				2865.00	0.00	2943.31	1.85	9.00	1.00	0.00	0.00	0.00	1.00
		AIR													
		2865.00													
		9d													
	Alternative 3	AMSD-HMB	HMB-LD			1114.88	2.00	1211.17	0.76	11.07	0.00	0.00	1.00	1.00	2.00
		RAIL	SEA												
		794.88	320.00												
		1.06d	8d												

5.1.1.3.1.2 Long distance

In the long-distance section in the Eurasia region, transporting one AKE cargo with no air mode participation, we can observe similar results to those in scenario 1—AKE with air. Two of the optimal plans involve transport by air only; the rest of them are lowest-cost and alternative plans.

However, there is one difference between the short-distance and long-distance transportation in this scenario. All the optimal plans for long-distance sections include an air transport mode, which indicates that the scenario of AKE with air involvement and the scenario of AKE without an air mode demonstrate similar results.

Nevertheless, the short-distance city pairs' optimal plans can have some optimal solutions without an air transport mode, as demonstrated in the previous section.

Table 23 Scenario 3 - Eurasia - Long distance

City pairs	Plans	Transit cities				Price-$	Delay-d	Total cost-$	Cost/kg	Total time-d	Modes				
											Air	Road	Rail	Sea	Sum
SH-AMSD	Lowest cost	SH-AMSD				226.50	0.00	570.20	0.36	39.50	0.00	0.00	0.00	1.00	1.00
		SEA													
		226.50													
		39.5d													
	Highest speed	SH-AMSD				11934.00	0.00	11999.26	7.56	7.50	1.00	0.00	0.00	0.00	1.00
		AIR													
		11934.00													
		7.5d													
	Alternative 1	SH-BGD	BGD-AMSD			3555.50	1.00	3677.32	2.32	14.00	1.00	1.00	0.00	0.00	2.00
		ROAD	AIR												
		825.00	2730.50												
		6d	7d												
	Alternative 2	SH-BGD	BGD-HMB	HMB-AMSD		5395.63	2.00	5535.43	3.49	16.07	1.00	1.00	1.00	0.00	3.00
		ROAD	AIR	RAIL											
		825.00	3706.00	864.63											
		6d	7d	1.06d											
	Alternative 3	SH-SGP	SGP-AMSD			6177.50	1.00	6334.12	3.99	18.00	1.00	1.00	0.00	0.00	2.00
		ROAD	AIR												
		64.00	6113.50												
		10d	7d												
SGP-LD	Lowest cost	SGP-LD				420.00	0.00	663.64	0.42	28.00	0.00	0.00	0.00	1.00	1.00
		SEA													
		420.00													
		28d													
	Highest speed	SGP-AMSD	AMSD-LD			6829.75	1.00	6908.24	4.35	9.02	1.00	0.00	1.00	0.00	2.00
		AIR	RAIL												
		6113.50	716.25												
		7d	1.02d												
	Alternative 1	SGP-HMB	HMB-LD			5537.38	1.00	5625.04	3.54	10.08	1.00	0.00	1.00	0.00	2.00
		AIR	RAIL												
		4589.50	947.88												
		7d	2.07d												
	Alternative 2	SGP-AMSD	AMSD-LD			6389.00	2.00	6519.52	4.11	15.00	1.00	0.00	0.00	1.00	2.00
		AIR	SEA												
		6113.50	275.50												
		7d	6d												
	Alternative 3	SGP-BGD	BGD-AMSD	AMSD-LD		4268.75	2.00	4403.80	2.77	15.52	1.00	1.00	1.00	0.00	3.00
		ROAD	AIR	RAIL											
		822.00	2730.50	716.25											
		5.5d	7d	1.02d											
TKY-HMB	Lowest cost	TKY-HMB				808.50	0.00	1143.50	0.72	38.50	0.00	0.00	0.00	1.00	1.00
		SEA													
		808.50													
		38.5d													
	Highest speed	TKY-HMB				4448.50	0.00	4509.41	2.84	7.00	1.00	0.00	0.00	0.00	1.00
		AIR													
		4448.50													
		7d													
	Alternative 1	TKY-AMSD	AMSD-HMB			3140.88	1.00	3219.77	2.03	9.07	1.00	0.00	1.00	0.00	2.00
		AIR	RAIL												
		2346.00	794.88												
		7d	1.06d												
	Alternative 2	TKY-AMSD	AMSD-HMB			2936.50	2.00	3036.57	1.91	11.50	1.00	0.00	0.00	1.00	2.00
		AIR	SEA												
		2346.00	590.50												
		7d	2.5d												
	Alternative 3	TKY-AMSD	AMSD-LD	LD-HMB		3912.75	3.00	4060.85	2.56	17.02	1.00	0.00	1.00	1.00	3.00
		AIR	RAIL	SEA											
		2346.00	716.25	850.50											
		7d	1.02d	6d											
AMSD-SH	Lowest cost	AMSD-SH				352.63	0.00	791.17	0.50	50.40	0.00	0.00	1.00	0.00	1.00
		RAIL													
		352.63													
		50.4d													
	Highest speed	AMSD-SH				1410.50	0.00	1471.41	0.93	7.00	1.00	0.00	0.00	0.00	1.00
		AIR													
		1410.50													
		7d													
	Alternative 1	AMSD-HMB	HMB-SH			2049.88	1.00	2128.77	1.34	9.07	1.00	0.00	1.00	0.00	2.00
		RAIL	AIR												
		794.88	1255.00												
		1.07d	7d												
	Alternative 2	AMSD-LD	LD-SH			1434.25	1.00	1530.15	0.96	11.02	1.00	0.00	1.00	0.00	2.00
		RAIL	AIR												
		716.25	718.00												
		1.02d	9d												
	Alternative 3	AMSD-HMB	HMB-SH			1845.50	2.00	1945.57	1.23	11.50	1.00	0.00	0.00	1.00	2.00
		SEA	AIR												
		590.50	1255.00												
		2.5d	7d												
LD-SGP	Lowest cost	LD-MSC	MSC-SGP			230.63	2.00	669.61	0.42	50.45	0.00	0.00	1.00	1.00	2.00
		RAIL	SEA												
		131.13	99.50												
		7.45d	41d												
	Highest speed	LD-MD	MD-SGP			4037.25	1.00	4162.91	2.62	14.44	1.00	0.00	1.00	0.00	2.00
		RAIL	AIR												
		478.25	3559.00												
		4.4d	9d												
	Alternative 1	LD-BGD	BGD-SGP			1604.00	1.00	1738.87	1.10	15.50	1.00	1.00	0.00	0.00	2.00
		AIR	ROAD												
		1548.50	55.50												
		9d	5.5d												
	Alternative 2	LD-SH	SH-SGP			782.00	1.00	956.03	0.60	20.00	1.00	1.00	0.00	0.00	2.00
		AIR	ROAD												
		718.00	64.00												
		9d	10d												
	Alternative 3	LD-AMSD	AMSD-SH	SH-SGP		2173.13	2.00	2350.56	1.48	20.39	1.00	1.00	1.00	0.00	3.00
		RAIL	AIR	ROAD											
		698.63	1410.50	64.00											
		1.39d	7d	10d											
HMB-TKY	Lowest cost	HMB-TKY				588.50	0.00	1023.57	0.64	50.00	0.00	0.00	0.00	1.00	1.00
		SEA													
		588.50													
		50d													
	Highest speed	HMB-TKY				3502.00	0.00	3562.91	2.24	7.00	1.00	0.00	0.00	0.00	1.00
		AIR													
		3502.00													
		7d													
	Alternative 1	HMB-AMSD	AMSD-TKY			5367.13	1.00	5450.37	3.43	9.57	1.00	0.00	1.00	0.00	2.00
		RAIL	AIR												
		864.63	4502.50												
		1.06d	7.5d												
	Alternative 2	HMB-MSC	MSC-TKY			3209.63	1.00	3337.25	2.10	14.67	1.00	0.00	1.00	0.00	2.00
		RAIL	AIR												
		1366.13	1843.50												
		5.16d	8.5d												
	Alternative 3	HMB-SH	SH-TKY			1857.50	2.00	2040.23	1.28	21.00	1.00	0.00	0.00	1.00	2.00
		AIR	SEA												
		1255.00	602.50												
		7d	12d												

5.1.1.3.2 North America

5.1.1.3.2.1 Short distance

In North America, to transport one AKE cargo in a situation where an air mode is not necessary, we can see that five of the six city pairs use the highest-speed plan as their optimal plan, and only one city pair, New Orleans-Los Angeles, chooses the lowest-cost plan as the optimal plan.

However, a deeper look at the table reveals that most of the highest-speed plans are not air only. For example, the Montreal-New York city pair's highest-speed plan is to transport goods from Montreal to New York by rail at a price of $1,826 and a speed of 2.48 days, compared to the transport mode of air only, which costs $7,304 and has a total transport time of 4 days. So, the new highest-speed plan without air mode participation is much better than the plan with an air mode only.

The Vancouver-to-Seattle city pair is another example; the itinerary is to travel from Vancouver to Seattle by rail only, at a total cost of $1,831.18 and total transport time of 0.6 days, whereas with the air-only transport mode, the total cost can be $7,334, and the total transport time is 4 days. To conclude, transporting goods by rail in North America is much more advantageous than transporting them by air or combinations of transport modes.

Table 24 Scenario 3 - North America - Short distance

City pairs	Plans	Transit cities				Price-$	Delay-d	Total cost-$	Cost/kg	Total time-d	Modes				
											Air	Road	Rail	Sea	Sum
MTL-NYC	Lowest cost	MTL-NYC SEA 285.00 30d				285.00		546.04	0.34	30.00	0.00	0.00	0.00	1.00	1.00
	Highest speed	MTL-NYC RAIL 1826.00 2.48d				1826.00		1847.61	1.16	2.48	0.00	0.00	1.00	0.00	1.00
	Alternative 1	MTL-HLF ROAD 710.50 3d	HLF-NYC RAIL 1826.00 3.61d			2536.50	1.00	2602.74	1.64	7.61	0.00	1.00	1.00	0.00	2.00
	Alternative 2	MTL-HLF AIR 1977.50 7d	HLF-NYC RAIL 1826.00 3.61d			3803.50	1.00	3904.54	2.46	11.61	1.00	0.00	1.00	0.00	2.00
	Alternative 3	MTL-NYC ROAD 3213.76 14.4d				3213.76	0.00	3339.06	2.10	14.40	0.00	1.00	0.00	0.00	1.00
NYC-MTL	Lowest cost	NYC-MTL RAIL 229.50 1.54d				229.50	0.00	242.91	0.15	1.54	0.00	0.00	1.00	0.00	1.00
	Highest speed	NYC-MTL RAIL 229.50 1.54d				229.50	0.00	242.91	0.15	1.54	0.00	0.00	1.00	0.00	1.00
	Alternative 1	NYC-HLF RAIL 485.50 3.6d	HLF-MTL ROAD 710.00 3d			1195.50	1.00	1261.70	0.79	7.61	0.00	1.00	1.00	0.00	2.00
	Alternative 2	NYC-MTL ROAD 403.92 10.8d				403.92	0.00	497.89	0.31	10.80	0.00	1.00	0.00	0.00	1.00
	Alternative 3	NYC-NOL ROAD 717.50 5.5d	NOL-MTL RAIL 383.75 6.75d			1101.25	1.00	1216.62	0.77	13.26	0.00	1.00	1.00	0.00	2.00
NOL-LA	Lowest cost	NOL-LA ROAD 752.00 5.5d				752.00		799.86	0.50	5.50	0.00	1.00	0.00	0.00	1.00
	Highest speed	NOL-LA AIR 1161.00 4d				1161.00	0.00	1195.81	0.75	4.00	1.00	0.00	0.00	0.00	1.00
	Alternative 1	NOL-LA RAIL 840.50 7.8d				840.50		909.10	0.57	7.88	0.00	0.00	1.00	0.00	1.00
	Alternative 2	NOL-STL AIR 1323.00 5d	STL-LA RAIL 550.50 4.7d			1873.50	1.00	1966.93	1.24	10.74	1.00	0.00	1.00	0.00	2.00
	Alternative 3	NOL-STL ROAD 1366.00 5.5d	STL-LA RAIL 550.50 4.7d			1916.50	1.00	2014.28	1.27	11.24	0.00	1.00	1.00	0.00	2.00
LA-NOL	Lowest cost	LA-NOL SEA 409.50 38d				409.50	0.00	740.15	0.47	38.00	0.00	0.00	0.00	1.00	1.00
	Highest speed	LA-NOL AIR 865.00 4d				865.00	0.00	899.81	0.57	4.00	1.00	0.00	0.00	0.00	1.00
	Alternative 1	LA-NOL ROAD 1366.00 5.5d				1366.00	0.00	1413.86	0.89	5.50	0.00	1.00	0.00	0.00	1.00
	Alternative 2	LA-NOL RAIL 1083.00 7.89d				1083.00	0.00	1151.67	0.73	7.89	0.00	0.00	1.00	0.00	1.00
	Alternative 3	LA-MIA AIR 1103.00 5d	MIA-NOL RAIL 471.00 3.6d			1574.00	1.00	1657.61	1.04	9.61	1.00	0.00	1.00	0.00	2.00
VCV-STL	Lowest cost	VCV-STL SEA 413.50 96d				413.50	0.00	1248.83	0.79	96.00	0.00	0.00	0.00	1.00	1.00
	Highest speed	VCV-STL RAIL 1826.00 0.6d				1826.00	0.00	1831.18	1.15	0.60	0.00	0.00	1.00	0.00	1.00
	Alternative 1	VCV-LA RAIL 1826.00 5.3d	LA-STL AIR 755.00 2d			2581.00	1.00	2653.51	1.67	8.33	1.00	0.00	1.00	0.00	2.00
	Alternative 2	VCV-LA RAIL 1826.00 5.3d	LA-STL ROAD 742.00 5.5d			2568.00	1.00	2670.97	1.68	11.83	0.00	1.00	1.00	0.00	2.00
	Alternative 3	VCV-HLF ROAD 281.00 8d	HLF-STL AIR 7304.00 4d			7585.00	1.00	7698.12	4.85	13.00	1.00	1.00	0.00	0.00	2.00
STL-VCV	Lowest cost	STL-VCV RAIL 137.00 0.6d				137.00		142.18	0.09	0.60	0.00	0.00	1.00	0.00	1.00
	Highest speed	STL-VCV RAIL 137.00 0.6d				137.00		142.18	0.09	0.60	0.00	0.00	1.00	0.00	1.00
	Alternative 1	STL-VCV ROAD 241.12 7.2d				241.12	0.00	303.77	0.19	7.20	0.00	1.00	0.00	0.00	1.00
	Alternative 2	STL-LA AIR 631.00 2d	LA-VCV RAIL 1417.75 5.32d			2048.75	1.00	2121.15	1.34	8.32	1.00	0.00	1.00	0.00	2.00
	Alternative 3	STL-VCV SEA 229.50 10d				229.50	0.00	316.51	0.20	10.00	0.00	0.00	0.00	1.00	1.00

5.1.1.3.2.2 Long Distance

The long-distance situation in North America is different from that in Eurasia. Three out of six city pairs in North America use a transport combination without air as their optimal plans. For example, for the Montreal-Los Angeles city pair, we can see from the table below that the optimal plan is alternative 1, in which the itinerary is to travel from Montreal to New York by rail at a price of $1,826 and a time of 2.4 days, and then, to transfer to road transport from New York to Los Angeles at a price of $905.5 and a time of 7.5 days. Compared to the optimal plan of such a city pair in AKE—with air—goods were transported from Montreal to Vancouver by road, then, from Vancouver to Seattle by rail, and finally, from Seattle to Los Angeles by air, with a total cost of $2,954.9 and a total transport time of 11.6 days.

Table 25 Scenario 3 - North America - Long distance

City pairs	Plans	Transit cities				Price-$	Delay-d	Total cost-$	Cost/kg	Total time-d	Modes				
											Air	Road	Rail	Sea	Sum
MTL-LA	Lowest cost	MTL-LA SEA 249.00 29d				249.00	0.00	501.34	0.32	29.00	0.00	0.00	0.00	1.00	1.00
	Highest speed	MTL-LA AIR 7304.00 4d				7304.00	0.00	7338.81	4.62	4.00	1.00	0.00	0.00	0.00	1.00
	Alternative 1	MTL-NYC RAIL 1826.00 2.4d	MYC-LA ROAD 905.50 7.5d			2731.50	1.00	2827.07	1.78	10.98	0.00	1.00	1.00	0.00	2.00
	Alternative 2	MTL-VCV ROAD 397.00 7d	VCV-STL RAIL 1826.00 0.59d	STL-LA AIR 631.00 2d		2854.00	2.00	2954.90	1.86	11.60	1.00	1.00	1.00	0.00	3.00
	Alternative 3	MTL-VCV ROAD 397.00 7d	VCV-LA RAIL 1826.00 5.33d			2223.00	1.00	2339.02	1.47	13.33	0.00	1.00	1.00	0.00	2.00
MIA-VCV	Lowest cost	MIA-VCV SEA 59.00 47d				59.00	0.00	467.96	0.29	47.00	0.00	0.00	0.00	1.00	1.00
	Highest speed	MIA-VCV AIR 1849.00 6d				1849.00	0.00	1901.21	1.20	6.00	1.00	0.00	0.00	0.00	1.00
	Alternative 1	MIA-STL AIR 649.00 10d	STL-VCV RAIL 137.00 0.59d			786.00	1.00	886.90	0.56	11.60	1.00	0.00	1.00	0.00	2.00
	Alternative 2	MIA-VCV RAIL 462.25 14.31d				462.25	0.00	586.82	0.37	14.32	0.00	0.00	1.00	0.00	1.00
	Alternative 3	MIA-MTL RAIL 379.75 6.81d	MTL-VCV ROAD 397.00 7d			776.75	1.00	905.64	0.57	14.81	0.00	1.00	1.00	0.00	2.00
NYC-STL	Lowest cost	NYC-STL SEA 249.50 36d				249.50	0.00	562.75	0.35	36.00	0.00	0.00	0.00	1.00	1.00
	Highest speed	NYC-STL AIR 1487.00 6d				1487.00	0.00	1539.21	0.97	6.00	1.00	0.00	0.00	0.00	1.00
	Alternative 1	NYC-STL ROAD 1366.00 7.5d				1366.00	0.00	1431.26	0.90	7.50	0.00	1.00	0.00	0.00	1.00
	Alternative 2	NYC-LA ROAD 905.50 7.5d	LA-STL AIR 755.00 2d			1660.50	1.00	1751.86	1.10	10.50	1.00	1.00	0.00	0.00	2.00
	Alternative 3	NYC-STL RAIL 1215.50 11.91d				1215.50	0.00	1319.12	0.83	11.91	0.00	0.00	1.00	0.00	1.00
LA-MTL	Lowest cost	LA-STL SEA 220.00 14d	STL-VCV RAIL 137.00 0.59d	VCV-MTL ROAD 281.00 7d		638.00	3.00	852.02	0.54	24.60	0.00	1.00	1.00	1.00	3.00
	Highest speed	LA-MTL AIR 5671.00 4d				5671.00	0.00	5705.81	3.59	4.00	1.00	0.00	0.00	0.00	1.00
	Alternative 1	LA-NYC ROAD 1366.00 7.5d	NYC-MTL RAIL 229.50 1.54d			1595.50	1.00	1682.88	1.06	10.04	0.00	1.00	1.00	0.00	2.00
	Alternative 2	LA-STL AIR 755.00 2d	STL-VCV RAIL 137.00 0.59d	VCV-MTL ROAD 281.00 7d		1173.00	2.00	1273.90	0.80	11.60	1.00	1.00	1.00	0.00	3.00
	Alternative 3	LA-NOL AIR 865.00 4d	NOL-MTL RAIL 383.75 6.75d			1248.75	1.00	1351.06	0.85	11.76	1.00	0.00	1.00	0.00	2.00
VCV-MIA	Lowest cost	VCV-MTL ROAD 281.00 7d	MTL-MIA SEA 146.50 16.5d			427.50	2.00	649.38	0.41	25.50	0.00	1.00	0.00	1.00	2.00
	Highest speed	VCV-MIA AIR 7304.00 4d				7304.00	0.00	7338.81	4.62	4.00	1.00	0.00	0.00	0.00	1.00
	Alternative 1	VCV-STL RAIL 1826.00 0.59d	STL-MIA ROAD 1366.00 8d			3192.00	1.00	3275.50	2.06	9.60	0.00	1.00	1.00	0.00	2.00
	Alternative 2	VCV-LA RAIL 1826.00 5.3d	LA-MIA AIR 1103.00 5d			2929.00	1.00	3027.62	1.91	11.33	1.00	0.00	1.00	0.00	2.00
	Alternative 3	VCV-STL VCV-STI 1826.00 0.59d	STL-MIA STL-MIA 776.00 10d			2602.00	1.00	2702.90	1.70	11.60	0.00	0.00	0.00	0.00	0.00
STL-NYC	Lowest cost	STL-NYC SEA 409.50 38d				409.50	0.00	740.15	0.47	38.00	0.00	0.00	0.00	1.00	1.00
	Highest speed	STL-VCV RAIL 137.00 0.59d	VCV-NYC AIR 7304.00 4d			7441.00	1.00	7489.69	4.72	5.60	1.00	0.00	1.00	0.00	2.00
	Alternative 1	STL-NYC ROAD 1366.00 7.5d				1366.00	0.00	1431.26	0.90	7.50	0.00	1.00	0.00	0.00	1.00
	Alternative 2	STL-NOL ROAD 1366.00 5.5d	NOL-NYC AIR 1341.00 3d			2707.00	1.00	2789.66	1.76	9.50	1.00	1.00	0.00	0.00	2.00
	Alternative 3	STL-LA AIR 631.00 2d	LA-NYC ROAD 1366.00 7.5d			1997.00	1.00	2088.36	1.32	10.50	1.00	1.00	0.00	0.00	2.00

5.1.1.3.3 Eurasia, North America, and Africa Together

5.1.1.3.3.1 Long distance

In this region, we can see that all the optimal plans include air mode transportation. However, half of the city pairs implement highest-speed plans as their optimal plans. One example could be the highest-speed plan of the Shanghai-Montreal city pair. The plan indicates the itinerary from Shanghai to New York by plane, and then, from New York to Montreal by rail; the total cost is $7,098 and the total time is 7.04 days. In comparison, the total cost of the air-only mode is $13,803, and its total time is 7.5 days. The highest-speed plan of the New York-Montreal city pair is thus superior to the air-only plan. The other best plans for the city pairs of Singapore to Los Angeles and Montreal to Shanghai use alternative plans as their optimal plans.

Table 26 Scenario 3 – Eurasia & North America & Africa- Long distance

City pairs	Plans	Transit cities				Price-$	Delay-d	Total cost-$	Cost/kg	Total time-d	Modes				
											Air	Road	Rail	Sea	Sum
SH-MTL	Lowest cost	SH-VCV	VCV-MTL			430.50	2.00	708.94	0.45	32.00	0.00	1.00	0.00	1.00	2.00
		SEA	ROAD												
		149.50	281.00												
		23d	7d												
	Highest speed	SH-NYC	NYC-MTL			7037.50	1.00	7098.77	4.47	7.04	1.00	0.00	1.00	0.00	2.00
		AIR	RAIL												
		6808.00	229.50												
		4.5d	1.54d												
	Alternative 1	SH-NYC	NYC-MTL			7211.92	1.00	7353.75	4.63	16.30	1.00	1.00	0.00	0.00	2.00
		AIR	ROAD												
		6808.00	403.92												
		4.5d	10.8d												
	Alternative 2	SH-SGP	SGP-NYC	NYC-MTL		6316.50	2.00	6482.19	4.08	19.04	1.00	1.00	1.00	0.00	3.00
		ROAD	AIR	RAIL											
		64.00	6023.00	229.50											
		10d	5.5d	1.54d											
	Alternative 3	SH-MB	MB-MTL			5020.00	1.00	5198.38	3.27	20.50	1.00	1.00	0.00	0.00	2.00
		ROAD	AIR												
		825.00	4195.00												
		9d	10.5d												
SGP-LA	Lowest cost	SGP-LA				780.50	0.00	1085.05	0.68	35.00	0.00	0.00	0.00	1.00	1.00
		SEA													
		780.50													
		35d													
	Highest speed	SGP-STL	STL-LA			16112.50	1.00	16197.23	10.20	9.74	1.00	0.00	1.00	0.00	2.00
		AIR	RAIL												
		15562.00	550.50												
		4d	4.73d												
	Alternative 1	SGP-SH	SH-LA			7280.00	1.00	7388.77	4.65	12.50	1.00	1.00	0.00	0.00	2.00
		ROAD	AIR												
		822.00	6458.00												
		7d	4.5d												
	Alternative 2	SGP-NYC	NYC-LA			6928.50	1.00	7050.32	4.44	14.00	1.00	1.00	0.00	0.00	2.00
		AIR	ROAD												
		6023.00	905.50												
		5.5d	7.5d												
	Alternative 3	SGP-BGD	BGD-LA			6348.50	1.00	6496.42	4.09	17.00	1.00	1.00	0.00	0.00	2.00
		ROAD	AIR												
		822.00	5526.50												
		5.5d	10.5d												
MTL-SH	Lowest cost	MTL-LD	LD-SH			671.92	2.00	1114.82	0.70	50.90	0.00	1.00	0.00	1.00	2.00
		SEA	ROAD												
		356.00	315.92												
		16.5d	32.4d												
	Highest speed	MTL-SH				4586.00	0.00	4651.26	2.93	7.50	1.00	0.00	0.00	0.00	1.00
		AIR													
		4586.00													
		7d													
	Alternative 1	MTL-SGP	SGP-SH			3350.50	1.00	3437.51	2.16	10.00	1.00	1.00	0.00	0.00	2.00
		AIR	ROAD												
		2528.50	822.00												
		2d	7d												
	Alternative 2	MTL-VCV	VCV-SH			4611.50	1.00	4742.02	2.99	15.00	1.00	1.00	0.00	0.00	2.00
		ROAD	AIR												
		397.00	4214.50												
		7d	7d												
	Alternative 3	MTL-SGP	SGP-BGD	BGD-SH		4635.00	2.00	4814.57	3.03	20.64	1.00	1.00	1.00	0.00	3.00
		AIR	RAIL	ROAD											
		2528.50	1284.50	822.00											
		2d	10.6d	6d											
LA-SGP	Lowest cost	LA-SGP				432.50	0.00	737.05	0.46	35.00	0.00	0.00	0.00	1.00	1.00
		SEA													
		432.50													
		35d													
	Highest speed	LA-SGP				2928.00	0.00	2958.45	1.86	3.50	1.00	0.00	0.00	0.00	1.00
		AIR													
		2928.00													
		3.5d													
	Alternative 1	LA-STL	STL-VCV	VCV-SGP		3407.50	2.00	3491.00	2.20	9.60	1.00	1.00	1.00	0.00	3.00
		ROAD	RAIL	AIR											
		742.00	137.00	2528.50											
		5.5d	0.59d	1.5d											
	Alternative 2	LA-STL	STL-VCV	VCV-SGP		3581.12	2.00	3715.37	2.34	15.43	1.00	1.00	1.00	0.00	3.00
		RAIL	ROAD	AIR											
		811.50	241.12	2528.50											
		4.72d	7.2d	1.5d											
	Alternative 3	LA-STL	STL-VCV	VCV-SGP		2885.50	3.00	3051.66	1.92	19.10	1.00	0.00	1.00	1.00	3.00
		SEA	RAIL	AIR											
		220.00	137.00	2528.50											
		14d	0.59d	1.5d											

5.1.1.4 Scenario 4-ASE-Air not required mode (ASE cargo, 33 CU.M, 11340kg)

Scenario 4 means to transport one ASE (Heavy) cargo from origins to destinations with the possibility of no air mode involvement; e.g. to transport one ASE cargo from Shanghai to Montreal, the itinerary can be from Shanghai to Amsterdam by the road, then from Amsterdam to Montreal by the sea, where air transport mode is not required.

5.1.1.4.1 Eurasia

5.1.1.4.1.1 Short Distance

For the ASE section in which air is not required, a short-distance scenario is quite different from that of the ASE section without air. The plans chosen as optimal plans are those of lowest cost, highest speed, and alternatives; however, only one of them involves transporting goods by air only. In some highest-speed plans, transportation by road or rail is sometimes faster than by air.

For example, with regard to the Shanghai-Singapore city pair, the highest-speed plan is to travel from Shanghai to Singapore by road only, and the total cost of this transportation route is $1,493.46 at a speed of 7 days. In comparison, the air-only plan has a total cost is $20,375.87, and the total transport time is 10 days. Neither price nor speed is more advantageous than the road-only plan.

However, taking into account the correctness of the data collected from the website, 10 days by air from Shanghai to Singapore is somehow too long. Transport by road only is still a suitable plan as an alternative to the air-only plans.

Table 27 Scenario 4 - Eurasia - Short distance

City pairs	Plans	Transit cities				Price-$	Delay-d	Total cost-$	Cost/kg	Total time-d	Modes				
											Air	Road	Rail	Sea	Sum
SH-SGP	Lowest cost	SH-SGP ROAD 1058.50 7d				1058.50	0.00	1493.46	0.13	7.00	0.00	1.00	0.00	0.00	1.00
	Highest speed	SH-SGP ROAD 1058.50 7d				1058.50	0.00	1493.46	0.13	7.00	0.00	1.00	0.00	0.00	1.00
	Alternative 1	SH-SGP SEA 2785.50 26.5d				2785.50	0.00	4432.13	0.39	26.50	0.00	0.00	0.00	1.00	1.00
	Alternative 2	SH-BGD ROAD 5959.00 6d	BGD-SGP SEA 1161.00 19.5d			7120.00	2.00	8828.77	0.78	27.50	0.00	1.00	0.00	1.00	2.00
	Alternative 3	SH-BGD SEA 3538.00 29d	BGD-SGP ROAD 436.00 5.5d			3974.00	2.00	6242.00	0.55	36.50	0.00	1.00	0.00	1.00	2.00
SGP-SH	Lowest cost	SGP-SH SEA 2997.50 26d				2997.50	0.00	4613.06	0.41	26.00	0.00	0.00	0.00	1.00	1.00
	Highest speed	SGP-SH ROAD 5959.00 7d				5959.00	0.00	6393.96	0.56	7.00	0.00	1.00	0.00	0.00	1.00
	Alternative 1	SGP-BGD SEA 2997.50 26d	BGD-SH ROAD 5959.00 6d			8956.50	2.00	11069.16	0.98	34.00	0.00	1.00	0.00	1.00	2.00
	Alternative 2	SGP-MB SEA 2982.00 26.5d	MB-SH ROAD 5959.00 9d			8941.00	2.00	11271.14	0.99	37.50	0.00	1.00	0.00	1.00	2.00
	Alternative 3	SGP-MB ROAD 5959.00 7d	MB-SH SEA 3522.00 30.5d			9481.00	2.00	11935.41	1.05	39.50	0.00	1.00	0.00	1.00	2.00
MB-ISTB	Lowest cost	MB-ISTB SEA 3353.00 35.5d				3353.00	0.00	5558.86	0.49	35.50	0.00	0.00	0.00	1.00	1.00
	Highest speed	MB-ISTB AIR 71450.00 10d				71450.00	0.00	72071.37	6.36	10.00	1.00	0.00	0.00	0.00	1.00
	Alternative 1	MB-RM AIR 16797.50 9.5d	RM-ISTB SEA 2242.50 10.5d			19040.00	2.00	20407.01	1.80	22.00	1.00	0.00	0.00	1.00	2.00
	Alternative 2	MB-HMB AIR 17952.50 9.5d	HMB-ISTB SEA 3656.50 16d			21609.00	2.00	23317.77	2.06	27.50	1.00	0.00	0.00	1.00	2.00
	Alternative 3	MB-SGP ROAD 514.00 7.5d	SGP-RM AIR 8626.00 10d	RM-ISTB SEA 2242.50 10.5d		11382.50	3.00	13308.75	1.17	31.00	1.00	1.00	0.00	1.00	3.00
ISTB-MB	Lowest cost	ISTB-MB SEA 2983.00 50d				2983.00	0.00	6089.85	0.54	50.00	0.00	0.00	0.00	1.00	1.00
	Highest speed	ISTB-MB AIR 27092.00 10.5d				27092.00	0.00	27744.44	2.45	10.50	1.00	0.00	0.00	0.00	1.00
	Alternative 1	ISTB-AMSD ROAD 1659.17 12.53d	AMSD-MB AIR 26279.00 11d			27938.17	1.00	29462.74	2.60	24.54	1.00	1.00	0.00	0.00	2.00
	Alternative 2	ISTB-MD SEA 2979.00 14d	MD-MB AIR 21486.50 12d			24465.50	2.00	26205.34	2.31	28.00	1.00	0.00	0.00	1.00	2.00
	Alternative 3	ISTB-LD SEA 4158.00 12.5d	LD-MB AIR 22588.50 16d			26746.50	2.00	28641.68	2.53	30.50	1.00	0.00	0.00	1.00	2.00
LD-AMSD	Lowest cost	LD-AMSD SEA 542.50 10.5d				542.50	0.00	1194.94	0.11	10.50	0.00	0.00	0.00	1.00	1.00
	Highest speed	LA-AMSD AIR 27797.00 9d				27797.00	0.00	28356.23	2.50	9.00	1.00	0.00	0.00	0.00	1.00
	Alternative 1	LD-ISTB SEA 2848.00 17d	ISTB-AMSD AIR 3770.83 3.48d			6618.83	2.00	8015.81	0.71	22.48	1.00	0.00	0.00	1.00	2.00
	Alternative 2	LD-ISTB SEA 2848.00 17d	ISTB-AMSD ROAD 1659.17 12.5d			4507.17	2.00	6466.70	0.57	31.54	0.00	1.00	0.00	1.00	2.00
	Alternative 3	LA-AMSD ROAD 12230.68 32.4d				12230.68	0.00	14243.92	1.26	32.40	0.00	1.00	0.00	0.00	1.00
AMSD-LD	Lowest cost	AMSD-HMB ROAD 2170.96 25.2d	HMB-LD SEA 2839.00 15.5d			5009.96	2.00	7663.21	0.68	42.70	0.00	1.00	0.00	1.00	2.00
	Highest speed	AMSD-LD AIR 21739.00 9d				21739.00	0.00	22298.23	1.97	9.00	1.00	0.00	0.00	0.00	1.00
	Alternative 1	AMSD-LD SEA 6845.50 17d				6845.50	0.00	7901.83	0.70	17.00	0.00	0.00	0.00	1.00	1.00
	Alternative 2	AMSD-HMB AIR 4934.00 7d	HMB-LD SEA 2839.00 15.5d			7773.00	2.00	9295.36	0.82	24.50	1.00	0.00	0.00	1.00	2.00
	Alternative 3	AMSD-LD ROAD 9565.16 32.4d				9565.16	0.00	11578.40	1.02	32.40	0.00	1.00	0.00	0.00	1.00

5.1.1.4.1.2 Long distance

Regarding the long-distance aspect in the ASE(for air not required) section, we can see that most of the optimal plans are lowest-cost plans and alternatives. Only one is the highest-speed plan, and it is from London to Singapore by air.

The other best plans all include the air mode except a city pair such as Shanghai-Amsterdam. The best route for transporting goods in ASE cargos is to travel from Shanghai to Hamburg by road at a price of $17,455.48 and a time of 7.2 days, and then, from Hamburg to Amsterdam by sea at a rate of $1,699.50 and a time of 3.5 days. However, the remaining plans all include air transport. For example, the Singapore-London city pair's best route is from Singapore to Rome by air at a price of $8,626 and a time of 10 days, and then, a transfer from Rome to London by sea at a rate of $2,315.50 and a time of 7 days; the total cost is $10,941.5, with a time of 19 days and a 2-day delay.

Table 28. Scenario 4: Eurasia—long distance

City pairs	Plans	Transit cities				Price-$	Delay-d	Total cost-$	Cost/kg	Total time-d	Modes				
											Air	Road	Rail	Sea	Sum
SH-AMSD	Lowest cost	SH-SGP	SGP-AMSD			2760.00	2.00	5245.48	0.46	40.00	0.00	1.00	0.00	1.00	2.00
		ROAD	SEA												
		1058.50	1701.50												
		7D	31D												
	Highest speed	SH-HMB	HMB-AMSD			41366.50	2.00	41832.53	3.69	7.50	1.00	0.00	0.00	1.00	2.00
		AIR	SEA												
		39667.00	1699.50												
		2D	3.5D												
	Alternative 1	SH-HMB	HMB-AMSD			19152.98	2.00	19942.12	1.76	12.70	0.00	1.00	0.00	1.00	2.00
		ROAD	SEA												
		17453.48	1699.50												
		7.2D	3.5D												
	Alternative 2	SH-MB	MB-AMSD			26291.50	1.00	27503.17	2.43	19.50	1.00	1.00	0.00	0.00	2.00
		ROAD	AIR												
		5959.00	20332.50												
		9D	9.5D												
	Alternative 3	SH-HMB	HMB-AMSD			11616.25	2.00	12852.78	1.13	19.90	0.00	0.00	1.00	1.00	2.00
		RAIL	SEA												
		9916.75	1699.50												
		14.4D	3.5D												
SGP-LD	Lowest cost	SGP-LD				3800.00	0.00	5819.45	0.51	32.50	0.00	0.00	0.00	1.00	1.00
		SEA													
		3800.00													
		32.5d													
	Highest speed	SGP-LD				30271.50	0.00	31017.14	2.74	12.00	1.00	0.00	0.00	0.00	1.00
		AIR													
		30271.50													
		12d													
	Alternative 1	SGP-RM	RM-LD			10941.50	2.00	12122.10	1.07	19.00	1.00	0.00	0.00	1.00	2.00
		AIR	SEA												
		8626.00	2315.50												
		10d	7d												
	Alternative 2	SGP-BGD	BGD-RM	RM-LD		16900.50	3.00	18484.99	1.63	25.50	1.00	1.00	0.00	1.00	3.00
		ROAD	AIR	SEA											
		5959.00	8626.00	2315.50											
		5.5d	10d	7d											
	Alternative 3	SGP-MB	MB-RM	RM-LD		25072.00	3.00	26718.63	2.36	26.50	1.00	1.00	0.00	1.00	3.00
		ROAD	AIR	SEA											
		5959.00	16797.50	2315.50											
		7d	9.5d	7d											
TKY-HMB	Lowest cost	TKY-HMB				3059.00	0.00	5513.41	0.49	39.50	0.00	0.00	0.00	1.00	1.00
		SEA													
		3059.00													
		39.5d													
	Highest speed	TKY-HMB				66965.00	0.00	67399.96	5.94	7.00	1.00	0.00	0.00	0.00	1.00
		AIR													
		66965.00													
		7d													
	Alternative 1	TKY-RM	RM-HMB			34405.00	2.00	35803.08	3.16	22.50	1.00	0.00	0.00	1.00	2.00
		AIR	SEA												
		29299.00	5106.00												
		7d	13.5d												
	Alternative 2	TKY-RM	RM-MD	MD-HMB		35183.50	3.00	36954.40	3.26	28.50	1.00	1.00	0.00	1.00	3.00
		AIR	ROAD	SEA											
		29299.00	790.00	5094.50											
		7d	5d	13.5d											
	Alternative 3	TKY-SH	SH-HMB			20473.98	2.00	22661.20	2.00	35.20	0.00	1.00	0.00	1.00	2.00
		SEA	ROAD												
		3020.50	17453.48												
		26d	7.2d												
AMSD-SH	Lowest cost	AMSD-SH				4792.50	0.00	7277.98	0.64	40.00	0.00	0.00	0.00	1.00	1.00
		SEA													
		4792.50													
		40d													
	Highest speed	AMSD-SH				36219.50	0.00	36840.87	3.25	10.00	1.00	0.00	0.00	0.00	1.00
		AIR													
		36219.50													
		10d													
	Alternative 1	AMSD-SGP	SGP-SH			32819.00	1.00	33782.12	2.98	15.50	1.00	1.00	0.00	0.00	2.00
		AIR	ROAD												
		26860.00	5959.00												
		7.5d	7d												
	Alternative 2	AMSD-MB	MB-SH			32238.00	1.00	33542.88	2.96	21.00	1.00	1.00	0.00	0.00	2.00
		AIR	ROAD												
		26279.00	5959.00												
		11d	9d												
	Alternative 3	AMSD-SH				15936.58	0.00	18173.51	1.60	36.00	0.00	1.00	0.00	0.00	1.00
		ROAD													
		15936.58													
		36d													
LD-SGP	Lowest cost	ILD-BGD	BGD-SGP			3877.00	2.00	6890.64	0.61	48.50	0.00	1.00	0.00	1.00	2.00
		SEA	ROAD												
		3441.00	436.00												
		41.00	5.50												
	Highest speed	LD-SGP				26797.00	0.00	27449.44	2.42	10.50	1.00	0.00	0.00	0.00	1.00
		AIR													
		26797.00													
		10.5d													
	Alternative 1	LA-AMSD	AMSD-SGP			27402.50	2.00	28645.24	2.53	20.00	1.00	0.00	0.00	1.00	2.00
		SEA	AIR												
		542.50	26860.00												
		10.5d	7.5d												
	Alternative 2	LA-MB	MB-SGP			23102.50	1.00	24624.86	2.17	24.50	1.00	1.00	0.00	0.00	2.00
		AIR	ROAD												
		22588.50	514.00												
		16d	7.5d												
	Alternative 3	LD-AMSD	AMSD-MB	MB-SGP		27335.50	3.00	29323.88	2.59	32.00	1.00	1.00	0.00	1.00	3.00
		SEA	AIR	ROAD											
		542.50	26279.00	514.00											
		10.5d	11d	7.5d											
HMB-TKY	Lowest cost	HMB-TKY				2512.50	0.00	5588.28	0.49	49.50	0.00	0.00	0.00	1.00	1.00
		SEA													
		2512.50													
		49.5d													
	Highest speed	HMB-TKY				44700.50	0.00	45135.46	3.98	7.00	1.00	0.00	0.00	0.00	1.00
		AIR													
		44700.50													
		7d													
	Alternative 1	HMB-RM	RM-MD	MD-HMB		35611.00	3.00	36978.01	3.26	22.00	1.00	1.00	0.00	1.00	3.00
		SEA	ROAD	AIR											
		2847.50	790.00	31973.50											
		7d	5d	7d											
	Alternative 2	TKY-MD	MD-HMB			36413.00	2.00	38059.63	3.36	26.50	1.00	0.00	0.00	1.00	2.00
		SEA	AIR												
		4439.50	31973.50												
		17.5d	7d												
	Alternative 3	TKY-SGP	SGP-HMB			32168.50	2.00	34312.23	3.03	34.50	1.00	0.00	0.00	1.00	2.00
		AIR	SEA												
		29688.00	2480.50												
		8d	24.5d												

5.1.1.4.2 North America

5.1.1.4.2.1 Short distance

In North America, transporting goods in an ASE cargo for short distances (air not required) is similar to that in scenario 2—ASE with air. Two of the optimal plans are found in the highest-speed section, and the rest of them are lowest-cost and alternative plans. However, the nuance is that those highest-speed plans no longer make use of air transportation only. On the contrary, goods are transported by road only because the highways are well developed in North America. Furthermore, the speed by road is slightly slower and the price is much less than those of the air mode. Also, the distance is relatively short; therefore, choosing the road-only mode from one city to another closely situated city is quite economical.

Table 29 Scenario 4 - North America - Short distance

City pairs	Plans	Transit cities				Price-$	Delay-d	Total cost-$	Cost/kg	Total time-d	Modes Air	Road	Rail	Sea	Sum
MTL-NYC	Lowest cost	MTL-NYC SEA 3914.00 30d				3914.00	0.00	5778.11	0.51	30.00	0.00	0.00	0.00	1.00	1.00
	Highest speed	MTL-NYC AIR 52164.00 4d				52164.00	0.00	52412.55	4.62	4.00	1.00	0.00	0.00	0.00	1.00
	Alternative 1	MTL-NYC ROAD 22952.16 14.4d				22952.16	0.00	23846.93	2.10	14.40	0.00	1.00	0.00	0.00	1.00
	Alternative 2	MTL-NYC RAIL 13041.00 28.8d				13041.00	0.00	14830.55	1.31	28.80	0.00	0.00	1.00	0.00	1.00
	Alternative 3	MTL-MIA SEA 3914.00 30d	MIA-NYC ROAD 4099.00 5.5d			8013.00	2.00	10343.14	0.91	37.50	0.00	1.00	0.00	1.00	2.00
NYC-MTL	Lowest cost	NYC-MTL SEA 3915.50 30d				3915.50	0.00	5779.61	0.51	30.00	0.00	0.00	0.00	1.00	1.00
	Highest speed	NYC-MTL AIR 40500.00 4d				40500.00	0.00	40748.55	3.59	4.00	1.00	0.00	0.00	0.00	1.00
	Alternative 1	NYC-MTL ROAD 17820.00 14.4d				17820.00	0.00	18714.77	1.65	14.40	0.00	1.00	0.00	0.00	1.00
	Alternative 2	NYC-HLF SEA 11225.00 23.5d	HLF-MTL ROAD 3223.50 3d			14448.50	2.00	16219.40	1.43	28.50	0.00	1.00	0.00	1.00	2.00
	Alternative 3	NYC-MTL RAIL 10125.00 28.8d				10125.00	0.00	11914.55	1.05	28.80	0.00	0.00	1.00	0.00	1.00
NOL-LA	Lowest cost	NOL-LA ROAD 8751.00 5.5d				8751.00	0.00	9092.75	0.80	5.50	0.00	1.00	0.00	0.00	1.00
	Highest speed	NOL-LA ROAD 8751.00 5.5d				8751.00	0.00	9092.75	0.80	5.50	0.00	1.00	0.00	0.00	1.00
	Alternative 1	NOL-MIA ROAD 4099.00 5.5d	MIA-LA AIR 20387.00 15.5d			24486.00	1.00	25853.01	2.28	22.00	1.00	1.00	0.00	0.00	2.00
	Alternative 2	NOL-NYC ROAD 4099.00 5.5d	NYC-LA AIR 20387.00 15.5d			24486.00	1.00	25853.01	2.28	22.00	1.00	1.00	0.00	0.00	2.00
	Alternative 3	NOL-LA SEA 14380.00 29.5d				14380.00	0.00	16213.04	1.43	29.50	0.00	0.00	0.00	1.00	1.00
LA-NOL	Lowest cost	LA-NOL SEA 6600.50 39.5d				6600.50	0.00	9054.91	0.80	39.50	0.00	0.00	0.00	1.00	1.00
	Highest speed	LA-NOL ROAD 8751.00 5.5d				8751.00	0.00	9092.75	0.80	5.50	0.00	1.00	0.00	0.00	1.00
	Alternative 1	LA-MIA AIR 20332.00 15.5d	MIA-NOL ROAD 4099.00 5.5d			24431.00	1.00	25798.01	2.27	22.00	1.00	1.00	0.00	0.00	2.00
	Alternative 2	LA-NYC AIR 20332.00 15.5d	NYC-NOL ROAD 4099.00 5.5d			24431.00	1.00	25798.01	2.27	22.00	1.00	1.00	0.00	0.00	2.00
	Alternative 3	LA-STL ROAD 4575.50 5.5d	STL-NOL AIR 20332.00 15.5d			24907.50	1.00	26274.51	2.32	22.00	1.00	1.00	0.00	0.00	2.00
VCV-STL	Lowest cost	VCV-STL RAIL 13041.00 28.8d				13041.00	0.00	14830.55	1.31	28.80	0.00	0.00	1.00	0.00	1.00
	Highest speed	VCV-STL AIR 52164.00 4d				52164.00	0.00	52412.55	4.62	4.00	1.00	0.00	0.00	0.00	1.00
	Alternative 1	VCV-STL ROAD 22952.16 14.4d				22952.16	0.00	23846.93	2.10	14.40	0.00	1.00	0.00	0.00	1.00
	Alternative 2	VCV-MTL AIR 11553.50 9d	MTL-STL ROAD 22952.16 14.4d			34505.66	1.00	36021.80	3.18	24.40	1.00	1.00	0.00	0.00	2.00
	Alternative 3	VCV-HLF AIR 11553.50 9d	HLF-STL ROAD 22952.16 14.4d			34505.66	1.00	36021.80	3.18	24.40	1.00	1.00	0.00	0.00	2.00
STL-VCV	Lowest cost	STL-VCV SEA 4860.00 22.4d				4860.00	0.00	6251.87	0.55	22.40	0.00	0.00	0.00	1.00	1.00
	Highest speed	STL-VCV AIR 40500.00 4d				40500.00	0.00	40748.55	3.59	4.00	1.00	0.00	0.00	0.00	1.00
	Alternative 1	STL-VCV ROAD 17820.00 14.4d				17820.00	0.00	18714.77	1.65	14.40	0.00	1.00	0.00	0.00	1.00
	Alternative 2	STL-VCV RAIL 10125.00 28.8d				10125.00	0.00	11914.55	1.05	28.80	0.00	0.00	1.00	0.00	1.00
	Alternative 3	STL-LA ROAD 4575.50 5.5d	LA-VCV SEA 4860.00 22.4d			9435.50	2.00	11293.40	1.00	29.90	0.00	1.00	0.00	1.00	2.00

5.1.1.4.2.2 Long distance

In the long-distance section, the optimal plans are mostly alternatives, followed by lowest-cost and highest-speed plans.

The highest-speed plans are not to transport by air but by road. For example, the two highest-speed plans are for the city pairs of New York to Seattle and Seattle to New York. They both chose to transport by road only to reduce the total cost and to maintain service levels.

The total cost and total transport time by road for the two city pairs are both $9,217.03 and 7.5 days respectively. In contrast, transporting goods from New York to Seattle by air costs $21,350.12 and takes 15.5 days, and from Seattle to New York, the figures are $21,290.12 and 15.5 days respectively. When comparing the two transport methods, transportation by road is both cheaper and faster than by air.

Table 30 Scenario 4 - North America - Long distance

City pairs	Plans	Transit cities		Price-$	Delay-d	Total cost-$	Cost/kg	Total time-d	Modes: Air	Road	Rail	Sea	Sum
MTL-LA	Lowest cost	MTL-LA RAIL 13041.00 28.8d		13041.00	0.00	14830.55	1.31	28.80	0.00	0.00	1.00	0.00	1.00
	Highest speed	MTL-LA AIR 52164.00 4d		52164.00	0.00	52412.55	4.62	4.00	1.00	0.00	0.00	0.00	1.00
	Alternative 1	MTL-LA ROAD 22952.16 14.4d		22952.16	0.00	23846.93	2.10	14.40	0.00	1.00	0.00	0.00	1.00
	Alternative 2	MTL-HLF ROAD 3238.50 3d	HLF-LA RAIL 13041.00 28.8d	16279.50	1.00	18317.59	1.62	32.80	0.00	1.00	1.00	0.00	2.00
	Alternative 3	MTL-NOL SEA 3914.00 30d	NOL-LA ROAD 8751.00 5.5d	12665.00	2.00	14995.14	1.32	37.50	0.00	1.00	0.00	1.00	2.00
MIA-VCV	Lowest cost	MIA-VCV SEA 254.50 48d		254.50	0.00	3237.08	0.29	48.00	0.00	0.00	0.00	1.00	1.00
	Highest speed	MIA-VCV AIR 40500.00 4d		40500.00	0.00	40748.55	3.59	4.00	1.00	0.00	0.00	0.00	1.00
	Alternative 1	MA-VCV ROAD 17820.00 14.4d		17820.00	0.00	18714.77	1.65	14.40	0.00	1.00	0.00	0.00	1.00
	Alternative 2	MIA-VCV RAIL 10125.00 28.8d		10125.00	0.00	11914.55	1.05	28.80	0.00	0.00	1.00	0.00	1.00
	Alternative 3	MIA-LA ROAD 8751.00 7d	LA-VCV SEA 4860.00 22.4d	13611.00	2.00	15562.10	1.37	31.40	0.00	1.00	0.00	1.00	2.00
NYC-STL	Lowest cost	NYC-STL ROAD 8751.00 7.5d		8751.00	0.00	9217.03	0.81	7.50	0.00	1.00	0.00	0.00	1.00
	Highest speed	NYC-STL ROAD 8751.00 7.5d		8751.00	0.00	9217.03	0.81	7.50	0.00	1.00	0.00	0.00	1.00
	Alternative 1	NYC-NOL ROAD 4099.00 5.5d	NOL-STL AIR 20387.00 15.5d	24486.00	1.00	25853.01	2.28	22.00	1.00	1.00	0.00	0.00	2.00
	Alternative 2	NYC-LA ROAD 8751.00 7.5d	LA-STL SEA 11134.00 16.5d	19885.00	2.00	21500.56	1.90	26.00	0.00	1.00	0.00	1.00	2.00
	Alternative 3	NYC-STL SEA 14380.00 29.5d		14380.00	0.00	16213.04	1.43	29.50	0.00	0.00	0.00	1.00	1.00
LA-MTL	Lowest cost	LA-MTL SEA 6515.00 35.5d		6515.00	0.00	8720.86	0.77	35.50	0.00	0.00	0.00	1.00	1.00
	Highest speed	LA-MTL AIR 40500.00 4d		40500.00	0.00	40748.55	3.59	4.00	1.00	0.00	0.00	0.00	1.00
	Alternative 1	LA-MTL ROAD 17820.00 14.4d		17820.00	0.00	18714.77	1.65	14.40	0.00	1.00	0.00	0.00	1.00
	Alternative 2	LA-MTL RAIL 10125.00 28.8d		10125.00	0.00	11914.55	1.05	28.80	0.00	0.00	1.00	0.00	1.00
	Alternative 3	LA-VCV SEA 4860.00 22.4d	VCV-MTL ROAD 2002.50 7d	6862.50	2.00	8813.60	0.78	31.40	0.00	1.00	0.00	1.00	2.00
VCV-MIA	Lowest cost	VCV-MTL ROAD 2002.50 7d	MTL-MIA SEA 3914.00 30d	5916.50	2.00	8339.84	0.74	39.00	0.00	1.00	0.00	1.00	2.00
	Highest speed	VCV-MIA AIR 52164.00 4d		52164.00	0.00	52412.55	4.62	4.00	1.00	0.00	0.00	0.00	1.00
	Alternative 1	VCV-MTL AIR 11553.50 9d	MTL-MIA ROAD 22952.16 14.4d	34505.66	1.00	36021.80	3.18	24.40	1.00	1.00	0.00	0.00	2.00
	Alternative 2	VCV-MIA RAIL 13041.00 28.8d		13041.00	0.00	14830.55	1.31	28.80	0.00	0.00	1.00	0.00	1.00
	Alternative 3	VCV-NOL RAIL 13041.00 28.8d	NOL-MIA ROAD 4099.00 5.5d	17140.00	1.00	19333.44	1.70	35.30	0.00	1.00	1.00	0.00	2.00
STL-NYC	Lowest cost	STL-NYC SEA 6600.50 39.5d		6600.50	0.00	9054.91	0.80	39.50	0.00	0.00	0.00	1.00	1.00
	Highest speed	STL-NYC ROAD 8751.00 7.5d		8751.00	0.00	9217.03	0.81	7.50	0.00	1.00	0.00	0.00	1.00
	Alternative 1	STL-NOL AIR 20332.00 15.5d	NOL-NYC ROAD 4099.00 5.5d	24431.00	1.00	25798.01	2.27	22.00	1.00	1.00	0.00	0.00	2.00
	Alternative 2	STL-MIA AIR 20332.00 15.5d	MIA-NYC ROAD 4099.00 5.5d	24431.00	1.00	25798.01	2.27	22.00	1.00	1.00	0.00	0.00	2.00
	Alternative 3	STL-LA SEA 11134.00 16.5d	LA-NYC ROAD 8751.00 7.5d	19885.00	2.00	21500.56	1.90	26.00	0.00	1.00	0.00	1.00	2.00

5.1.1.4.3 Eurasia, North America, and Africa

5.1.1.4.3.1 Long distance

To transport ASE cargos across three continents in scenario 4 (ASE—air not required) is not similar to that in scenario 2 (ASE with air). The optimal plans are all alternative plans, and there is no example of air mode absence.

For example, the best route for transporting an ASE cargo from Shanghai to Montreal is from Shanghai to Vancouver by air at a price of $34,241 and a time of 6 days, and then, from Vancouver to Montreal by road at a rate of $2,002.50 and a time of 7 days. The other best plans all use the air mode as a multimodal transport transferring bridge to reduce the transporting time between continents because the transit time for transportation by sea is too long.

Table 31 Scenario 4 - Eurasia & North America & Africa- Long distance

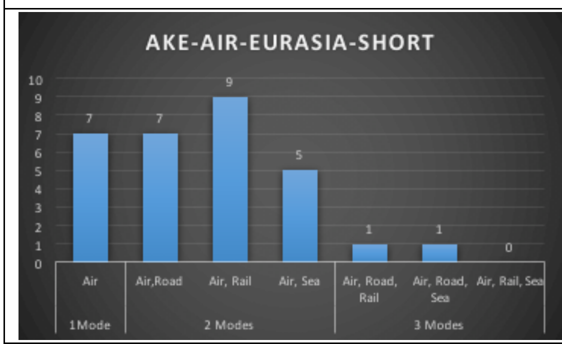
City pairs	Plans	Transit cities				Price-$	Delay-d	Total cost-$	Cost/kg	Total time-d	Modes				
											Air	Road	Rail	Sea	Sum
SH-MTL	Lowest cost	SH-MTL				3996.50	0.00	6264.50	0.55	36.50	0.00	0.00	0.00	1.00	1.00
		SEA													
		3996.50													
		36.5d													
	Highest speed	SH-MTL				62484.50	0.00	63230.14	5.58	12.00	1.00	0.00	0.00	0.00	1.00
		AIR													
		62484.50													
		12d													
	Alternative 1	SH-VCV	VCV-MTL			36243.50	1.00	37113.42	3.27	14.00	1.00	1.00	0.00	0.00	2.00
		AIR	ROAD												
		34241.00	2002.50												
		6d	7d												
	Alternative 2	SH-MB	MB-MTL			34568.50	1.00	35873.38	3.16	21.00	1.00	1.00	0.00	0.00	2.00
		ROAD	AIR												
		5959.00	28609.50												
		9d	11d												
	Alternative 3	SH-HMB	HMB-MTL			20791.48	2.00	22481.61	1.98	27.20	0.00	1.00	0.00	1.00	2.00
		ROAD	SEA												
		17453.48	3338.00												
		7.2d	18d												
SGP-LA	Lowest cost	SGP-LA				5965.50	0.00	8854.87	0.78	46.50	0.00	0.00	0.00	1.00	1.00
		SEA													
		5965.50													
		46.5d													
	Highest speed	SGP-LA				43298.00	0.00	43813.96	3.86	8.30	1.00	0.00	0.00	0.00	1.00
		AIR													
		43298.00													
		8.3d													
	Alternative 1	SGP-MB	MB-LA			38785.00	1.00	39530.64	3.49	12.00	1.00	1.00	0.00	0.00	2.00
		ROAD	AIR												
		5959.00	32826.00												
		7d	4d												
	Alternative 2	SGP-HMB	HMB-LA			34923.00	2.00	36880.32	3.25	31.50	1.00	0.00	0.00	1.00	2.00
		SEA	AIR												
		2831.00	32092.00												
		25.5d	4d												
	Alternative 3	SGP-RM	RM-LA			33765.50	2.00	35753.88	3.15	32.00	1.00	0.00	0.00	1.00	2.00
		SEA	AIR												
		1673.50	32092.00												
		26d	4d												
MTL-SH	Lowest cost	MTL-SH				5518.00	0.00	8252.03	0.73	44.00	0.00	0.00	0.00	1.00	1.00
		SEA													
		5518.00													
		44d													
	Highest speed	MTL-SH				34349.00	0.00	35063.58	3.09	11.50	1.00	0.00	0.00	0.00	1.00
		AIR													
		34349.00													
		11.5d													
	Alternative 1	MTL-HLF	HLF-SH			37587.50	1.00	38550.62	3.40	15.50	1.00	1.00	0.00	0.00	2.00
		ROAD	AIR												
		3238.50	34349.00												
		3d	11.5d												
	Alternative 2	MTL-SGP	SGP-SH			29833.00	1.00	30858.26	2.72	16.50	1.00	1.00	0.00	0.00	2.00
		AIR	ROAD												
		23874.00	5959.00												
		8.5d	7d												
	Alternative 3	MTL-SGP	SGP-SH			26871.50	2.00	29139.50	2.57	36.50	1.00	0.00	0.00	1.00	2.00
		AIR	SEA												
		23874.00	2997.50												
		8.5d	26d												
LA-SGP	Lowest cost	LA-SGP				3273.00	0.00	6659.47	0.59	54.50	0.00	0.00	0.00	1.00	1.00
		SEA													
		3273.00													
		4.5d													
	Highest speed	LA-SGP				20482.00	0.00	20699.48	1.83	3.50	1.00	0.00	0.00	0.00	1.00
		AIR													
		20482.00													
		3.5d													
	Alternative 1	LA-MB	MB-SGP			12429.00	1.00	13174.64	1.16	12.00	1.00	1.00	0.00	0.00	2.00
		AIR	ROAD												
		11915.00	514.00												
		3.5d	7.5d												
	Alternative 2	LA-MB	MB-SGP			13060.50	2.00	14644.99	1.29	25.50	1.00	0.00	0.00	1.00	2.00
		AIR	SEA												
		11915.00	1145.50												
		3.5d	20d												
	Alternative 3	LA-AMSD	AMSD-SGP			28898.40	1.00	30855.72	2.72	31.50	1.00	1.00	0.00	0.00	2.00
		AIR	ROAD												
		17080.00	11818.40												
		3.5d	27d												

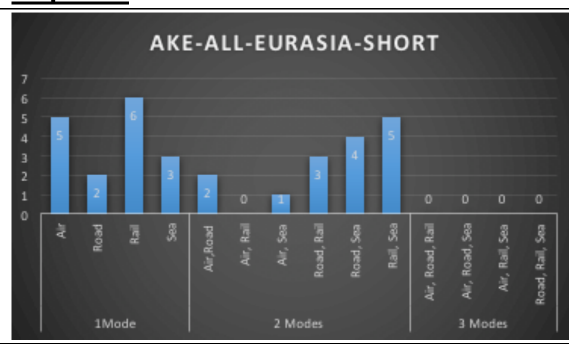
5.1.2 Data analysis for value of $10/kg

The table below depicts the generalization of the most frequently used combinations of transport modes and transit cities in the "top five" plans for each city pair in four scenarios. These are scenario 1—AKE with air, scenario 2—AKE air not required, scenario 3—ASE with air, and scenario 4—ASE air not required. In the charts of transport mode frequency, the vertical axis represents the frequency number of each mode combinations appearing in the top 5 plans, and the horizontal axis stands for different modes combinations. In the charts of route frequency, the vertical axis also represents the frequency number of each route (Transit cities) that has been mostly used, and the horizontal axis stands for the transit cities name.

Comparing these four scenarios regarding the most frequent combination of transport modes and routes in the optimal plans can provide us with a snapshot of the potentially popular multimodal transport terminals and favorable routes between city pairs.

Table 32. Comparison of four scenarios—transport modes and city frequency

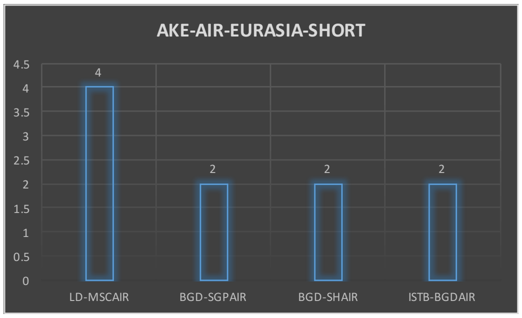
<table>
<tr>
<td><u>Scenario 1: AKE (Small cargo)—with air</u></td>
<td><u>Scenario 3: AKE (Small cargo)—air not required</u></td>
</tr>
<tr>
<td>


</td>
<td>


</td>
</tr>
<tr>
<td>From the figure above, we can see that there are seven city pairs with top plans (the top five plans for each city pair). In this scenario, in the Eurasia region, goods are transported by air only, and seven plans contain two modes: air and road combinations. Furthermore, nine plans comprise two mode combinations of air and rail; five plans entail two modes, namely air and sea; and only one plan involves either air-road-rail or air-road-sea, in a three-mode combination.

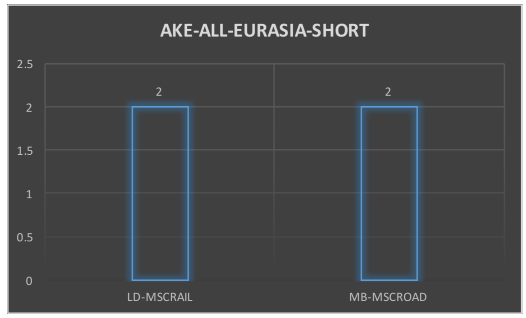
So, we can conclude that the most frequent way in which to transport goods in Eurasia for short-distance city pairs is to use a two-mode combination. The air-rail and air-road modes are the two most efficient ways to reduce total costs while maintaining a high speed.</td>
<td>The use of unimodal transport is much more popular in the short-distance section in the Eurasia continent. To transport by rail or air is both profitable and time effective. However, there are also some popular two-mode combinations that we could find from the chart.

Therefore, in short-distance transportation, we can summarize that the most effective mode is rail or air, or a road-sea or rail-sea combination.</td>
</tr>
</table>



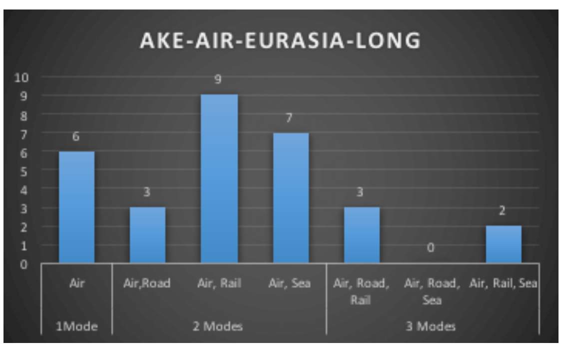
From the figure above, we can see that the most popular transit city pair in the Eurasia short-distance section is London to Moscow when transporting one AKE cargo. Also, there are three low-cost and high-speed transport routes depicted in the figure; they are the routes from Bangladesh to Singapore by air, Bangladesh to Shanghai by air, and Istanbul to Bangladesh by air.

The reason Bangladesh has been a low-cost transit city is that the Chinese government has built a highway between China, Bangladesh, and Mumbai to avoid the traffic jam in the Strait of Malacca; therefore, Bangladesh has been an important transit city in the east-Asian area.

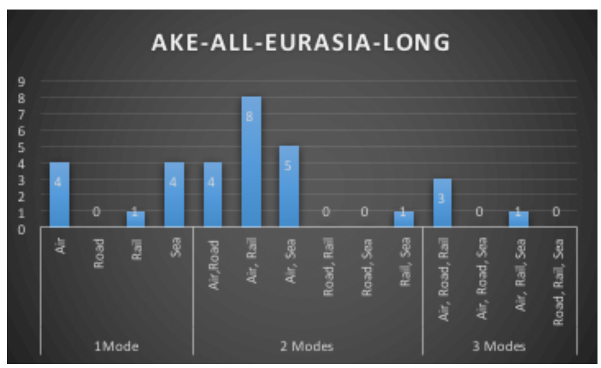


The figure indicates that the two most frequently used routes in scenario 2 in the Eurasia region are London to Moscow by rail and Mumbai to Moscow by road. Moscow seems to be a popular city of transit in the multimodal transport system in Eurasia because Russia is crosses over both Asia and Europe and thus connects the two continents.

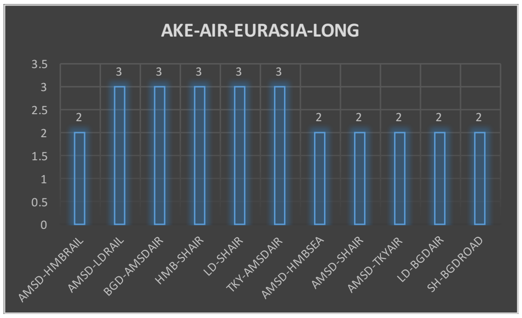
The reason to use road or rail modes is that Eurasia is considered to be a whole continent with one piece of land; therefore, highways and railroads can be built to connect the two continents, and average road and rail rates are much less than air rates, making them popular modes of transport in Eurasia.

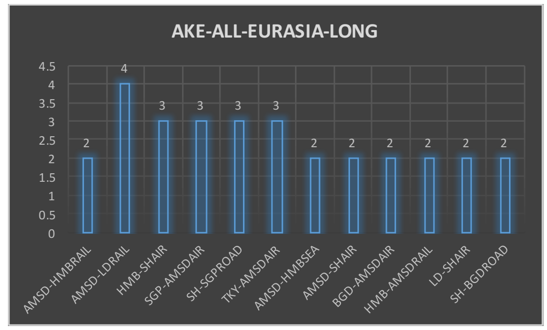


In the long-distance section in Eurasia, we can see that the most frequently used modes are two-mode combinations. Of these, the most frequently used ones are air-rail and air-sea combinations. This means that in Eurasia, travelling by the multimodal transport system, including air-rail and air-sea modes, is most profitable when transporting small cargo such as AKE cargo.



In the section of long distance in the AKE scenario (with air not being required), the optimal plans are mostly two-mode combinations. Air-rail and air-sea modes ranked first and second respectively, which means that for long-distance travel, the most profitable transport mode combination is still the same as that for the AKE-with-air section.



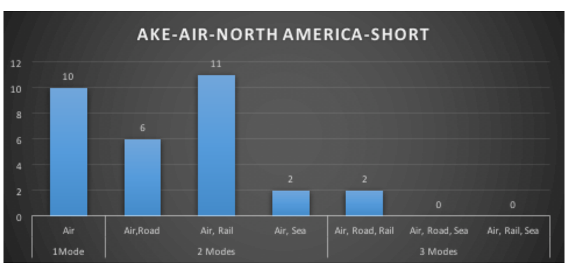


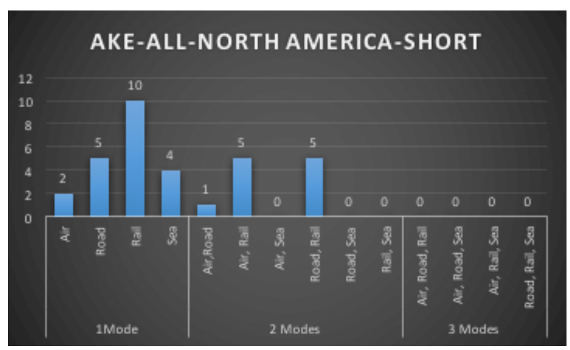
The figure above illustrates that the routes of Amsterdam to London by rail, Bangladesh to Amsterdam by air, Hamburg to Shanghai by air, London to Shanghai by air, and Tokyo to Amsterdam by air are the most popular itineraries among all the city pairs with transport mode combinations.

The routes are easy to understand for the following reasons: from Amsterdam to London by rail, railroads are quite economical and developed in Western Europe; with regard to travelling from Bangladesh to Amsterdam by air, Bangladesh has become a new connecting place in East Asia from China's inland transport; and in relation to the routes from Hamburg and London to Shanghai and Tokyo, those three cities boast high quantities of trade, and they contain substantial sea ports as well.

The figure of AKE—air not required—in Eurasia's long-distance city pairs demonstrates that transporting goods from Amsterdam to London by rail is quite popular. The reason is the same as that for scenario 1: the advanced railway construction in western Europe leads to the low cost of transporting goods across the whole of Europe at a high speed.

Other popular routes are the same as in scenario 1: from Hamburg to Shanghai by air and Tokyo to Amsterdam by air as well as Singapore to Amsterdam by air. Only one different route appeared, which is from Shanghai to Singapore by road. The reason is that Singapore is a South Asian country with an important transportation junction—the Straits of Malacca. Therefore, to transit in Singapore is quite popular in Asia.



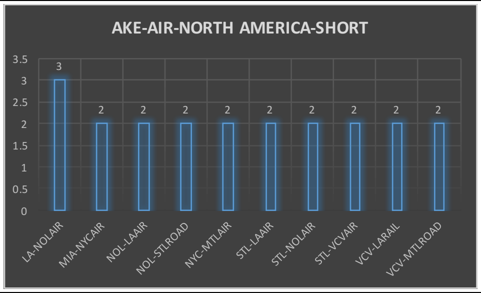


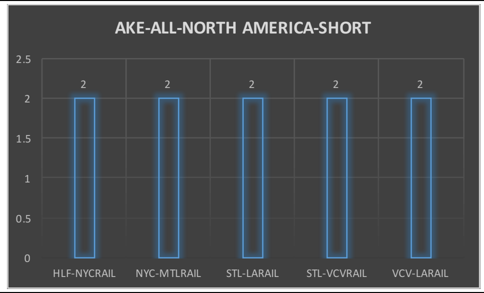
The figure above presents the most popular short-distance route in North America when transporting small cargo: transport by air or using an air-rail combination.

The most popular transport mode is to travel by rail or by road.

The road-only mode, air-rail combination, and road-rail combination are ranked third in popularity in transport mode combinations.

This means that railway transport is quite developed in North America, and it is fairly economical, with less transport costs and high transport speeds.



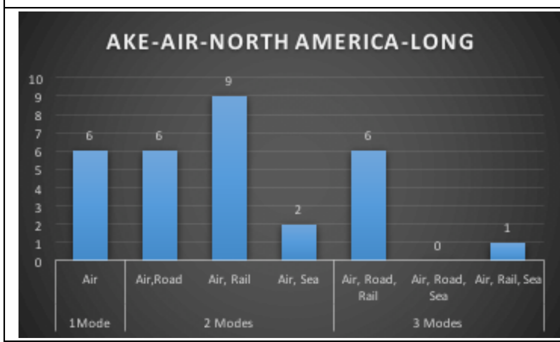


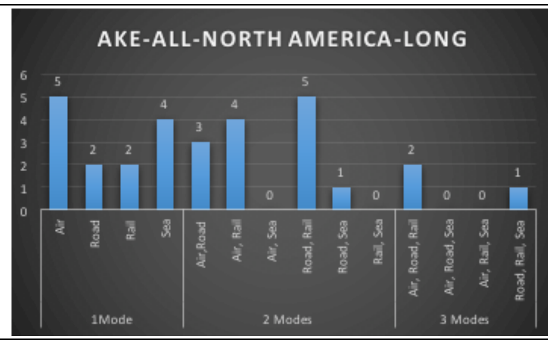
The figure above indicates that transportation from Los Angeles to New Orleans by air ranked first.

In other frequent combinations of origin and destination (OD) pairs, almost all transport modes include air transport mode. Only two of them are by road: New Orleans to Seattle and Vancouver to Montreal.

The transport price is low in those two itineraries, and transport transit times are long.

The most popular combination of OD pairs are Halifax-New York by rail, New York-Montreal by rail, Seattle-Los Angeles by rail, Seattle-Vancouver by rail, and Vancouver-Los Angeles by rail. In the AKE scenario without air, we can see that the railway transport mode is becoming a major transport method in North America.

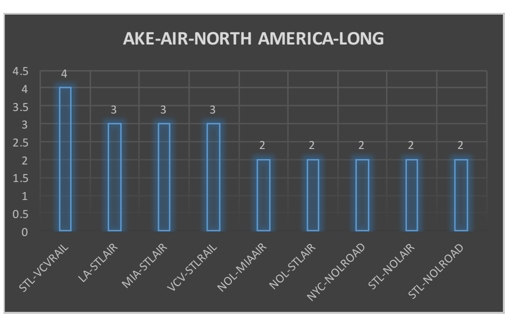


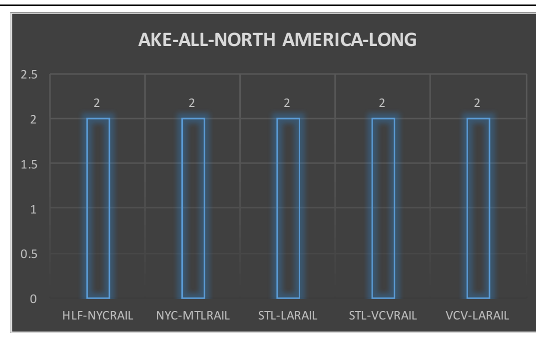


For long-distance city pairs in North America, transporting AKE cargo is more profitable when done using a two- or three-mode combination. The air-rail and air-road combinations are the two most efficient ways to transport goods over a long-distance journey. The air, road, and rail combination is the most valuable of all three-mode combinations.

The long-distance journey for transporting AKE cargo in North America, when the air mode is not required, is quite different from the situation in AKE with air.

Transportation by air and sea are the two most efficient ways of transporting using a one-mode combination, while road-rail, air-rail, and air-road are the most efficient two-mode combinations.





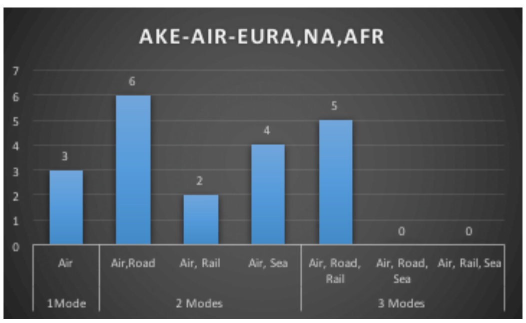
The routes for transporting AKE cargo in North America in long-distance city pairs are most frequently from Seattle to Vancouver by rail, from Los Angeles to Seattle by air, from Miami to Seattle by air, and Vancouver to Seattle by rail.

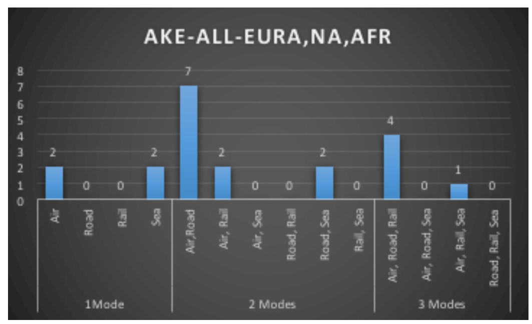
Seattle is an important transit city between America and Canada, both in air and railway transport.

When the air mode is not required in the multimodal transport system, transporting AKE cargo in North America between the long-distance city pairs is most frequently done using railway transport.

The figure above demonstrates that the most frequently used transport routes in North America are from Halifax to New York City by rail, New York to Montreal by rail, Seattle to Los Angeles by rail, Seattle to Vancouver by rail, and Vancouver to Los Angeles by rail.

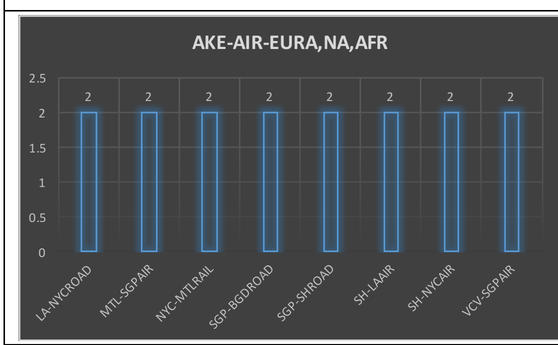
Railway is an important transport mode in North America because the railway transport system is quite developed. Furthermore, the average transportation cost per product is much lower than for road and air, and the transport time is much less than that of the sea mode. Therefore, transportation by railroad has great potential in the multimodal transport system.

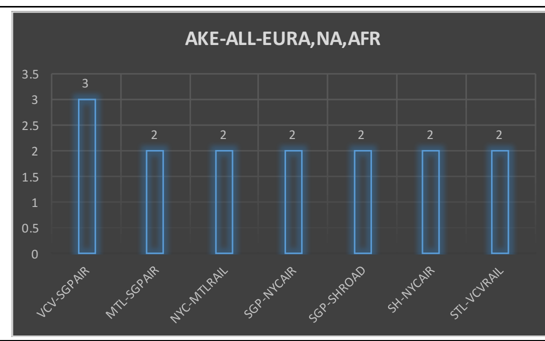




The air-road and air-sea modes are the two most efficient two-mode combinations for transporting one AKE cargo across the continent, and air-road-rail is the most efficient three-mode combination.

Two-mode combinations are the most popular methods; i.e., using two of the four typical modes, and the air-road combination is the most popular of these combinations. This means that using the combination of air and road modes to transport one AKE cargo across the continent will reduce total cost the most.

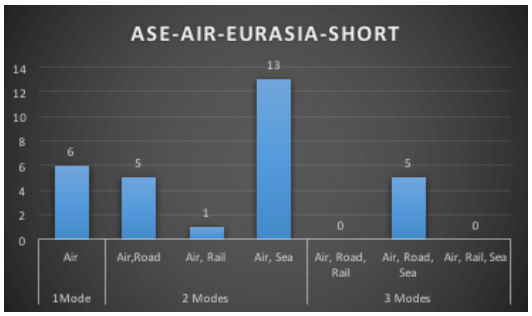


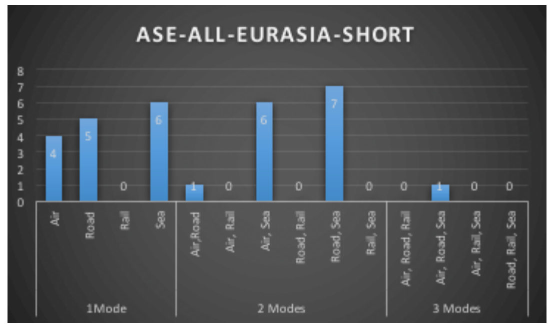


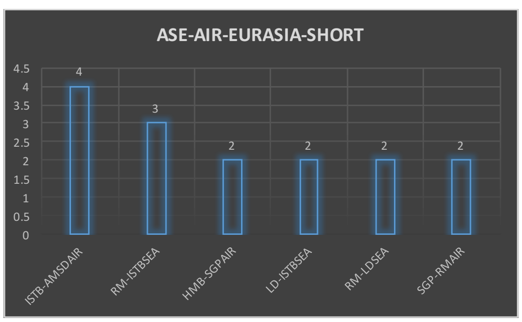
The most popular routes are from Los Angeles to New York by road, Montreal to Singapore by air, New York to Montreal by rail, Singapore to Bangladesh by road, Singapore to Shanghai by road, Shanghai to

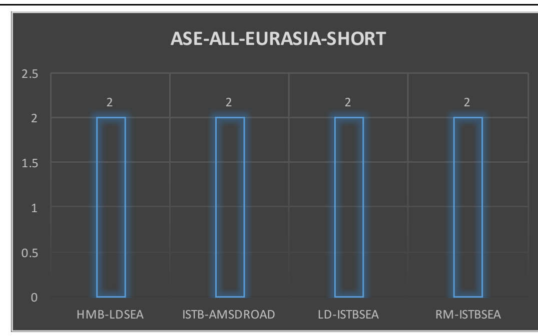
The cross-continent route situation in the "air not required involvement" scenario, when transporting one AKE cargo, is similar to that in the "with air involvement" scenario. The repeated routes are Vancouver to Singapore by air, Montreal to Singapore by air,

Los Angeles by air, Shanghai to New York by air, and Vancouver to Singapore by air. The air mode involved in these combinations is easy to understand—those air routes are the cheapest and offer the highest speeds.	New York to Montreal by rail, Singapore to Shanghai by road, and Shanghai to New York by air, and the two different routes are from Singapore to New York by air and Seattle to Vancouver by rail.

<table>
<tr><th><u>Scenario 2: ASE(Big cargo)—with air</u></th><th><u>Scenario 4: ASE(Big cargo)—air not required</u></th></tr>
<tr><td>


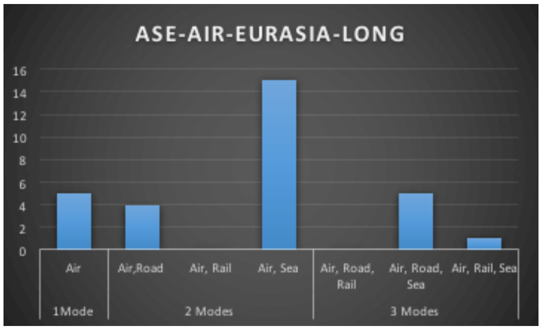
</td><td>


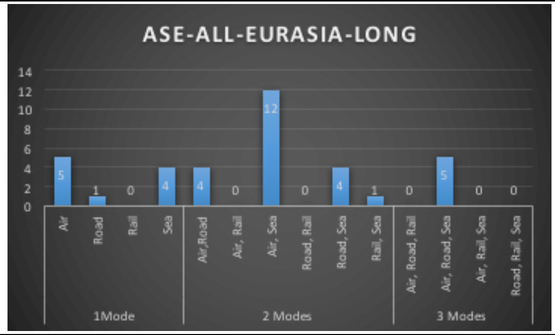
</td></tr>
<tr><td>In the section of short-distance transport in Eurasia, the most popular transport mode is an air-sea combination in the scenario of ASE with air. This means that this combination is the most effective method for transporting one large cargo within Eurasia over a short distance.</td><td>To transport large cargos between short-distance city pairs in Eurasia when the air mode is not required, one- and two-mode combinations are both effective. Transportation by road or sea, and an air-sea or road-sea combination are all cost-effective and transit-time efficient.</td></tr>
<tr><td>


</td><td>


</td></tr>
<tr><td>The most frequent itineraries in short-distance travel in Eurasia are Istanbul-Amsterdam by air, then Rome-Istanbul by the sea, and finally London-Istanbul by sea, Rome-London by sea, and Singapore-Rome by air.</td><td>With the possibility of air transport not being required, the most popular routes in Eurasia for short-distance journeys are Hamburg-London by sea, Istanbul-Amsterdam by road, London-Istanbul by sea, and Rome-Istanbul by sea.

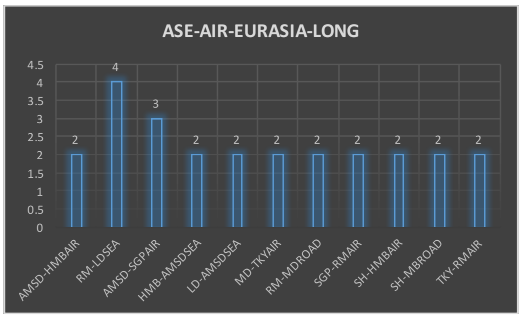
We can see that in both scenarios 2 and 4, the city of Istanbul frequently appears in the statistics. The reason Istanbul is so popular is that it is at the conjunction of Asia and Europe, sharing the same responsibility for the city of Moscow, and transport costs will be reduced from Istanbul to western Europe.</td></tr>
</table>

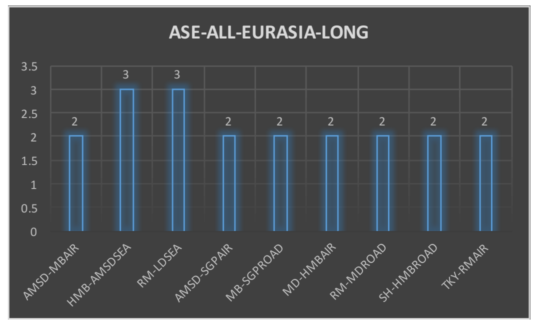




To transport large cargos in Eurasia between long-distance city pairs, the air and sea combination is most profitable due to the cost and time analysis.

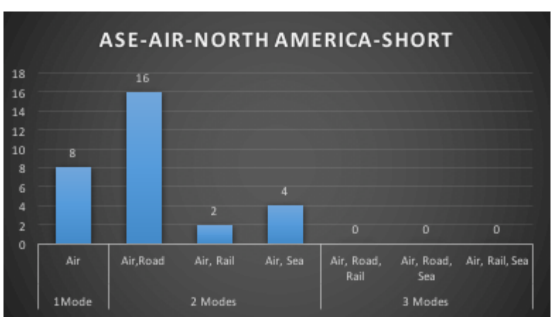
When the air mode is not required, the air-sea combination is still the top transport combination, which means that in long-distance transportation, the air mode is important for ensuring the service level.

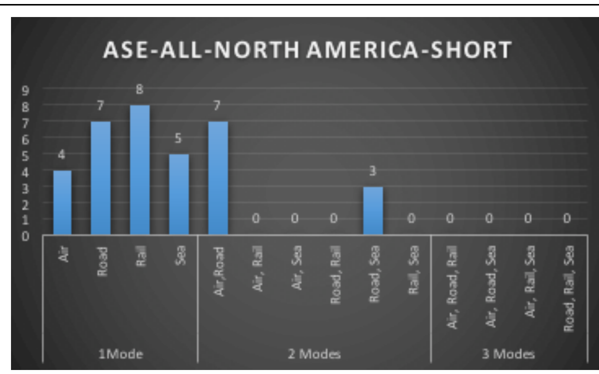




The most popular routes here are from Rome to London by sea and Amsterdam to Singapore by air. The reason is the same as in western Europe: inland waterway transportation is fast and cheap, and traveling from Amsterdam to Singapore by air is cheap, Also, these two cities are the two top sea ports in the world; goods from other parts of the world will gather in those two cities for transport to other parts of the word.

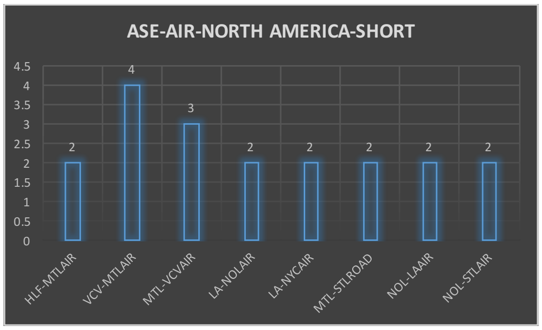
When the air mode is not required for transporting ASE cargos, the itineraries of Hamburg-Amsterdam by sea and Rome-London by sea are the two most frequent routes. Others are either by road or by air. The reason is also the same as for scenario 3: transporting heavy goods between long-distance city pairs in Eurasia often involves transferring goods in the cities of Rome, Amsterdam, London, and Hamburg, and then transporting within western Europe by sea.



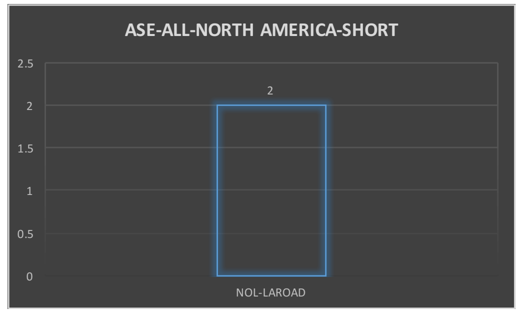


Transporting a large cargo (ASE cargo) between short-distance city pairs in North America occurs mostly by the air-road mode combination.

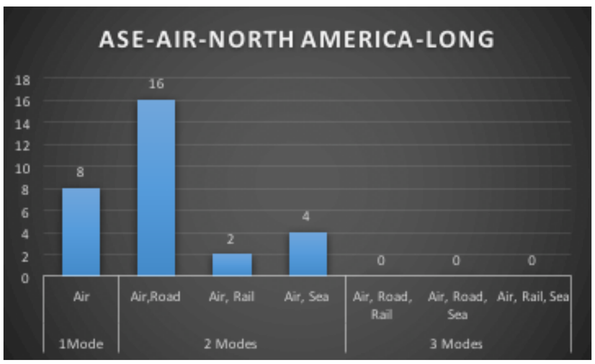
When the air mode is not required, the optimal plan will be altered to one-mode transport, such as road only or rail only in North America. However, the air and road combination is still a suitable option.



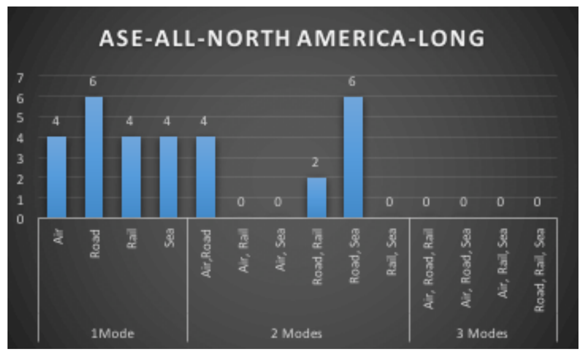
The most frequently listed city-pair transport mode combinations are from Vancouver to Montreal by air and from Montreal to Vancouver by air. This is because when the air mode is required, the itinerary of Montreal-Vancouver presented as the most effective route.



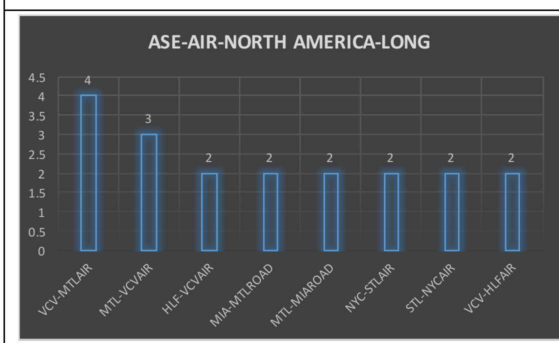
When the air mode is not required in heavy cargo transport within North America, the most frequent route is from New Orleans to Los Angeles by road. The reason is that to travel from south to west, the air mode is quite expensive; road transport is much cheaper and still maintains a similar speed.



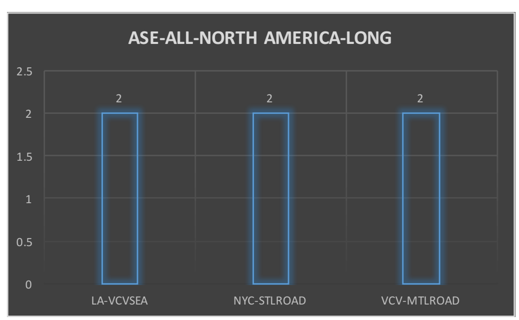
The transport of ASE cargo between long-distance city pairs in North America, with the air mode, utilizes a combination of air and road the most. The result is quite different from that of the AKE cargo transportation: railway transport is no longer the best choice in North America. On the contrary, transporting large cargo by road is more profitable.



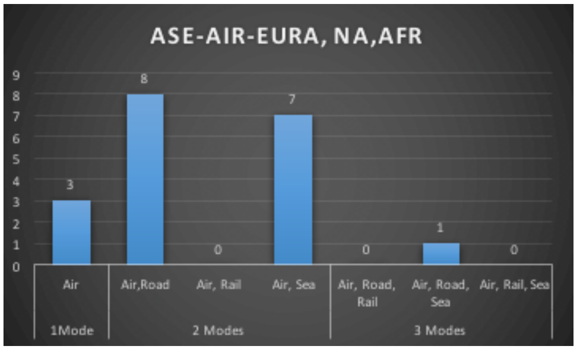
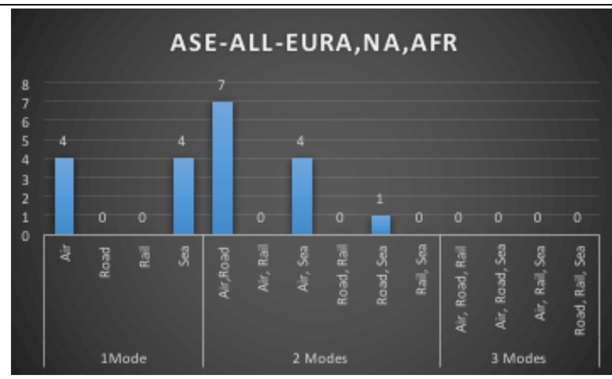
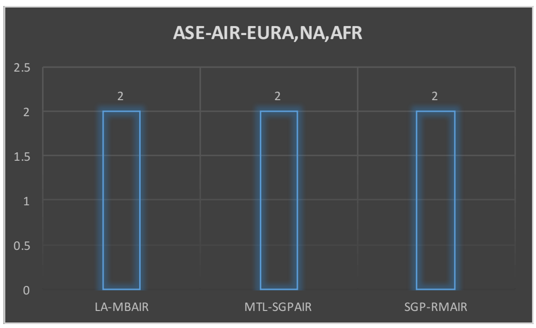
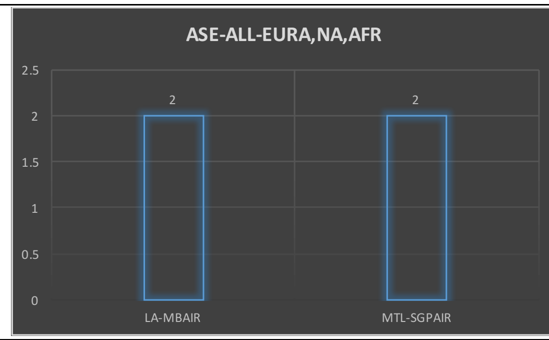
The North American short distance section is quite different from that in scenario 2. Transportation by the road-sea mode combination and by road only are the two most frequently used combinations.



The most popular route for transporting one ASE cargo between long-distance city pairs in North America is from Vancouver to Montreal by air, which means that transit in either the city of Montreal or Vancouver will reduce the total cost while retaining high transport speeds.



When the air mode is not required, transporting one ASE cargo between long-distance city pairs in North America is occurs mostly from Los Angeles by road, from New York to Seattle by road, and from Vancouver to Montreal by road.

	Compared to the result in scenario 3, the road mode is an alternative to the air transportation mode.
	
To transport ASE cargo across the continent, a two-mode multimodal transportation combination is employed. The air-road and air-sea combinations are the top two options.	When the air mode is not required, air-road and air-sea combinations are still the top two options, which means that the air mode is significant for long-distance transportation.
	
The most frequently appearing city pairs and transportation mode combination are from Los Angeles to Mumbai by air, Montreal to Singapore by air, and Singapore to Rome by air.	The results here are similar to those of scenario 3; however, travel from Singapore to Rome by air does not appear in this section. This means that Los Angeles, Mumbai, Montreal, and Singapore are four important transit cities for transporting heavy cargo across continents when the origins and destinations are located in North America and East Asia respectively.

The table below lists the general information of four scenarios (AKE—with air, AKE—air not required, ASE—with air, and ASE—air not required) in terms of optimal plans (by intuition) and their transport mode combinations, average total transport costs, and average total transport times in different regions with various situations. Comparing those criteria with different scenarios can provide us with a better view of the differences and similarities between each situation in each scenario.

From the table below, we can see that average transport costs (among the five top plans) in a situation of "air not required" are less than those in a situation of "air required."

Table 33. Detailed comparison of four scenarios

		AKE—with air	AKE—air not required	ASE—with air	ASE—air not required
Short distance					
Eurasia	Optimal plans	Mostly highest-speed plans	Lowest-cost or alternative plans	Lowest-cost or alternative plans	Highest-speed or alternative plans
	Optimal plan transport modes	Air only	Road or rail only	Air-road or air-sea	Road, sea only, or air-sea
	Average transport cost (among top 5 plans)	3,340.07	1,799.64	27,173.44	14,586.50
	Average transport time (among top 5 plans)	19.84	15.61	26.29	24.99
North America	Optimal plans	Mostly highest-speed plans	Mostly highest-speed plans	Alternative plans	Lowest-cost or alternative plans
	Optimal plan transport modes	Air only	Mostly rail only	Air-road	Road or sea only
	Average transport cost (among top 5 plans)	2,390.74	1,585.98	30,640.05	21,158.92
	Average transport time (among top 5 plans)	10.15	12.06	24.64	20.38
Long distance					
Eurasia	Optimal plans	Lowest-cost or alternative plans	Mostly alternative plans	Alternative or lowest-cost plans	Mostly alternative plans
	Optimal plan transport modes	Air-rail, air-road, or air-sea	Air-road, air-rail, or air-road-rail	Air-road, air-sea, or air-road-sea	Air-road, air-sea, or air-road-sea
	Average transport cost (among top 5 plans)	3,764.22	3,378.87	29,975.35	25,883.18
	Average transport time (among top 5 plans)	16.58	18.93	27.84	24.84
North America	Optimal plans	Lowest-cost or alternative plans	Mostly alternative plans	Lowest-cost or alternative plans	Alternative or lowest-cost plans
	Optimal plan transport modes	Air-road or air-road-rail	Air-rail, air-road-rail, or road-rail	Air-road or air-sea	Road or rail only

	Average transport cost (among top 5 plans)	2,807.63	2,323.76	30,199.83	20,259.98
	Average transport time (among top 5 plans)	12.73	14.32	23.15	23.31
Eurasia, North America, and Africa	Optimal plans	Half highest-speed and half alternative plans	Half highest-speed and half alternative plans	Lowest-cost or alternative plans	Alternative plans
	Optimal plan transport modes	Air only, air-rail, or air-road	Air-road, air-rail, or air only	Air-road	Air-road
	Average transport cost (among top 5 plans)	5,049.93	4,888.68	31,637.21	27,884.75
	Average transport time (among top 5 plans)	18.61	18.49	22.59	24.60

5.1.3 Sensitivity analysis—varying product value from $10/kg to $1,500/kg

The sensitivity analysis aims to vary the value of low-value and high-value products. The exact boundaries of these two types of products should be validated by the method of sensitivity analysis, through which we can observe the changing point of the old optimal plan to the new one in each city pair, in every scenario, with different thresholds.

5.1.3.1 Scenario 1: AKE—with air

The color red is used to mark the best original plan among the selected top five plans of each city pair. Furthermore, the color green indicates the new optimal plan with new itineraries, and the color orange represents the overlapped result of the new optimal plan and the best original plan.

For the sensitivity analysis, a value growth rate of 100% was used based on the value of between $100/kg and $1,500/kg.

The blue color represents the lowest-cost plan's changing point, while green represents the optimal plan's changing point.

In this scenario, we test the optimal plan's changing point in terms of a change of value when transporting an AKE cargo—with air.

5.1.3.1.1 Eurasia

5.1.3.1.1.1 Short distance

Table 34. Sensitivity analysis of AKE with air in Eurasia—short distance

		City pairs	Plans	Transit cities			Price-$	Total time-d	Total cost-$($10/kg)	Vaule growth rate of 100% based on value of $100/kg														
										100.00	200.00	300.00	400.00	500.00	600.00	700.00	800.00	900.00	1000.00	1100.00	1200.00	1300.00	1400.00	1500.00
Short distance	East	SH-SGP	Lowest cost	SH-SGP			1601.00	6.50	1657.00	2166.59	2732.18	3297.77	3863.36	4428.95	4994.53	5560.12	6125.71	6691.30	7256.89	7822.48	8388.07	8953.66	9519.25	10084.8
				AIR																				
				1601.00																				
				6.5d																				
			Highest speed	SH-SGP			1601.00	6.50	1657.00	2166.59	2732.18	3297.77	3863.36	4428.95	4994.53	5560.12	6125.71	6691.30	7256.89	7822.48	8388.07	8953.66	9519.25	10084.8
				AIR						1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				1601.00																				
				6.5d																				
			Alternative 1	SH-BGD	BGD-SGP		4742.00	17.50	4894.27	6264.74	7787.48	9310.22	10832.95	12355.70	13878.44	15401.18	16923.92	18446.65	19969.40	21492.14	23014.88	24537.62	26060.35	27583.1
				ROAD	AIR					1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				825.00	3917.00																			
				6d	10.5d																			
			Alternative 2	SH-TKY	TKY-SGP		2516.00	24.00	2724.83	4604.33	6692.66	8780.99	10869.32	12957.64	15045.97	17134.30	19222.63	21310.95	23399.29	25487.62	27575.95	29664.27	31752.60	33840.9
				SEA	AIR					1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				602.50	1193.50																			
				6d	10.5d																			
			Alternative 3	SH-MB	MB-BGD	BGD-SGP	5424.75	27.09	5660.45	7781.95	10139.15	12496.35	14853.55	17210.75	19567.95	21925.15	24282.35	26639.55	28996.75	31353.95	33711.15	36068.35	38425.57	40782.7
				ROAD	RAIL	AIR				1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				825.00	682.75	3917.00																		
				9d	5.59d	10.5d																		
		SGP-SH	Lowest cost	SGP-LD	LD-SH		1138.00	39.00	1477.35	4531.53	7925.07	11318.60	14712.14	18105.67	21499.21	24892.74	28286.27	31679.81	35073.34	38466.88	41860.41	45253.95	48647.48	52041.0
				SEA	AIR																			
				420.00	718.00																			
				28d	9d																			
			Highest speed	SGP-SH			1465.50	7.00	1526.41	2074.60	2683.69	3292.79	3901.88	4510.98	5120.08	5729.17	6338.27	6947.36	7556.46	8165.55	8774.65	9383.75	9992.84	10601.9
				AIR						BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				1465.50																				
				7d																				
			Alternative 1	SGP-BGD	BGD-SH		4766.00	14.00	4887.82	5984.19	7202.38	8420.58	9638.77	10856.96	12075.15	13293.34	14511.53	15729.73	16947.92	18166.11	19384.30	20602.49	21820.68	23038.8
				ROAD	AIR					1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				822.00	3944.00																			
				5.5d	7.5d																			
			Alternative 2	SGP-BGD	BGD-SH		5228.50	19.14	5395.02	6893.94	8559.38	10224.83	11890.27	13555.71	15221.15	16886.60	18552.04	20217.48	21882.92	23548.36	25213.81	26879.25	28544.69	30210.1
				RAIL	AIR					1.00	1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				1284.50	3944.00																			
				10.6d	7.5d																			
			Alternative 3	SGP-MB	MB-SH		4104.00	19.50	4273.68	5800.77	7497.53	9194.30	10891.07	12587.84	14284.60	15981.37	17678.14	19374.90	21071.67	22768.44	24465.21	26161.97	27858.74	29555.5
				AIR	ROAD					1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				3282.00	822.00																			
				9.5d	9d																			
	Mddle	MB-ISTB	Lowest cost	MB-LD	LD-MSC	MSC-ISTB	1643.00	53.00	2104.17	6254.73	10866.45	15478.18	20089.90	24701.63	29313.35	33925.08	38536.81	43148.53	47760.25	52371.99	56983.71	61595.44	66207.16	70818.8
				SEA	AIR	ROAD																		
				426.00	524.50	692.50																		
				37.5d	9d	3.5d																		
			Highest speed	MB-ISTB			4577.00	10.50	4668.36	5490.64	6404.29	7317.93	8231.58	9145.22	10058.85	10972.51	11886.15	12799.79	13713.44	14627.08	15540.73	16454.37	17368.01	18281.6
				AIR						BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				4577.00						1.00	1.00	1.00	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
				10.5d																				
			Alternative 1	MB-ATHS	ATHS-ISTB		3422.00	14.30	3546.50	4666.30	5910.59	7154.89	8399.18	9643.48	10887.78	12132.07	13376.37	14620.65	15864.95	17109.25	18353.55	19597.85	20842.14	22086.4
				AIR	RAIL					BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				2304.00	1118.00																			
				9.5d	3.8d																			
			Alternative 2	MB-HMB	HMB-ISTB		5111.38	18.36	5271.15	6708.95	8306.52	9904.09	11501.66	13099.23	14696.80	16294.38	17891.95	19489.52	21087.09	22684.66	24282.23	25879.80	27477.38	29074.9
				AIR	RAIL					1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				3808.50	1302.88																			
				9.5d	7.8d																			
			Alternative 3	MB-AMSD	AMSD-ISTB		3311.75	18.96	3476.75	4961.75	6611.74	8261.74	9911.74	11561.74	13211.73	14861.73	16511.73	18161.73	19811.72	21461.72	23111.72	24761.71	26411.71	28061.7
				AIR	RAIL					BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				2444.00	867.75																			
				9.5d	8.46d																			
		ISTB-MB	Lowest cost	ISTB-SGP	SGP-MB		1595.50	70.50	2208.95	7729.97	13864.43	19998.90	26133.36	32267.83	38402.29	44536.75	50671.23	56805.69	62940.16	69074.62	75209.09	81343.55	87478.02	93612.4
				AIR	ROAD																			
				773.50	822.00																			
				62d	7.5d																			
			Highest speed	ISTB-MB			3883.00	11.50	3983.07	4883.66	5884.32	6884.97	7885.63	8886.29	9886.95	10887.60	11888.26	12888.92	13889.58	14890.23	15890.89	16891.55	17892.21	18892.8
				AIR						BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				3883.00																				
				11.5d																				
			Alternative 1	ISTB-BGD	BGD-MB		4598.00	15.50	4732.87	5946.71	7295.42	8644.14	9992.85	11341.56	12690.27	14038.99	15387.70	16736.41	18085.12	19433.84	20782.55	22131.26	23479.97	24828.6
				AIR	ROAD					BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				3776.00	822.00																			
				9.5d	5d																			
			Alternative 2	ISTB-BGD	BGD-MB		4809.38	16.09	4949.36	6209.21	7609.04	9008.87	10408.71	11808.54	13208.37	14608.21	16008.04	17407.87	18807.70	20207.54	21607.37	23007.20	24407.04	25806.8
				AIR	RAIL					BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				3776.00	1033.38																			
				9.5d	5.58d																			
			Alternative 3	ISTB-MSC	MSC-MB		4699.50	16.50	4843.07	6135.23	7570.95	9006.68	10442.40	11878.13	13313.85	14749.58	16185.31	17621.03	19056.76	20492.49	21928.21	23363.94	24799.66	26235.3
				ROAD	AIR					BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				692.50	4007.00																			
				3.5d	12d																			
	West	LD-AMSD	Lowest cost	LD-MSC	MSC-AMSD		629.00	20.00	803.03	2369.27	4109.55	5849.82	7590.10	9330.37	11070.64	12810.92	14551.19	16291.47	18031.74	19772.01	21512.29	23252.56	24992.84	26733.1
				AIR	SEA																			
				524.50	104.50																			
				9d	9d																			
			Highest speed	LD-AMSD			2794.50	9.00	2872.81	3577.62	4360.75	5143.87	5926.99	6710.12	7493.24	8276.36	9059.49	9842.61	10625.73	11408.86	12191.98	12975.10	13758.23	14541.3
				AIR						1.00	1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				2794.50						1.00	1.00	1.00	1.00	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
				9d																				
			Alternative 1	LD-MSC	MSC-AMSTD		1502.84	12.00	1607.26	2547.00	3591.17	4635.33	5679.50	6723.66	7767.83	8811.99	9856.16	10900.32	11944.48	12988.65	14032.81	15076.98	16121.14	17165.3
				AIR	ROAD					1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				524.50	978.34																			
				9d	2d																			
			Alternative 2	LD-MSC	MSC-AMSD		1080.38	16.20	1221.19	2490.00	3899.62	5309.24	6718.86	8128.48	9538.11	10947.73	12357.35	13766.97	15176.59	16586.22	17995.84	19405.46	20815.08	22224.7
				AIR	RAIL					1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				524.50	555.88																			
				9d	6.18d																			
			Alternative 3	LD-ATHS	ATHS-AMSD		1553.50	16.40	1696.17	2980.52	4407.55	5834.57	7261.60	8688.62	10115.65	11542.67	12969.70	14396.72	15823.75	17250.77	18677.80	20104.82	21531.85	22958.8
				AIR	RAIL					1.00	1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				727.50	826.00																			
				9d	6.3d																			
		AMSD-LD	Lowest cost	AMSD-SH	SH-LD		1871.50	48.50	2293.52	6091.66	10311.83	14531.99	18752.16	22972.32	27192.49	31412.65	35632.82	39852.98	44073.14	48293.31	52513.47	56733.64	60953.80	65173.9
				AIR	SEA																			
				1410.50	461.00																			
				7d	39.5d																			
			Highest speed	AMSD-LD			2865.00	9.00	2943.31	3648.12	4431.25	5214.37	5997.49	6780.62	7563.74	8346.86	9129.99	9913.11	10696.23	11479.36	12262.48	13045.60	13828.73	14611.8
				AIR						BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				2865.00																				
				9d																				
			Alternative 1	AMSD-HMB	HMB-LD		4127.38	10.08	4215.04	5004.04	5880.70	6757.36	7634.03	8510.69	9387.35	10264.02	11140.68	12017.34	12894.01	13770.67	14647.33	15523.99	16400.66	17277.3
				AIR	RAIL					BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				3179.50	947.88																			
				7d	2.07d																			
			Alternative 2	AMSD-HMB	HMB-LD		4382.00	13.50	4499.47	5556.68	6731.37	7906.05	9080.74	10255.42	11430.11	12604.79	13779.48	14954.16	16128.85	17303.53	18478.22	19652.90	20827.59	22002.2
				SEA	AIR					BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				590.50	3791.50																			
				2.5d	9d																			
			Alternative 3	AMSD-ATHS	ATHS-LD		3981.25	15.05	4112.17	5290.44	6599.64	7908.83	9218.02	10527.22	11836.41	13145.61	14454.80	15763.99	17073.19	18382.38	19691.57	21000.77	22309.96	23619.1
				AIR	RAIL					BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				3098.50	882.75																			
				7d	7.04d																			

Table 35. Optimal plan changing point in AKE with air in Eurasia—short distance

City pairs	Plans	Transit cities		Total time-d	Total cost-$($10/kg)	100.00	200.00	300.00	400.00	500.00	600.00	700.00	800.00	900.00	1000.00	1100.00	1200.00	1300.00	1400.00	1500.00
SH-SGP	Highest speed	SH-SGP		6.50	$1,657.00	2166.59	2732.18	3297.77	3863.36	4428.95	4994.53	5560.12	6125.71	6691.30	7256.89	7822.48	8388.07	8953.66	9519.25	10084.84
		AIR				1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		$1,601.00																		
		6.5d																		
SHGP-SH	Highest speed	SGP-SH		7.00	$1,526.41	2074.60	2683.69	3292.79	3901.88	4510.98	5120.08	5729.17	6338.27	6947.36	7556.46	8165.55	8774.65	9383.75	9992.84	10601.94
		AIR				BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		$1,465.50																		
		7d																		
MB-ISTB	Highest speed	MB-ISTB		10.50	$4,668.36	5490.64	6404.29	7317.93	8231.58	9145.22	10058.86	10972.51	11886.15	12799.79	13713.44	14627.08	15540.73	16454.37	17368.01	18281.66
		AIR				BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		$4,577.00				1.00	1.00	1.00	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
		10.5d																		
	Alternative 1	MB-ATHS	ATHS-ISTB	14.30	$3,546.50	4666.30	5910.59	7154.89	8399.18	9643.48	10887.78	12132.07	13376.37	14620.66	15864.96	17109.25	18353.55	19597.85	20842.14	22086.44
		AIR	RAIL			BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		$2,304.00	$1,118.00																	
		9.5d	3.8d																	
ISTB-MB	Highest speed	ISTB-MB		11.50	$3,983.07	4883.66	5884.32	6884.97	7885.63	8886.29	9886.95	10887.60	11888.26	12888.92	13889.58	14890.23	15890.89	16891.55	17892.21	18892.86
		AIR				BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		$3,883.00																		
		11.5d																		
LD-AMSD	Highest speed	LD-AMSD		9.00	$2,872.81	3577.62	4360.75	5143.87	5926.99	6710.12	7493.24	8276.36	9059.49	9842.61	10625.73	11408.86	12191.98	12975.10	13758.23	14541.35
		AIR				1.00	1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		$2,794.50				1.00	1.00	1.00	1.00	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
		9d																		
	Alternative 1	LD-MSC	MSC-AMSTD	12.00	$1,607.26	2547.00	3591.17	4635.33	5679.50	6723.66	7767.83	8811.99	9856.16	10900.32	11944.48	12988.65	14032.81	15076.98	16121.14	17165.31
		AIR	ROAD			1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		$524.50	$978.34																	
		9d	2d																	
AMSD-LD	Highest speed	AMSD-LD		9.00	$2,943.31	3648.12	4431.25	5214.37	5997.49	6780.62	7563.74	8346.86	9129.99	9913.11	10696.23	11479.36	12262.48	13045.60	13828.73	14611.85
		AIR				BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		$2,865.00																		
		9d																		

Table 34 and table 35 are the filtered tables with the optimal plan's changing points. For example, in Table 34, all the blue cells mean at specific points, the lowest cost plans change with the increase of product value, and obviously they all changed from the original lowest cost plans to the highest speed plans, with only one exception of London-Amsterdam, where the new lowest cost plan became the alternative 1 plan. And the green cells represent the specific points where new optimal plans change: all optimal plans changed from the original best plan to highest speed plans with the increased value of products. Thus, we can summarize data into Table 36 shown below.

Table 36. Comparison of old and new optimal plans (with new threshold) for AKE with air in Eurasia—short distance

City pairs	Old optimal plan (new threshold)	New optimal plan
SH-SGP	Same highest-speed plan	Same highest-speed plan
SHP-SH	Same highest-speed plan	Same highest-speed plan
MB-ISTB	Alternative1; MB-ATHS-AIR, ATHS-ISTB-RAIL; Value: $400/kg; $8,399.18, 14.3d.	Highest speed; MB-ISTB-AIR; Value: $400/kg; $8,231.58,10.5d.
ISTB-MB	Same highest-speed plan	Same highest-speed plan
LD-AMSD	Alternative1; LD-MSC-AIR, MSC-AMSD-ROAD; Value: $500/kg; $6,723.66, 12d.	Highest speed; LD-AMSD-AIR; Value: $500/kg; $6,710.12, 9d.
AMSD-LD	Same highest-speed plan	Same highest-speed plan

5.1.3.1.1.2 Long distance

Table 37. Sensitivity analysis of AKE with air in Eurasia—long distance

Long distance	East-West	SH-AMSD	Lowest cost	SH-LD	LD-MSC	MSC-AMSD	1541.38	57.68	2043.30	6560.62	11579.86	16599.10	21618.34	26637.58	31656.82	36676.06	41695.30	46714.54	51733.78	56753.02	61772.26	66791.50	71810.74	76829.9
				SEA	AIR	RAIL																		
				461.00	524.50	555.88																		
				39.5d	9d	6.2d																		
			Highest speed	SH-AMSD			11934.00	7.50	11999.26	12586.60	13239.21	13891.81	14544.41	15197.01	15849.62	16502.22	17154.82	17807.42	18460.03	19112.63	19765.23	20417.84	21070.44	21723.0
				AIR						1.00	1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				11934.00						1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	GREEN
				7.50																				
			Alternative 1	SH-HMB	HMB-AMSD		9582.63	9.57	9665.87	10415.06	11247.49	12079.92	12912.35	13744.78	14577.21	15409.64	16242.07	17074.50	17906.94	18739.37	19571.80	20404.23	21236.66	22069.0
				AIR	RAIL					1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				8718.00	864.63																			
				7.5d	1.06d																			
			Alternative 2	SH-BGD	BGD-AMSD		3555.50	14.00	3677.32	4773.69	5991.88	7210.08	8428.27	9646.46	10864.65	12082.84	13301.03	14519.23	15737.42	16955.61	18173.80	19391.99	20610.18	21828.3
				ROAD	AIR					BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				825.00	2730.50																			
				6d	7d																			
			Alternative 3	SH-BGD	BGD-AMSD		5395.63	16.07	5535.43	6793.65	8191.67	9589.69	10987.71	12385.73	13783.75	15181.77	16579.79	17977.81	19375.83	20773.85	22171.87	23569.89	24967.91	26365.9
				ROAD	AIR	RAIL				1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				825.00	3706.00	864.63																		
				6d	7d	1.06d																		
		SGP-LD	Lowest cost	SGP-SH	SH-LD		1926.50	48.50	2348.52	6146.66	10366.83	14586.99	18807.16	23027.32	27247.49	31467.65	35687.82	39907.98	44128.14	48348.31	52568.47	56788.64	61008.80	65228.9
				AIR	SEA																			
				1465.50	461.00																			
				7d	39.5d																			
			Highest speed	SGP-AMSD	AMSD-LD		6829.75	9.02	6908.24	7614.61	8399.48	9184.34	9969.20	10754.07	11538.93	12323.79	13108.66	13893.52	14678.39	15463.25	16248.11	17032.98	17817.84	18602.7
				AIR	RAIL					1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				6113.50	716.25					1.00	1.00	1.00	1.00	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
				7d	1.02d																			
			Alternative 1	SGP-HMB	HMB-LD		5537.38	10.08	5625.04	6414.04	7290.70	8167.36	9044.03	9920.69	10797.35	11674.02	12550.68	13427.34	14304.01	15180.67	16057.33	16933.99	17810.66	18687.3
				AIR	RAIL					1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				4589.50	947.88																			
				7d	2.07d																			
			Alternative 2	SGP-LD			5066.50	12.00	5170.92	6110.66	7154.83	8198.99	9243.16	10287.32	11331.49	12375.65	13419.82	14463.98	15508.14	16552.31	17596.47	18640.64	19684.80	20728.9
				AIR						BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				5066.50																				
				12d																				
			Alternative 3	SGP-BGD	BGD-AMSD	AMSD-LD	4268.75	15.52	4403.80	5619.28	6969.80	8320.33	9670.85	11021.38	12371.90	13722.43	15072.95	16423.48	17774.00	19124.53	20475.05	21825.58	23176.10	24526.6
				ROAD	AIR	RAIL				BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				822.00	2730.50	716.25																		
				5.5d	7d	1.02d																		
		TKY-HMB	Lowest cost	TKY-SGP	SGP-HMB		2390.00	40.00	2738.05	5870.55	9351.10	12831.64	16312.19	19792.74	23273.29	26753.84	30234.38	33714.93	37195.48	40676.03	44156.58	47637.12	51117.67	54598.2
				AIR	SEA																			
				1913.50	476.50																			
				10d	28d																			
			Highest speed	TKY-HMB			4448.50	7.00	4509.41	5057.60	5666.69	6275.79	6884.88	7493.98	8103.08	8712.17	9321.27	9930.36	10539.46	11148.55	11757.65	12366.75	12975.84	13584.9
				AIR						BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				4448.50						1.00	1.00	1.00	1.00	1.00	1.00	1.00	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
				7.00																				
			Alternative 1	TKY-AMSD	AMSD-HMB		3140.88	9.07	3219.77	3929.80	4718.72	5507.65	6296.57	7085.50	7874.42	8663.34	9452.27	10241.19	11030.12	11819.04	12607.97	13396.89	14185.81	14974.7
				AIR	RAIL					BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				2346.00	794.88																			
				7d	1.06d																			
			Alternative 2	TKY-AMSD	AMSD-HMB		2936.50	11.50	3036.57	3937.16	4937.82	5938.47	6939.13	7939.79	8940.45	9941.10	10941.76	11942.42	12943.08	13943.73	14944.39	15945.05	16945.71	17946.3
				AIR	SEA					BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				2346.00	590.50																			
				7d	2.5d																			
			Alternative 3	TKY-AMSD	AMSD-LD	LD-HMB	3912.75	17.02	4060.85	5393.80	6874.84	8355.89	9836.93	11317.98	12799.02	14280.07	15761.12	17242.16	18723.21	20204.25	21685.30	23166.34	24647.39	26128.4
				AIR	RAIL	SEA				BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				2346.00	716.25	850.50																		
				7d	1.02d	6d																		
	West-East	AMSD-SH	Lowest cost	AMSD-LD	LD-SH		993.50	17.00	1141.42	2472.73	3951.97	5431.20	6910.43	8389.66	9868.90	11348.13	12827.36	14306.60	15785.83	17265.06	18744.29	20223.53	21702.76	23181.9
				SEA	AIR																			
				275.50	718.00																			
				6d	9d																			
			Highest speed	AMSD-SH			1410.50	7.00	1471.41	2019.60	2628.69	3237.79	3846.88	4455.98	5065.08	5674.17	6283.27	6892.36	7501.46	8110.55	8719.65	9328.75	9937.84	10546.9
				AIR						BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				1410.50						GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
				7d																				
			Alternative 1	AMSD-HMB	HMB-SH		2049.88	9.07	2128.77	2838.80	3627.72	4416.65	5205.57	5994.50	6783.42	7572.34	8361.27	9150.19	9939.12	10728.04	11516.97	12305.89	13094.81	13883.7
				RAIL	AIR					1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				794.88	1255.00																			
				1.06d	7d																			
			Alternative 2	AMSD-LD	LD-SH		1434.25	11.02	1530.15	2393.21	3352.18	4311.14	5270.10	6229.07	7188.03	8146.99	9105.96	10064.92	11023.88	11982.85	12941.81	13900.78	14859.74	15818.7
				RAIL	AIR					BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				716.25	718.00																			
				1.02d	9d																			
			Alternative 3	AMSD-HMB	HMB-SH		1845.50	11.50	1945.57	2846.16	3846.82	4847.47	5848.13	6848.79	7849.45	8850.10	9850.76	10851.42	11852.08	12852.73	13853.39	14854.05	15854.71	16855.3
				SEA	AIR					1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				590.50	1255.00																			
				2.5d	7d																			
		LD-SGP	Lowest cost	LD-SH	SH-SGP		782.00	20.00	956.03	2522.27	4262.55	6002.82	7743.10	9483.37	11223.64	12963.92	14704.19	16444.47	18184.74	19925.01	21665.29	23405.56	25145.84	26886.1
				AIR	ROAD																			
				718.00	64.00																			
				9d	10d																			
			Highest speed	LD-SGP			2576.50	15.00	2707.02	3881.71	5186.91	6492.12	7797.32	9102.53	10407.73	11712.94	13018.14	14323.35	15628.55	16933.76	18238.97	19544.17	20849.38	22154.5
				AIR						1.00	1.00	1.00	1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				2576.50						1.00	1.00	1.00	1.00	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
				15d																				
			Alternative 1	LD-BGD	GD-SGP		1604.00	15.50	1738.87	2952.71	4301.42	5650.14	6998.85	8347.56	9696.27	11044.99	12393.70	13742.41	15091.12	16439.84	17788.55	19137.26	20485.97	21834.6
				AIR	ROAD					1.00	1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				1548.50	55.50																			
				9d	5.5d																			
			Alternative 2	LD-AMSD	AMSD-SH	SH-SGP	2173.13	20.39	2350.56	3947.48	5721.83	7496.19	9270.54	11044.90	12819.25	14593.61	16367.96	18142.31	19916.67	21691.02	23465.38	25239.73	27014.09	28788.4
				RAIL	AIR	ROAD				1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				698.63	1410.50	64.00																		
				1.39d	7d	10d																		
			Alternative 3	LD-BGD	BGD-SGP		2527.75	20.64	2707.36	4323.86	6119.97	7916.07	9712.18	11508.29	13304.40	15100.50	16896.61	18692.72	20488.83	22284.94	24081.04	25877.15	27673.26	29469.3
				AIR	RAIL					1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				1548.50	979.25																			
				9d	10.6d																			
		HMB-TKY	Lowest cost	HMB-SH	SH-TKY		1857.50	21.00	2040.23	3684.79	5512.08	7339.36	9166.65	10993.94	12821.23	14648.51	16475.80	18303.09	20130.38	21957.66	23784.95	25612.24	27439.53	29266.8
				AIR	SEA																			
				1255.00	602.50																			
				7d	12d																			
			Highest speed	HMB-TKY			3502.00	7.00	3562.91	4111.10	4720.19	5329.29	5938.38	6547.48	7156.58	7765.67	8374.77	8983.86	9592.96	10202.05	10811.15	11420.25	12029.34	12638.4
				AIR						1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				3502.00						1.00	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
				7d																				
			Alternative 1	HOM-AMSD	AMSD-TKY		5367.13	9.57	5450.37	6199.56	7031.99	7864.42	8696.85	9529.28	10361.71	11194.14	12026.57	12859.00	13691.44	14523.87	15356.30	16188.73	17021.16	17853.5
				RAIL	AIR					1.00	1.00	1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				864.63	4502.50																			
				1.06d	7.5d																			
			Alternative 2	HMB-AMSD	AMSD-TKY		4799.00	13.50	4916.47	5973.68	7148.37	8323.05	9497.74	10672.42	11847.11	13021.79	14196.48	15371.16	16545.85	17720.53	18895.22	20069.90	21244.59	22419.2
				SEA	AIR					1.00	1.00	1.00	1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				296.50	4502.50																			
				4d	7.5d																			
			Alternative 3	HMB-MSC	MSC-TKY		3209.63	14.67	3337.25	4485.83	5762.03	7038.23	8314.43	9590.63	10866.83	12143.03	13419.23	14695.43	15971.63	17247.84	18524.04	19800.24	21076.44	22352.6
				RAIL	AIR					1.00	1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
				1366.13	1843.50																			
				5.17d	8.5d																			

The table above shows general information of lowest cost switching points with blue cells and optimal plan to switch points with green cells.

Table 38. Optimal plan changing point in AKE with air in Eurasia—long distance

City pairs	Plans	Transit cities			Total time-d	Total cost-$($10/kg)	Vaule growth rate of 100% based on value of $100/kg														
							100.00	200.00	300.00	400.00	500.00	600.00	700.00	800.00	900.00	1000.00	1100.00	1200.00	1300.00	1400.00	1500.00
SH-AMSD	Highest speed	SH-AMSD			7.50	$11,999.26	12586.60	13239.21	13891.81	14544.41	15197.01	15849.62	16502.22	17154.82	17807.42	18460.03	19112.63	19765.23	20417.84	21070.44	21723.04
		AIR					1.00	1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		$11,934.00					1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	GREEN
		$7.50																			
	Alternative 2	SH-BGD	BGD-AMSD		14.00	$3,677.32	4773.69	5991.88	7210.08	8428.27	9646.46	10864.65	12082.84	13301.03	14519.23	15737.42	16955.61	18173.80	19391.99	20610.18	21828.38
		ROAD	AIR				BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		$825.00	$2,730.50																		
		6d	7d																		
SGP-LD	Highest speed	SGP-AMSD	AMSD-LD		9.02	$6,908.24	7614.61	8399.48	9184.34	9969.20	10754.07	11538.93	12323.79	13108.66	13893.52	14678.39	15463.25	16248.11	17032.98	17817.84	18602.70
		AIR	RAIL				1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		$6,113.50	$716.25				1.00	1.00	1.00	1.00	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
		7d	1.02d																		
	Alternative 3	SGP-BGD	BGD-AMSD	AMSD-LD	15.52	$4,403.80	5619.28	6969.80	8320.33	9670.85	11021.38	12371.90	13722.43	15072.95	16423.48	17774.00	19124.53	20475.05	21825.58	23176.10	24526.63
		ROAD	AIR	RAIL			BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		$822.00	$2,730.50	$716.25																	
		5.5d	7d	1.02d																	
TKY-HMB	Highest speed	TKY-HMB			7.00	$4,509.41	5057.60	5666.69	6275.79	6884.88	7493.98	8103.08	8712.17	9321.27	9930.36	10539.46	11148.55	11757.65	12366.75	12975.84	13584.94
		AIR					BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		$4,448.50					1.00	1.00	1.00	1.00	1.00	1.00	1.00	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
		7.00																			
	Alternative 1	TKY-AMSD	AMSD-HMB		9.07	$3,219.77	3929.80	4718.72	5507.65	6296.57	7085.50	7874.42	8663.34	9452.27	10241.19	11030.12	11819.04	12607.97	13396.89	14185.81	14974.74
		AIR	RAIL				BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		$2,346.00	$794.88																		
		7d	1.06d																		
AMSD-SH	Lowest cost	AMSD-LD	LD-SH		17.00	$1,141.42	2472.73	3951.97	5431.20	6910.43	8389.66	9868.90	11348.13	12827.36	14306.60	15785.83	17265.06	18744.29	20223.53	21702.76	23181.99
		SEA	AIR																		
		$275.50	$718.00																		
		6d	9d																		
	Highest speed	AMSD-SH			7.00	$1,471.41	2019.60	2628.69	3237.79	3846.88	4455.98	5065.08	5674.17	6283.27	6892.36	7501.46	8110.55	8719.65	9328.75	9937.84	10546.94
		AIR					BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		$1,410.50					GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
		7d																			
LD-SGP	Lowest cost	LD-SH	SH-SGP		20.00	$956.03	2522.27	4262.55	6002.82	7743.10	9483.37	11223.64	12963.92	14704.19	16444.47	18184.74	19925.01	21665.29	23405.56	25145.84	26886.11
		AIR	ROAD																		
		$718.00	$64.00																		
		9d	10d																		
	Highest speed	LD-SGP			15.00	$2,707.02	3881.71	5186.91	6492.12	7797.32	9102.53	10407.73	11712.94	13018.14	14323.35	15628.55	16933.76	18238.97	19544.17	20849.38	22154.58
		AIR					1.00	1.00	1.00	1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		$2,576.50					1.00	1.00	1.00	1.00	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
		15d																			
HMB-TKY	Lowest cost	HMB-SH	SH-TKY		21.00	$2,040.23	3684.79	5512.08	7339.36	9166.65	10993.94	12821.23	14648.51	16475.80	18303.09	20130.38	21957.66	23784.95	25612.24	27439.53	29266.82
		AIR	SEA																		
		$1,255.00	$602.50																		
		7d	12d																		
	Highest speed	HMB-TKY			7.00	$3,562.91	4111.10	4720.19	5329.29	5938.38	6547.48	7156.58	7765.67	8374.77	8983.86	9592.96	10202.05	10811.15	11420.25	12029.34	12638.44
		AIR					1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		$3,502.00					1.00	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
		7d																			

The table above is the filtered table with the optimal plan's switching points. To summarize the information, the table below compares the old optimal plan—with a new threshold—to the new optimal plan.

Table 39. Comparison of old and new optimal plans (with new threshold) for AKE with air in Eurasia—long distance

City pairs	Old optimal plan (new threshold)	New optimal plan
SH-AMSD	Alternative 2; SH-BGD-ROAD, BGD-AMSD-AIR; Value: $1,500/kg; $21,828.38, 14d.	Highest speed; SH-AMSD-AIR; Value: $1,500/kg; $21,723.04, 7.5d.
SGP-LD	Alternative 3; SGP-BGD-ROAD, BGD-AMSD-AIR, AMSD-LD-RAIL; Value: $500/kg; $11,021, 15d.	Highest speed; SGP-AMSD-AIR, AMSD-LD-RAIL; Value: $500/kg; $10,754.06, 9.02d.
TKY-HMB	Alternative 1; TKY-AMSD-AIR, AMSD-HMB-RAIL; Value: $800/kg; $9,452.27, 9.07d.	Highest speed; TKY-HMB-AIR; Value: $800/kg $9,321.27, 7d.
AMSD-SH	Lowest cost; AMSD-LD-SEA, LD-SH-AIR; Value: $100/kg $2,472.13, 17d.	Highest speed; AMSD-SH-AIR; Value: $100/kg; $2,019.60, 7d.
LD-SGP	Lowest cost; LD-SH-AIR, SH-SGP-ROAD; Value: $500/kg; $9,483.37, 20d.	Highest speed; LD-SGP-AIR; Value: $500/kg; $9,102.53, 15d.
HMB-TKY	Lowest cost; HMB-SH-AIR, SH-TKY-SEA; Value: $200/kg; $5,512.08, 21d.	Highest speed; HMB-TKY-AIR; Value: $200/kg; $4,720.19, 7d.

SH-AMSD	Lowest cost	SH-LD	LD-MSC	MSC-AMSD		$1,541.38	3	$2,043.30	$1.29	57.68
		SEA	AIR	RAIL						
		$461.00	$524.50	$555.88						
		39.5d	9d	6.2d						
	Highest speed	SH-AMSD				$11,934.00	0	$11,999.26	$7.56	7.50
		AIR								
		$11,934.00								
		$7.50								
	Alternative 1	SH-HMB	HMB-AMSD			$9,582.63	1	$9,665.87	$6.09	9.57
		AIR	RAIL							
		$8,718.00	$864.63							
		7.5d	1.06d							
	Alternative 2	SH-BGD	BGD-AMSD			$3,555.50	1	$3,677.32	$2.32	14.00
		ROAD	AIR							
		$825.00	$2,730.50							
		6d	7d							
	Alternative 3	SH-BGD	BGD-AMSD			$5,395.63	2	$5,535.43	$3.49	16.07
		ROAD	AIR	RAIL						
		$825.00	$3,706.00	$864.63						
		6d	7d	1.06d						

To explain one detailed cost example for the city pairs SH-AMSD, the old optimal plan was alternative 2; which is to transport from Shanghai to Bangladesh by road, then from Bangladesh to Amsterdam by road, when the value is less than $1500/kg, with total cost of $21,828.38, total transport time of 14 days.

And the new optimal plan is the highest-speed plan; which is from Shanghai to Amsterdam by air, when the value is more than $1,500/kg, with the total cost of $21,723.04, total transport time of 7.5 days.

The total delay time for Alternative 2 is 1 day, and the transit time of SH-BGD by road is 6 days; then, BGD-AMSD is 7 days, so the total transport time is 14 days. Furthermore, the price to travel from SH to BGD by road is $825, and then, from BGD-AMSD by air costs $2,730.50; therefore, the total price is $3,555.50. With the growth of the value of the product, the holding cost varies. Through the sensitivity analysis, we found that when the value of the product increased to $1,500/kg, the holding cost was 14 days/365 days * 1,588 kg * $1,500/kg * 20% = $18,272.87, so the total cost is $3,555.50 + $18,272.87 = $21,828.38.

To use the same method to calculate the plan of highest speed from SH-AMSD, we obtained the result of a total cost of $21,723.04 and a total transport time of 7.5 days.

The threshold value for the Shanghai-to-Amsterdam city pair is $1,500/kg. Therefore, the best present plan is ideal for values less than $1,500/kg, and the new optimal plan becomes more economical for values starting at $1,500/kg.

5.1.3.2 Scenario 2: ASE—with air

Scenario 2 aims to test the changing points of optimal plans when transporting one ASE (heavy) cargo between each city pair with the involvement of air transport modes. Then, we compare the old optimal plans (with a new threshold) and the new optimal plans, in terms of the optimal plans' names, itineraries, total transport costs and total transport times, at specific product values.

5.1.3.2.1 Eurasia

5.1.3.2.1.1 Short distance

Table 40. Sensitivity analysis of ASE with air in Eurasia—short distance

		City pairs	Plans	Transit cities			Price-$	Total time-d	Total cost-$	Vaule growth rate of 100% based on value of $100/kg														
										100.00	200.00	300.00	400.00	500.00	600.00	700.00	800.00	900.00	1000.00	1100.00	1200.00	1300.00	1400.00	1500.00
Short distance	East	SH-SGP	Lowest cost	SH-ISTB	ISTB-SGP		11466.50	109.50	18270.50	11466.50	11466.50	11466.50	11466.50	11466.50	11466.50	11466.50	11466.50	11466.50	11466.50	11466.50	11466.50	11466.50	11466.50	11466.50
				SEA	AIR																			
				3729.00	7737.50																			
				45.5d	62d																			
			Highest speed	SH-SGP			19754.50	10.00	20375.87	19754.50	19754.50	19754.50	19754.50	19754.50	19754.50	19754.50	19754.50	19754.50	19754.50	19754.50	19754.50	19754.50	19754.50	19754.50
				AIR																				
				19754.50																				
				10d																				
			Alternative 1	SH-HMB	HMB-SGP		47141.48	16.20	48148.10	47141.48	47141.48	47141.48	47141.48	47141.48	47141.48	47141.48	47141.48	47141.48	47141.48	47141.48	47141.48	47141.48	47141.48	47141.48
				ROAD	AIR																			
				17453.48	29688.00																			
				7.2d	8d																			
			Alternative 2	SH-BGD	BGD-SGP		43943.50	23.00	45372.65	43943.50	43943.50	43943.50	43943.50	43943.50	43943.50	43943.50	43943.50	43943.50	43943.50	43943.50	43943.50	43943.50	43943.50	43943.50
				AIR	ROAD																			
				43507.50	436.00																			
				16.5d	5.5d																			
			Alternative 3	SH-HMB	HMB-SGP		39604.75	23.40	41058.76	39604.75	39604.75	39604.75	39604.75	39604.75	39604.75	39604.75	39604.75	39604.75	39604.75	39604.75	39604.75	39604.75	39604.75	39604.75
				RAIL	AIR																			
				9916.75	29688.00																			
				14.4d	8d																			
		SGP-SH	Lowest cost	SGP-RM	RM-MD	MD-SH	11051.00	61.50	14872.42	11051.00	11051.00	11051.00	11051.00	11051.00	11051.00	11051.00	11051.00	11051.00	11051.00	11051.00	11051.00	11051.00	11051.00	11051.00
				AIR	ROAD	SEA																		
				8626.00	790.00	1635.00																		
				10.00	5.00	43.50																		
			Highest speed	SGP-SH			45627.00	11.50	46341.58	45627.00	45627.00	45627.00	45627.00	45627.00	45627.00	45627.00	45627.00	45627.00	45627.00	45627.00	45627.00	45627.00	45627.00	45627.00
				AIR																				
				45627.00																				
				11.5d																				
			Alternative 1	SGP-MB	MB-SH		51738.50	22.00	53105.51	51738.50	51738.50	51738.50	51738.50	51738.50	51738.50	51738.50	51738.50	51738.50	51738.50	51738.50	51738.50	51738.50	51738.50	51738.50
				ROAD	AIR																			
				5959.00	45779.50																			
				7d	14d																			
			Alternative 2	SGP-MB	MB-SG		33773.50	22.50	35171.58	33773.50	33773.50	33773.50	33773.50	33773.50	33773.50	33773.50	33773.50	33773.50	33773.50	33773.50	33773.50	33773.50	33773.50	33773.50
				AIR	ROAD																			
				27814.50	5959.00																			
				12.5d	9d																			
			Alternative 3	SGP-HMB	HMB-SH		41100.00	37.50	43430.14	41100.00	41100.00	41100.00	41100.00	41100.00	41100.00	41100.00	41100.00	41100.00	41100.00	41100.00	41100.00	41100.00	41100.00	41100.00
				SEA	AIR																			
				2831.00	38269.00																			
				25.5d	10d																			
	Mddle	MB-ISTB	Lowest cost	MB-SGP	SGP-RM	RM-ISTB	11382.50	31.00	13308.75	11382.50	11382.50	11382.50	11382.50	11382.50	11382.50	11382.50	11382.50	11382.50	11382.50	11382.50	11382.50	11382.50	11382.50	11382.50
				ROAD	AIR	SEA																		
				514.00	8626.00	2242.50																		
				7.50	10.00	10.50																		
			Highest speed	MB-ISTB			71450.00	10.00	72071.37	71450.00	71450.00	71450.00	71450.00	71450.00	71450.00	71450.00	71450.00	71450.00	71450.00	71450.00	71450.00	71450.00	71450.00	71450.00
				AIR																				
				71450.00																				
				10d																				
			Alternative 1	MB-RM	RM-ISTB		19040.00	22.00	20407.01	19040.00	19040.00	19040.00	19040.00	19040.00	19040.00	19040.00	19040.00	19040.00	19040.00	19040.00	19040.00	19040.00	19040.00	19040.00
				AIR	SEA																			
				16797.50	2242.50																			
				9.5d	10.5d																			
			Alternative 2	MB-HMB	HMB-IST		21609.00	27.50	23317.77	21609.00	21609.00	21609.00	21609.00	21609.00	21609.00	21609.00	21609.00	21609.00	21609.00	21609.00	21609.00	21609.00	21609.00	21609.00
				AIR	SEA																			
				17952.50	3656.50																			
				9.5d	16d																			
			Alternative 3	MB-BGD	BGD-RM	RM-ISTB	16827.50	28.50	18598.40	16827.50	16827.50	16827.50	16827.50	16827.50	16827.50	16827.50	16827.50	16827.50	16827.50	16827.50	16827.50	16827.50	16827.50	16827.50
				ROAD	AIR	SEA																		
				5959.00	8626.00	2242.50																		
				5d	10d	10.5d																		
		ISTB-MB	Lowest cost	ISTB-AMSD	AMSD-MB		7214.33	45.98	10071.53	7214.33	7214.33	7214.33	7214.33	7214.33	7214.33	7214.33	7214.33	7214.33	7214.33	7214.33	7214.33	7214.33	7214.33	7214.33
				AIR	SEA																			
				3770.83	3443.50																			
				3.48	40.50																			
			Highest speed	ISTB-MB			27092.00	10.50	27744.44	27092.00	27092.00	27092.00	27092.00	27092.00	27092.00	27092.00	27092.00	27092.00	27092.00	27092.00	27092.00	27092.00	27092.00	27092.00
				AIR																				
				27092.00																				
				10.5d																				
			Alternative 1	ISTB-AMSD	ASMD-MB		27938.17	24.54	29462.74	27938.17	27938.17	27938.17	27938.17	27938.17	27938.17	27938.17	27938.17	27938.17	27938.17	27938.17	27938.17	27938.17	27938.17	27938.17
				ROAD	AIR																			
				1659.17	26279.00																			
				12.5d	11d																			
			Alternative 2	ISTB-MD	MD-MB		24465.50	28.00	26205.34	24465.50	24465.50	24465.50	24465.50	24465.50	24465.50	24465.50	24465.50	24465.50	24465.50	24465.50	24465.50	24465.50	24465.50	24465.50
				SEA	AIR																			
				2979.00	21486.50																			
				14d	12d																			
			Alternative 3	ISTB-LD	LD-MB		26746.50	30.50	28641.68	26746.50	26746.50	26746.50	26746.50	26746.50	26746.50	26746.50	26746.50	26746.50	26746.50	26746.50	26746.50	26746.50	26746.50	26746.50
				SEA	AIR																			
				4158.00	22588.50																			
				12.5d	16d																			
	West	LD-AMSD	Lowest cost	LD-ISTB	ISTB-AMSD		6618.83	22.48	8015.81	6618.83	6618.83	6618.83	6618.83	6618.83	6618.83	6618.83	6618.83	6618.83	6618.83	6618.83	6618.83	6618.83	6618.83	6618.83
				SEA	AIR																			
				2848.00	3770.83																			
				17.00	3.48																			
			Highest speed	LD-AMSD			27797.00	9.00	28356.23	27797.00	27797.00	27797.00	27797.00	27797.00	27797.00	27797.00	27797.00	27797.00	27797.00	27797.00	27797.00	27797.00	27797.00	27797.00
				AIR																				
				27797.00																				
				9d																				
			Alternative 1	LD-HMB	HMB-AMSD		27116.50	14.50	28017.49	27116.50	27116.50	27116.50	27116.50	27116.50	27116.50	27116.50	27116.50	27116.50	27116.50	27116.50	27116.50	27116.50	27116.50	27116.50
				AIR	SEA																			
				25417.00	1699.50																			
				9d	3.5d																			
			Alternative 2	LD-ISTB	ISTB-AMSD		6618.83	22.48	8015.81	6618.83	6618.83	6618.83	6618.83	6618.83	6618.83	6618.83	6618.83	6618.83	6618.83	6618.83	6618.83	6618.83	6618.83	6618.83
				SEA	AIR																			
				2848.00	3770.83																			
				17d	3.4d																			
			Alternative 3	LD-MSC	MSC-ISTB	ISTB-AMSD	11558.83	28.48	13328.63	11558.83	11558.83	11558.83	11558.83	11558.83	11558.83	11558.83	11558.83	11558.83	11558.83	11558.83	11558.83	11558.83	11558.83	11558.83
				SEA	ROAD	AIR																		
				2848.00	4940.00	3770.83																		
				18.5d	3.5d	3.4d																		
		AMSD-LD	Lowest cost		HAMBURG		7773.00	24.50	9295.36	7773.00	7773.00	7773.00	7773.00	7773.00	7773.00	7773.00	7773.00	7773.00	7773.00	7773.00	7773.00	7773.00	7773.00	7773.00
				AIR	SEA																			
				4934.00	2839.00																			
				7.00	15.50																			
			Highest speed	AMSD-LD			21739.00	9.00	22298.23	21739.00	21739.00	21739.00	21739.00	21739.00	21739.00	21739.00	21739.00	21739.00	21739.00	21739.00	21739.00	21739.00	21739.00	21739.00
				AIR																				
				21739.00																				
				9d																				
			Alternative 1	AMSD-RM	RM-LD		23399.00	16.00	24393.19	23399.00	23399.00	23399.00	23399.00	23399.00	23399.00	23399.00	23399.00	23399.00	23399.00	23399.00	23399.00	23399.00	23399.00	23399.00
				AIR	SEA																			
				21083.50	2315.50																			
				7d	7d																			
			Alternative 2	AMSD-MD	MD-RM	RM-LD	26844.00	22.00	28211.01	26844.00	26844.00	26844.00	26844.00	26844.00	26844.00	26844.00	26844.00	26844.00	26844.00	26844.00	26844.00	26844.00	26844.00	26844.00
				AIR	ROAD	SEA																		
				23738.50	790.00	2315.50																		
				7d	5d	7d																		
			Alternative 3	AMSD-HMB	HMB-LD		7773.00	24.50	9295.36	7773.00	7773.00	7773.00	7773.00	7773.00	7773.00	7773.00	7773.00	7773.00	7773.00	7773.00	7773.00	7773.00	7773.00	7773.00
				AIR	SEA																			
				4934.00	2839.00																			
				7d	15.5d																			

The table above presents the results of the lowest-cost plan's change points and the optimal plan's change points when transporting ASE air cargo (large cargo).

Table 41. Optimal plan changing point in ASE with air in Eurasia—short distance

City pairs	Plans	Transit cities			Price-$	Total time-d	Total cost-$	Vaule growth rate of 100% based on value of $100/kg														
								100.00	200.00	300.00	400.00	500.00	600.00	700.00	800.00	900.00	1000.00	1100.00	1200.00	1300.00	1400.00	1500.00
SH-SGP	Highest speed	SH-SGP			19754.50	10.00	20375.87	25968.20	32181.90	38395.60	44609.29	50822.99	57036.69	63250.39	69464.09	75677.79	81891.49	88105.18	94318.88	100532.58	106746.28	112959.98
		AIR						BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		19754.50																				
		10d																				
SGP-SH	Highest speed	SGP-SH			45627.00	11.50	46341.58	52772.75	59918.51	67064.26	74210.01	81355.77	88501.52	95647.27	102793.03	109938.78	117084.53	124230.29	131376.04	138521.79	145667.55	152813.30
		AIR							BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		45627.00							GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
		11.5d																				
	Alternative 2	SGP-MB	MB-SG		33773.50	22.50	35171.58	47754.32	61735.14	75715.97	89696.79	103677.61	117658.43	131639.25	145620.08	159600.90	173581.72	187562.54	201543.36	215524.18	229505.01	243485.83
		AIR	ROAD					BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		27814.50	5959.00																			
		12.5d	9d																			
MB-ISTB	Highest speed	MB-ISTB			71450.00	10.00	72071.37	77663.70	83877.40	90091.10	96304.79	102518.49	108732.19	114945.89	121159.59	127373.29	133586.99	139800.68	146014.38	152228.08	158441.78	164655.48
		AIR										BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		71450.00													GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
		10d																				
	Alternative 1	MB-RM	RM-ISTB		19040.00	22.00	20407.01	32710.14	46380.27	60050.41	73720.55	87390.68	101060.82	114730.96	128401.10	142071.23	155741.37	169411.51	183081.64	196751.78	210421.92	224092.05
		AIR	SEA						BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		16797.50	2242.50																			
		9.5d	10.5d																			
ISTB-MB	Highest speed	ISTB-MB			27092.00	10.50	27744.44	33616.38	40140.77	46665.15	53189.53	59713.92	66238.30	72762.68	79287.07	85811.45	92335.84	98860.22	105384.60	111908.99	118433.37	124957.75
		AIR						BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		27092.00																				
		10.5d																				
LD-AMSD	Lowest cost	LD-ISTB	ISTB-AMSD		6618.83	22.48	8015.81	20588.56	34558.29	48528.01	62497.74	76467.46	90437.19	104406.92	118376.64	132346.37	146316.09	160285.82	174255.55	188225.27	202195.00	216164.72
		SEA	AIR																			
		2848.00	3770.83																			
		17.00	3.48																			
	Highest speed	LD-AMSD			27797.00	9.00	28356.23	33389.33	38981.66	44573.99	50166.32	55758.64	61350.97	66943.30	72535.63	78127.96	83720.29	89312.62	94904.95	100497.27	106089.60	111681.93
		AIR								BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		27797.00								GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
		9d																				
AMSD-LD	Lowest cost		HAMBURG		7773.00	24.50	9295.36	22996.56	38220.12	53443.68	68667.25	83890.81	99114.37	114337.93	129561.49	144785.05	160008.62	175232.18	190455.74	205679.30	220902.86	236126.42
		AIR	SEA																			
		4934.00	2839.00																			
		7.00	15.50																			
	Highest speed	AMSD-LD			21739.00	9.00	22298.23	27331.33	32923.66	38515.99	44108.32	49700.64	55292.97	60885.30	66477.63	72069.96	77662.29	83254.62	88846.95	94439.27	100031.60	105623.93
		AIR							BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		21739.00							GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
		9d																				

The table is the filtered table with the optimal plan change. We summarize the data in the table below.

Table 42. Comparison of old and new optimal plans (with new threshold) for ASE with air in Eurasia—short distance

City pairs	**Old optimal plan (new threshold)**	**New optimal plan**
SH-SGP	Same highest-speed plan	Same highest-speed plan
SHP-SH	Alternative 2; SGP-MB-AIR, MB-SH-ROAD; Value: $200/kg; 61,735.14, 22.5d.	Highest speed; SGP-SH-AIR; Value: $200/kg; $59,918.51, 11.5d.
MB-ISTB	Alternative1; MB-RM-AIR, RM-ISTB-SEA; Value: $800/kg; $121,401.1, 22d.	Highest speed; MB-ISTB-AIR; Value: $800/kg; $121,159.59,10d.
ISTB-MB	Same highest-speed plan	Same highest-speed plan
LD-AMSD	Lowest cost; LD-ISTB-SEA, ISTB-AMSD-AIR; Value: $300/kg; $48,528.01, 22.48d.	Highest speed; LD-AMSD-AIR; Value: $300/kg; $44,573.99, 9d.
AMSD-LD	Lowest cost; AMSD-HMB-AIR, HMB-LD-SEA; Value: $200/kg; $38,220.12, 24.5d.	Highest speed; AMSD-LD-AIR; Value: $200/kg; $32,923.66, 9d.

5.1.3.2.1.2 Long distance

Table 43. Sensitivity analysis of ASE with air in Eurasia—long distance

Long distance	East-West	SH-AMSD	Lowest cost	SH-ISTB	ISTB-AMSD		7499.83	50.98	10667.71	7499.83	7499.83	7499.83	7499.83	7499.83	7499.83	7499.83	7499.83	7499.83	7499.83	7499.83	7499.83	7499.83	7499.83	7499.83
				SEA	AIR																			
				3729.00	3770.83																			
				45.5d	3.4d																			
			Highest speed	SH-HMB	HMB-AMSD		41366.50	7.50	41832.53	41366.50	41366.50	41366.50	41366.50	41366.50	41366.50	41366.50	41366.50	41366.50	41366.50	41366.50	41366.50	41366.50	41366.50	41366.50
				AIR	SEA																			
				39667.00	1699.50																			
				2d	3.5d																			
			Alternative 1	SH-MB	MB-AMSD		26291.50	19.50	27503.17	26291.50	26291.50	26291.50	26291.50	26291.50	26291.50	26291.50	26291.50	26291.50	26291.50	26291.50	26291.50	26291.50	26291.50	26291.50
				ROAD	AIR																			
				5959.00	20332.50																			
				9d	9.5d																			
			Alternative 2	SH-LD	LD-AMSD		37573.00	24.50	39095.36	37573.00	37573.00	37573.00	37573.00	37573.00	37573.00	37573.00	37573.00	37573.00	37573.00	37573.00	37573.00	37573.00	37573.00	37573.00
				AIR	SEA																			
				37030.50	542.50																			
				12d	10.5d																			
			Alternative 3	SH-MB	MB-HMB	HMB-AMSD	25611.00	25.00	27164.42	25611.00	25611.00	25611.00	25611.00	25611.00	25611.00	25611.00	25611.00	25611.00	25611.00	25611.00	25611.00	25611.00	25611.00	25611.00
				ROAD	AIR	SEA																		
				5959.00	17952.50	1699.50																		
				9d	9.5d	3.5d																		
		SGP-LD	Lowest cost	SGP-RM	RM-LD		10941.50	19.00	12122.10	10941.50	10941.50	10941.50	10941.50	10941.50	10941.50	10941.50	10941.50	10941.50	10941.50	10941.50	10941.50	10941.50	10941.50	10941.50
				AIR	SEA																			
				8626.00	2315.50																			
				10.00	7.00																			
			Highest speed	SGP-LD			30271.50	12.00	31017.14	30271.50	30271.50	30271.50	30271.50	30271.50	30271.50	30271.50	30271.50	30271.50	30271.50	30271.50	30271.50	30271.50	30271.50	30271.50
				AIR																				
				30271.50																				
				12d																				
			Alternative 1	SGP-RM	RM-LD		10941.50	19.00	12122.10	10941.50	10941.50	10941.50	10941.50	10941.50	10941.50	10941.50	10941.50	10941.50	10941.50	10941.50	10941.50	10941.50	10941.50	10941.50
				AIR	SEA																			
				8626.00	2315.50																			
				10d	7d																			
			Alternative 2	SGP-BGD	BGD-RM	RM-LD	16900.50	25.50	18484.99	16900.50	16900.50	16900.50	16900.50	16900.50	16900.50	16900.50	16900.50	16900.50	16900.50	16900.50	16900.50	16900.50	16900.50	16900.50
				ROAD	AIR	SEA																		
				5959.00	8626.00	2315.50																		
				5.5d	10d	7d																		
			Alternative 3	SGP-MB	MB-RM	RM-LD	25072.00	26.50	26718.63	25072.00	25072.00	25072.00	25072.00	25072.00	25072.00	25072.00	25072.00	25072.00	25072.00	25072.00	25072.00	25072.00	25072.00	25072.00
				ROAD	AIR	SEA																		
				5959.00	16797.50	2315.50																		
				7d	9.5d	7d																		
		TKY-HMB	Lowest cost	TKY-AMSD	AMSD-HMB		8203.00	45.50	11030.23	8203.00	8203.00	8203.00	8203.00	8203.00	8203.00	8203.00	8203.00	8203.00	8203.00	8203.00	8203.00	8203.00	8203.00	8203.00
				SEA	AIR																			
				3269.00	4934.00																			
				36.5d	7d																			
			Highest speed	TYK-HMB			66965.00	7.00	67399.96	66965.00	66965.00	66965.00	66965.00	66965.00	66965.00	66965.00	66965.00	66965.00	66965.00	66965.00	66965.00	66965.00	66965.00	66965.00
				AIR																				
				66965.00																				
				7d																				
			Alternative 1	TKY-RM	RM-HMB		34405.00	22.50	35803.08	34405.00	34405.00	34405.00	34405.00	34405.00	34405.00	34405.00	34405.00	34405.00	34405.00	34405.00	34405.00	34405.00	34405.00	34405.00
				AIR	SEA																			
				29299.00	5106.00																			
				7d	13.5d																			
			Alternative 2	TKY-RM	RM-MD	MD-HMB	35183.50	28.50	36954.40	35183.50	35183.50	35183.50	35183.50	35183.50	35183.50	35183.50	35183.50	35183.50	35183.50	35183.50	35183.50	35183.50	35183.50	35183.50
				AIR	ROAD	SEA																		
				29299.00	790.00	5094.50																		
				7d	5d	13.5d																		
			Alternative 3	TKY-SH	SH-HMB		42687.50	30.00	44551.61	42687.50	42687.50	42687.50	42687.50	42687.50	42687.50	42687.50	42687.50	42687.50	42687.50	42687.50	42687.50	42687.50	42687.50	42687.50
				SEA	AIR																			
				3020.50	39667.00																			
				26d	2d																			
	West-East	AMSD-SH	Lowest cost	AMSD-HMB	HMB-SH		7080.00	56.00	10559.67	7080.00	7080.00	7080.00	7080.00	7080.00	7080.00	7080.00	7080.00	7080.00	7080.00	7080.00	7080.00	7080.00	7080.00	7080.00
				AIR	SEA																			
				4934.00	2146.00																			
				7d	47d																			
			Highest speed	AMSD-SH			36219.50	10.00	36840.87	36219.50	36219.50	36219.50	36219.50	36219.50	36219.50	36219.50	36219.50	36219.50	36219.50	36219.50	36219.50	36219.50	36219.50	36219.50
				AIR																				
				36219.50																				
				10d																				
			Alternative 1	AMSD-SGP	SGP-SH		32819.00	15.50	33782.12	32819.00	32819.00	32819.00	32819.00	32819.00	32819.00	32819.00	32819.00	32819.00	32819.00	32819.00	32819.00	32819.00	32819.00	32819.00
				AIR	ROAD																			
				26860.00	5959.00																			
				7.5d	7d																			
			Alternative 2	AMSD-MB	MB-SH		32238.00	21.00	33542.88	32238.00	32238.00	32238.00	32238.00	32238.00	32238.00	32238.00	32238.00	32238.00	32238.00	32238.00	32238.00	32238.00	32238.00	32238.00
				AIR	ROAD																			
				26279.00	5959.00																			
				11d	9d																			
			Alternative 3	AMSD-SGP	SGP-SH		29857.50	35.50	32063.36	29857.50	29857.50	29857.50	29857.50	29857.50	29857.50	29857.50	29857.50	29857.50	29857.50	29857.50	29857.50	29857.50	29857.50	29857.50
				AIR	SEA																			
				26860.00	2997.50																			
				7.5d	26d																			
		LD-SGP	Lowest cost	LD-ISTB	ISTB-SGP		10585.50	81.00	15618.60	10585.50	10585.50	10585.50	10585.50	10585.50	10585.50	10585.50	10585.50	10585.50	10585.50	10585.50	10585.50	10585.50	10585.50	10585.50
				SEA	AIR																			
				2848.00	7737.50																			
				17d	62d																			
			Highest speed	LD-SGP			26797.00	10.50	27449.44	26797.00	26797.00	26797.00	26797.00	26797.00	26797.00	26797.00	26797.00	26797.00	26797.00	26797.00	26797.00	26797.00	26797.00	26797.00
				AIR																				
				26797.00																				
				10.5d																				
			Alternative 1	LD-HMB	HMB-SGP		34755.50	15.50	35718.62	34755.50	34755.50	34755.50	34755.50	34755.50	34755.50	34755.50	34755.50	34755.50	34755.50	34755.50	34755.50	34755.50	34755.50	34755.50
				SEA	AIR																			
				5067.50	29688.00																			
				5.5d	8d																			
			Alternative 2	LD-AMSD	AMSD-SGP		27402.50	20.00	28645.24	27402.50	27402.50	27402.50	27402.50	27402.50	27402.50	27402.50	27402.50	27402.50	27402.50	27402.50	27402.50	27402.50	27402.50	27402.50
				SEA	AIR																			
				542.50	26860.00																			
				10.5d	7.5d																			
			Alternative 3	LD-MB	MB-SGP		23102.50	24.50	24624.86	23102.50	23102.50	23102.50	23102.50	23102.50	23102.50	23102.50	23102.50	23102.50	23102.50	23102.50	23102.50	23102.50	23102.50	23102.50
				AIR	ROAD																			
				22588.50	514.00																			
				16d	7.5d																			
		HMB-TKY	Lowest cost	HMB-MD	MD-RM	RM-TKY	10611.88	100.80	16875.28	10611.88	10611.88	10611.88	10611.88	10611.88	10611.88	10611.88	10611.88	10611.88	10611.88	10611.88	10611.88	10611.88	10611.88	10611.88
				RAIL	AIR	SEA																		
				5950.38	2335.00	2326.50																		
				46.8d	7d	44d																		
			Highest speed	HMB-TKY			44700.50	7.00	45135.46	44700.50	44700.50	44700.50	44700.50	44700.50	44700.50	44700.50	44700.50	44700.50	44700.50	44700.50	44700.50	44700.50	44700.50	44700.50
				AIR																				
				44700.50																				
				7d																				
			Alternative 1	HMB-RM	RM-MD	MD-TKY	35611.00	22.00	36978.01	35611.00	35611.00	35611.00	35611.00	35611.00	35611.00	35611.00	35611.00	35611.00	35611.00	35611.00	35611.00	35611.00	35611.00	35611.00
				SEA	ROAD	AIR																		
				2847.50	790.00	31973.50																		
				7d	5d	7d																		
			Alternative 2	HMB-MD	MD-TKY		36413.00	26.50	38059.63	36413.00	36413.00	36413.00	36413.00	36413.00	36413.00	36413.00	36413.00	36413.00	36413.00	36413.00	36413.00	36413.00	36413.00	36413.00
				SEA	AIR																			
				4439.50	31973.50																			
				17.5d	7d																			
			Alternative 3	HMB-ISTB	ISTB-TKY		39252.50	26.50	40899.13	39252.50	39252.50	39252.50	39252.50	39252.50	39252.50	39252.50	39252.50	39252.50	39252.50	39252.50	39252.50	39252.50	39252.50	39252.50
				SEA	AIR																			
				3656.50	35596.00																			
				16d	8.5d																			

Table 44 Optimal plan changing point in ASE-With air in Eurasia-Long distance

City pairs	Plans	Transit cities			Price-$	Total time-d	Total cost-$	Vaule growth rate of 100% based on value of $100/kg														
								100.00	200.00	300.00	400.00	500.00	600.00	700.00	800.00	900.00	1000.00	1100.00	1200.00	1300.00	1400.00	1500.00
SH-AMSD	Highest speed	SH-HMB	HMB-AMSD		41366.50	7.50	41832.53	46026.77	50687.05	55347.32	60007.60	64667.87	69328.14	73988.42	78648.69	83308.97	87969.24	92629.51	97289.79	101950.06	106610.34	111270.61
		AIR	SEA					1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		39667.00	1699.50					1.00	1.00	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
		2d	3.5d																			
	Alternative 1	SH-MB	MB-AMSD		26291.50	19.50	27503.17	38408.21	50524.92	62641.64	74758.35	86875.06	98991.77	111108.49	123225.20	135341.91	147458.62	159575.34	171692.05	183808.76	195925.47	208042.18
		ROAD	AIR					BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		5959.00	20332.50																			
		9d	9.5d																			
SGP-LD	Lowest cost	SGP-RM	RM-LD		10941.50	19.00	12122.10	22747.53	34553.55	46359.58	58165.61	69971.64	81777.66	93583.69	105389.72	117195.75	129001.77	140807.80	152613.83	164419.86	176225.88	188031.91
		AIR	SEA																			
		8626.00	2315.50																			
		10.00	7.00																			
	Highest speed	SGP-LD			30271.50	12.00	31017.14	37727.94	45184.38	52640.82	60097.25	67553.69	75010.13	82466.57	89923.01	97379.45	104835.88	112292.32	119748.76	127205.20	134661.64	142118.08
		AIR						1.00	1.00	1.00	1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		30271.50						1.00	1.00	1.00	1.00	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
		12d																				
TKY-HMB	Highest speed	TYK-HMB			66965.00	7.00	67399.96	71314.59	75664.18	80013.77	84363.36	88712.95	93062.53	97412.12	101761.71	106111.30	110460.89	114810.48	119160.07	123509.66	127859.25	132208.84
		AIR						1.00	1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		66965.00						1.00	1.00	1.00	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
		7d																				
	Alternative 1	TKY-RM	RM-HMB		34405.00	22.50	35803.08	48385.82	62366.64	76347.47	90328.29	104309.11	118289.93	132270.75	146251.58	160232.40	174213.22	188194.04	202174.86	216155.68	230136.51	244117.33
		AIR	SEA					1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		29299.00	5106.00																			
		7d	13.5d																			
AMSD-SH	Highest speed	AMSD-SH			36219.50	10.00	36840.87	42433.20	48646.90	54860.60	61074.29	67287.99	73501.69	79715.39	85929.09	92142.79	98356.49	104570.18	110783.88	116997.58	123211.28	129424.98
		AIR						1.00	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		36219.50																				
		10d																				
LD-SGP	Highest speed	LD-SGP			26797.00	10.50	27449.44	33321.38	39845.77	46370.15	52894.53	59418.92	65943.30	72467.68	78992.07	85516.45	92040.84	98565.22	105089.60	111613.99	118138.37	124662.75
		AIR						BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		26797.00																				
		10.5d																				
HMB-TKY	Highest speed	HMB-TKY			44700.50	7.00	45135.46	49050.09	53399.68	57749.27	62098.86	66448.45	70798.03	75147.62	79497.21	83846.80	88196.39	92545.98	96895.57	101245.16	105594.75	109944.34
		AIR						BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		44700.50						GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN
		7d																				
	Alternative 1	HMB-RM	RM-MD	MD-TKY	35611.00	22.00	36978.01	49281.14	62951.27	76621.41	90291.55	103961.68	117631.82	131301.96	144972.10	158642.23	172312.37	185982.51	199652.64	213322.78	226992.92	240663.05
		SEA	ROAD	AIR				BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE	BLUE
		2847.50	790.00	31973.50																		
		7d	5d	7d																		

Table 45. Comparison of old and new optimal plans (with new threshold) for ASE with air in Eurasia—long distance

City pairs	Old optimal plan (new threshold)	New optimal plan
SH-AMSD	Alternative 1; SH-MB-ROAD, MB-AMSD-AIR; Value: $300/kg; $62,641.64, 19.5d.	Highest speed; SH-HMB-AIR, HMB-AMSD-SEA; Value: $300/kg; $55,347.32. 7.5d.
SGP-LD	Lowest cost; SGP-RM-AIR, RM-LD-SEA; Value: $500/kg; $69,971.64, 19d,	Highest speed; SGP-LD-AIR; Value: $500/kg; $67,553.69, 12d,
TKY-HMB	Alternative 1; TKY-RM-AIR, RM-HMB-SEA; Value: $400/kg; $90,328.29, 22.5d,	Highest speed; TKY-HMB-AIR; Value: $400/kg; $84,363.36, 7d,
AMSD-SH	Same highest-speed plan	Same highest-speed plan
LD-SGP	Same highest-speed plan	Same highest-speed plan
HMB-TKY	Lowest cost; HMB-RM-SEA, RM-MD-ROAD, MD-TKY-AIR; Value: $100/kg;	Highest speed; HMB-TKY-AIR; Value: $100/kg;

	$49,281.14, 22d.	$49,050.09, 7d.

The sensitivity analysis of the two scenarios tells us that from a certain point (high value), all the optimal plans are switching to the highest-speed plans, which means that the higher the value, the less shippers consider total transport costs because the product inventory holding cost will be boosted along with the value of the products. Therefore, total costs will increase sharply due to the rise in inventory holding costs.

6 Interviews and results validation

6.1 Interview with Canadian National Railway (CN)

6.1.1 Background

The CN is a Canadian-based, fully fledged North American railway that serves customers across North America and beyond. It offers transportation services in rail, intermodal, trucking, freight forwarding, trans loading, and distribution.

6.1.2 Questions and answers

The interviewee looked at our research results and said that the city pairs' top plans (lowest cost, highest speed, and three alternatives), which we presented, in the three continents (Europe, Asia, and North America) are interesting and useful for freight-forwarding companies. We presented to the interviewee the method of data collection. Since there was lack of data about the railway mode in some areas, we decided to use the ratio from the research of the U.S. Chamber of Commerce, 2006. The interviewee said that the data of costs are reasonable; however, the transit time of rail in North America should be faster now—as fast as that by road in 2017. For example, if road transport takes 5 days on average from origin A to destination B, then railway transport only takes 6 days from origin A to destination B. Moreover, he spoke highly of our thesis methodology, from city selection to transport-mode and product-value differentiation. He said that differentiating the product from low value to high value is quite reasonable because if the value of the product is high enough, then the transport time ranks first.

Apart from the data collection, the interviewee complimented the research on the "To and Return" routes that we conducted separately because in some cases, transporting cargo from origin A to destination B is somewhat different from origin B to destination A. For example, the cost of transportation from China to North America is sometimes higher because there are plenty of goods to be exported from Asia to North America; then, the empty cargos will be returned to Asia from North America, at which point the total cost of transportation is lower from North America to Asia.

As for the transit time, he said that the combination of air and rail is not often used. Only one situation could use the multimodal transport of an air-rail combination: if the rail transport process is delayed, there should be a recovery action to save total transit time; in this situation, air mode transport could be used to transport goods from the rail terminal to the destination. He shared an example of fresh pork from North America to Japan: if the pork should stay fresh enough, and the train is delayed by 5 days, then the air mode could be utilized to transport the goods to Japan instead of transporting goods by rail and sea.

Moreover, the interviewee said that if the total volume of transport is not heavy enough, such as the small cargo of AKE that we chose in the research, then the total cost of transportation can be high, and the transportation risk will be higher by rail than by road or air because the handling process of large bulk goods in rail transportation is quite risky for high-value products. He provided the example of electronic devices: high-value products transported by rail can sometimes be damaged because of the large volume of goods handled at the rail terminal.

Overall, the interviewee said that our research is valuable for freight forwarding as well as the transportation industry. The final result of the five plans (the lowest-cost and highest-speed plans, and alternatives 1, 2, and 3) of different city pairs are clear and useful for potential customers when they are ready for shipping. Furthermore, the methods we have chosen for the alternative plans are reasonable as heuristics.

6.2 Interview with Delmar Cargo Inc.

6.2.1 Background

Delmar Cargo Inc. is a company dealing with freight forwarding, customs brokerage, transportation of commercial cargo, and logistics. It was established as a customs brokerage in Montreal in 1965. Since then, Delmar has grown in size and scope to a company with over 1,000 employees in 12 countries, mainly providing cargo management and supply-chain services.

Karina Ayres is the solutions and business development manager, offering customer visibility tools in the Delmar Cargo Montreal office and dealing with service delivery to over 30 charities and environmental organizations.

Daniel Labelle is the business development manager in the Delmar Cargo Montreal office as well. He deals with the development of profitable business in the area of airfreight, sea freight, trucking, customs brokerage, warehousing, and supply-chain management.

6.2.2 Questions and answers

We conducted semi-structured interviews with the two of them. First, we shared with them the method of data collection, including the price-time source of all four transport modes around the world and the results of the thesis, including the five top plans of city pairs in three regions (Eurasia, North America, and cross-continent—Eurasia, North America, and Africa) in four different scenarios (Scenario 1—AKE with air, Scenario 2—ASE with air, Scenario 3—AKE air not required, and—Scenario 4—ASE air not required).

Mr. Labelle and Mrs. Ayres agreed on the method of choosing five top plans between each city pair in three regions (Eurasia, North America, and cross-continent among Eurasia, North America, and Africa). The logic of the selection of the optimal plan out of the five top plans is reasonable; however, they pointed out that some data, such as the transit time of the air mode between two cities, are not reliable; a transit time of over 4 days between any cities is considered to be too long. The reason the data sources (two websites) provide data with much longer transit times is that the transit time includes door-to-door services; airport-to-airport services will cut down the transit time by half. Another problem is that the transit time data of railways in North America is not highly accurate because we have estimated the rail mode by calculating the ratio to air transport according to research conducted by the U.S. Chamber of Commerce in 2006; this ratio is not the exact quote we found on websites, and some errors exist as a result. The actual speed of rail in North America should be much faster.

Then, we discussed the topic of air cargo in multimodal transport with the two professionals. The questions are divided into four parts—the customers that Delmar Cargo deals with, the products it transports, the transport modes it uses, and the way in which it selects optimal routes with cost and time considerations.

With regard to the first part, Mr. LaBelle said that customers include food, clothing, jewelry, and electronic device companies, among others.

In relation to the second part, Mr. Labelle stated that Delmar Cargo sometimes transports goods that are time sensitive, such as high-value products and perishable goods, and even some fast-changing seasonal clothing. Sometimes, the criterion of time is not necessary. To differentiate between products with low value and high value, the company usually uses a threshold of $800/kg, which means that a product above $800/kg is considered to be of high value, and a product below $800/kg is considered to be low value. There is no specific sensitivity analysis of value for specific products between any specific city pairs (origin-destination pairs).

With regard to the third part, Mrs. Ayres said that the most-used air cargo is AKE (which this thesis discusses) for small shipments and XAW (14 Cu.M, 5, 000 kg) for large shipments. The most common multimodal transport combination is sea-rail; however, if the air cargo should be involved in a multimodal transport system, then sea-air is also very frequently used in today's logistics business. Once air transport is used in multimodal transport, we have to take into account the value of the products and the level of emergency of the goods. For example, if the goods are pharmaceutical and high-value products, then they have to be transported by air. However, if the goods are low-value clothing items with fast-changing designs, or low-value goods that are time sensitive, then the sea-air multimodal transport method is always used. As a further example (see the table below), if there is an AKE cargo to be transported from Montreal to Shanghai, as the table below demonstrates, then the sea-air combination is the lowest-cost plan, and the route is from Montreal to London by sea at a price of $356 and a time of 16.5 days, and then, from London to Shanghai by air at a price of $718 and a time of 9 days. Therefore, the total transport cost is $1,313.29 (including the inventory holding cost during transportation), and the total transport time is 27.5 days (including a delay time of 2 days for modal transfer). Another situation in which air transport is used in the multimodal transport system is when the whole shipment is delayed due to the weather, or because of sea congestion; in this instance, freight forwarders will usually suggest that customers ship a small portion of the high-value or emergency goods by air and the rest by a sea-air combination.

Table 46. Example of Montreal-Shanghai optimal plan selection

MTL-SH	Lowest cost	MTL-LD	LD-SH			$1,074.00	2	$1,313.29	$0.83	27.50	1			1	2
		SEA	AIR												
		$356.00	$718.00												
		16.5d	9d												
	Highest speed	MTL-SH				$4,586.00	0	$4,651.26	$2.93	7.50	1				1
		AIR													
		$4,586.00													
		7.5d													
	Alternative 1	MTL-SGP	SGP-SH			$3,350.50	1	$3,437.51	$2.16	10.00	1	1			2
		AIR	ROAD												
		$2,528.50	$822.00												
		2d	7d												
	Alternative 2	MTL-VCV	VCV-SH			$4,611.50	1	$4,742.02	$2.99	15.00	1	1			2
		ROAD	AIR												
		$397.00	$4,214.50												
		7d	7d												
	Alternative 3	MTL-SGP	SGP-BDG	BGD-SH		$4,635.00	2	$4,814.57	$3.03	20.64	1	1	1		3
		AIR	RAIL	ROAD											
		$2,528.50	$1,284.50	$822.00											
		2d	10.6d	6d											

Mrs. Ayres emphasized that the more transport modes are involved in the whole supply chain, the more risk there is because when handling processes (transfer processes) are added, the possibilities of damage to goods will rise accordingly.

With regard to the fourth part, Mrs. Ayres said that Delmar Cargo currently uses a landed-cost calculator—credit- and transit-time analysis tool to calculate the total cost and time of transport one 40-foot container by rail (depicted in table 26). The internal financing rate is 8%; the transit time is 30 days, as an assumption; the freight cost is $2,950 per 40-foot container; and the inventory transporting cost is calculated by cost per container * 8% * transit time/360. This is the same as our calculation for the holding cost; however, we assumed a financing rate of 20%, and we used product value instead of cost per container/shipment for the calculation. Mrs. Ayres said that the most popular airports or sea ports used as multimodal transport hubs are large airports in the world, for example, Amsterdam in the Netherlands, Frankfurt in Germany, and London in England. She confirmed the results of this research that the air route between London and Moscow is quite cheap and popular, and she also confirmed other frequently used routes.

Mr. Labelle confirmed that in the multimodal transport method, two-mode combinations are the most popular combinations, including sea-air, sea-rail, and air-road combinations. The total cost of the whole transporting line includes, inter alia, transport costs, handling costs, insurance, and inspection costs, and the total transport time includes transit time, handling time (delay time), and time of custom declaration.

Table 47. Landed-cost calculator—credit- and transit-time analysis tool

Landed Cost Calculator - Credit & Transit Time Analysis Tool			
Time value is not considered			
Shipment & Cargo Details	**Current**	**Proposed**	
Annual Volume (est)	400	400	
Number of Days / Year	360	360	
Internal Financing Rate	8%	8%	
Cost of Goods per container/shipment	50,000.00	50,000.00	
Customer Profit Margin	1%	1%	
Transit Time (to door)	30	23	
Forwarder Credit	30	30	
Inventory Turnaround (From Cargo Receipt)	30	30	
Vendor Credit (From FOB)	30	30	
Working Capital (Cost of Goods)	**Current**	**Proposed**	**Variance**
Cash Conversion Cycle	30	23	-7
Freight Costs	**Per Container**	**Per Container.**	**Variance**
Origin / FOB charges	$ -	$ -	$ -
Freight	$ 2,950.00	$ 3,150.00	$ 200.00
Destination charges	$ -	$ -	$ -
Total freight cost	$ 2,950.00	$ 3,150.00	$ 200.00
Inventory Carrying Cost	$ 312.50	$ 239.58	$ (72.92)
Savings from Forwarder Credit Terms		$ -	$ -
Potential saving from earlier customer payment		$ (0.73)	$ (0.73)
Landed Cost Comparison	$ 3,262.50	$ 3,388.85	$ 126.35
Estimated Total Annual Comparison	$ 1,305,000.00	$1,355,541.67	$50,541.67

Source: Delmar Cargo Inc., 2017

The table above is the landed-cost calculator that Delmar Cargo Inc. now uses, and it is used to analyze transporting credit and transit time. The first part of the table displays the details of a shipment, which contains the current situation and the proposed situation. Annual volume indicates the total volume of shipment in a year, and the current situation is the same as the proposed one. The number of days/year is assumed to be 360 days per year, and the internal financing rate is 8% for both situations, which means that holding inventory during the transporting period is 8% per year. The cost of goods per container is $50,000, which means that the total value of each container is assumed to be $50,000. The customers' profit margin is 1%, and the transit time in a door-to-door service is assumed to be 23 days; however, the current situation is 30 days. Furthermore, forwarder credit is 30 units, inventory turnaround is 30 times, and vendor credit is 30 units.

The second part of the table is the calculation process of total landed cost and total annual cost. It starts with a calculation of the working capital, in which the cash conversion cycle is calculated by (transit time + inventory turnaround – vendor credit). The freight cost includes origins/free on board (FOB) charges, freight cost, and destination charges; the total freight cost is the sum of these three costs. The inventory transporting cost is calculated by [(cost of goods per container * internal financing rates/number of days per year) * (cash conversion cycle)]. The total landed cost is the sum of the total freight cost, and the inventory transporting cost minus savings from forwarder credit terms and potential savings from earlier customer payment; the total annual cost is thus calculated by (total landed cost * annual volume).

In summary, Mr. Labelle and Mrs. Ayres both agreed that our research is interesting and useful for freight-forwarding companies, although there are some data errors due to the secondary database. The overall method of combining the cost and transport time to choose the best routes in terms of OD pairs' transportation modes around the world is quite new in freight-forwarding companies because the method that they currently use is to simply choose the most familiar routes with their own contacts. They also said that further developing the method into a model with a formula would attract more freight-forwarding companies.

6.3 Interview with Kuehne + Nagel Inc.

6.3.1 Background

Kuehne + Nagel Inc. has been an international logistics provider since 1890. It is the largest global sea freight forwarder, the second-largest global air cargo forwarder with a "Global Cargo iQ phase 2" certification, and the second-largest global contract logistics provider with a worldwide network of warehouse and distribution facilities (Kuehne + Nagel, 2017).

Mr. Filipe Costa is the Quality and Environment, Health, and Safety (EHS) Manager in Kuehne + Nagel. He deals with mapping and optimization support in the airfreight and customs brokerage department.

6.3.2 Questions and answers

According to Mr. Costa, most of the customers of Kuehne + Nagel are manufacturers. He primarily deals with companies in the pharmaceutical and cosmetics industries. Pharmaceutical products are extremely sensitive to time and temperature. He said that while some products, such as cosmetics, use multimodal transport methods with a combination of air and other transport modes, pharmaceutical products are mostly shipped by air.

The products Mr. Costa deals with are high-value products that are time sensitive. He said that there are specific boundaries between low-value and high-value products. For example, the function of (product/cargo cost of invoice) is the formula for calculating the ratio of the product value in the total transport cost; the higher the ratio, the higher the value of the product. Examples of this type of product would be specific substances used in medicine, with small volumes but high costs.

According to Mr. Costa, air cargo transport is used in all markets, covering Asia, Europe, and North America. Kuehne + Nagel sometimes cooperates with integrators such as UPS and FedEx for a part of the routes when transporting goods from factories to airports; otherwise, the company mostly works with airlines. Mr. Costa said that multimodal transport methods have been used quite often in transportation companies, and all of these methods are used in international trade—the air-truck combination is most frequently used in the multimodal transport system when time-sensitive, temperature-controlled and perishable shipments are involved.

To choose the optimal route between origins and destinations, it uses “the best available transportation structures” strategy. For example, it chooses the official and main ports and airports where the main carriers operate. It also chooses the preferable multimodal terminals where carriers offer more route options.

As CO2 emissions are becoming increasingly important and accounted for on customers’ shipments, customers are also evaluating total CO2 emissions when transporting products. In terms of risk, the following are considered to be the main risks in multimodal transport systems: delays, wrong documents, damages, and lost cargo during any modal transfer. To reduce the possibility of these risks, Kuehne + Nagel uses computer systems, carriers’ systems, and checklists for follow-up.

Overall, he said that our research is quite useful for finding alternative ways of transporting both low-value and high-value products that are highly sensitive to time.

6.4 Interview with Propulsion Plus Logistics Inc.

6.4.1 Background

Propulsion Plus Logistics is a supply-chain service company in Montreal. The main service is to provide instructions to customers in transporting high-value and time-sensitive products. Mr. Yves D. Gagnon is the owner and president of the company.

6.4.2 Questions and answers

The company mainly deals with the automobile, aerospace, and food industries, including transporting unfinished and finished goods. All the products it handles are time sensitive or high value, and the company often uses the air cargo mode to transport goods. According to Mr. Gagnon, the most important factor in transporting goods is the order environment, which includes customer demand, the destination legal environment, and the world economic environment. Propulsion Plus cooperates with integrators such as UPS and FedEx when the weight of the goods is light, which means they can be packed into small parcels—less than 100 kg per parcel. Otherwise, it ships goods directly through transporting companies. It uses all types of transport modes: air, road, rail, and sea. Multimodal transport is a transport method that they use often, including the road-rail or air-road combination in the domestic Canadian market, or sea-air in the international market. For example, in the domestic market, goods can be transported from Vancouver to Toronto by rail, and then, from Toronto to Montreal by road, and in the international market, they could be transported from Montreal to Singapore by sea, and from Singapore to Shanghai by air. Mr. Gagnon emphasized that when the value of the product is high enough, for example, medical products, the company will only use the air cargo mode to ship the goods because the more urgent the customer needs are, the faster the products should be shipped.

According to Mr. Gagnon, his company does not use any algorithms to choose the best routes between OD pairs; the only platform it uses is Freightos.com, which is the same platform from which we collected data, to estimate the potential transport cost and time for the customers. Also, Mr. Gagnon said that to choose the preferred multimodal hub, the company relies mostly on the familiarity of the existing hubs with which it currently does business, such as Vancouver in Canada, Paris in France, and Las Vegas in the US.

We showed Mr. Gagnon the data of the four transport modes gathered from the secondary websites and the methodology we chose for the best routes among the five top plans, and he agreed on the method we used. The only problem is that a small portion of the data, such as transit time of air and rail, is not realistic; however, the research result has no significant errors.

Overall, Mr. Gagnon demonstrated great interest in our research, and he positively expressed that if we could develop this study into algorithms and models, then he would be willing to purchase the platform.

6.5 Interview with Traffictech International Inc.

6.5.1 Background

Traffictech International Inc. is one of the largest logistics companies in North America, and its services cover land, sea, and air. Truck transport is one of the company's most powerful shipping methods for the following reasons: 1) there are dry, refrigerated, and heated services by truck; 2) trucks can transport 20-foot, 40-foot, 48-foot, and 53-foot containers; and 3) there are specialized equipment and services by truck.

Traffictech International Inc. also deals with the intermodal transport business, mostly by truck, rail, or ship. The air and ocean freight multimodal transport is also a popular business mode for goods transported between North America, Hong Kong, China, South America, and the Indian subcontinent. The company provides weekly air and ocean consolidation, expedited services, equipment chartering, project cargo services and domestic North American airfreight services. There are also warehousing and customs brokerage services in Traffictech International Inc. (Traffictech International, 2017).

The interviewee is the operations manager at Traffictech International Inc. and is in charge of operations, customer service for the freight-forward department, establishing negotiated rates for warehousing and transportation, and managing and developing the ocean-import department.

6.5.2 Questions and answers

According to the interviewee, the company deals with manufacturers, retailers, and wholesalers. Most of them are in clothing, hardware, and home furniture industries.

Customers that produce fashion clothes are more sensitive to time and transport costs, while perishable goods, such as flowers, and high-value products, such as electronics, are sensitive to delivery time but not cost. The combination of air and other types of transport, such as air-sea and air-truck, is often used in the multimodal transport system. The interviewee said that there are no boundaries to differentiate between products of low value and those of high value because the standard of value of products is different depending on the different customer requirements.

In each market in North America, Europe, and Asia, air cargo is used frequently. The interviewee said that Traffictech Inc. does business with almost all well-known integrators in the world, such as FedEx, UPS, and DHL. The most-used air cargo type is pallets, and the dimensions of the pallets are different depending on the number of products to be shipped.

The interviewee said that multimodal transport is an important method for transporting goods between origins and destinations. Nearly all types of goods, except high-value products, can be transported by a multimodal transport method. When the goods are transported in a rush or when there is a deadline from the customers, the air mode of transport is often included in the multimodal transport system. When the transported product is of low value, and there is no rush to transport it, air transport is seldom used because airplanes have limited space, meaning that, in some cases, not all products can be transported in the airplane at once. The interviewee also provided an example of the air mode involved in multimodal transport system from Shanghai to Montreal: transporting products by air from Shanghai to Vancouver, and then, transferring from Vancouver to Montreal by rail. Transporting products by rail is much cheaper than by sea. The railway between Vancouver and Montreal is called the Mainland Bridge (MLB), and it is important in Canada for multimodal transport. The interviewee also emphasized that in North America, rail transport is the most important city-to-city mode due to its low transport cost. Air-sea and air-truck combinations are now the most important transport mode combinations when the air mode is involved in multimodal transport system.

Traffictech Inc. does not use any algorithms or heuristics to lower transport costs and to achieve higher transport speeds. Instead, it has used the operations manager’s intuition and judgment. The favorable multimodal terminals are mostly large ports in the world, such as Shanghai, Hong Kong, Singapore, and Bangladesh in Asia; Amsterdam, London, and Paris in Europe; and New York and Vancouver in North America. These are also called airports and sea-port hubs. Those most favorable multimodal terminals for reducing transaction risks are those that they know better in the former business, in terms of facilities, laws, and other criteria.

However, in one multimodal transport route, there could be multiple transit sites, for example, the route from Shanghai to Montreal by sea could be divided as follows: from Shanghai to Singapore, and then from Singapore to Vancouver. Singapore is thus a transit site for this transport route.

The interviewee also indicated that in reality, the transit time for transporting one cargo between any origin to destination should be within three days, including handling processes. Therefore, the data that we collected is somewhat inaccurate in terms of air transit time if it is over three days.

6.6 Interview with Hitek Logistics Inc.

6.6.1 Background

Hitek Logistic Inc. is a logistics company based in Montreal. It provides ground transport, air transport, and maritime transport services.

Mr. Brian Schwenger is the vice president and operations manager in Hitek Logistic Inc.

6.6.2 Questions and answers

According to Mr. Shwenger, Hitek's business is mostly with manufacturers that produce electronic devices. Most of the products within the shipment are time sensitive. The selection of transportation modes, particularly with regard to whether to use an air cargo method, is based on customer needs or the speed at which customers produce products. If the customer produces slowly, then the air cargo mode can be included in order to transport the goods to satisfy the demands. The company has different strategies for transporting various types of shipments. For example, when it is transporting low-value products that are time sensitive, it uses UPS and DHL; when it is transporting low-value shipments that are not time sensitive, it usually uses ground services such as trucks or rail; and if it is transporting high-value products that are time sensitive, then it sometimes contract the shipment to FedEx to transport by air. The company has not yet dealt with high-value goods that are not time sensitive.

To differentiate between shipments of high value and those of low value, Hitek uses the standard value of $2,500. When the total shipment is over $2,500, it is considered to be a high-value shipment; otherwise, it is a low-value shipment.

According to Mr. Shwenger, the Australian market is a large air cargo market in the world, ranking third in the world for the air cargo shipment of electronic devices.

When we were talking about multimodal transport, Mr. Shwenger said that there are many sea-rail combinations in the transportation world, and the sea-air combination is also a popular method to save money. If multimodal transport is not used, the reason could be timing. Mr. Shwenger also mentioned that there is a so-called feeder vessel transport mode in the world, in which a small ship feeds the mother ship. For example, there is a feeder ship in Indonesia and the mother ship in Shanghai; if the connection in Indonesia is delayed, then the shipment should use the air cargo mode to speed up the transporting time.

When discussing the optimal route between origins and destinations, Mr. Shwenger said that the three criteria of time, price, and routing are the most important during the decision-making process. He took sea transport as an example: from Shanghai to Montreal, there can be various route choices, and the total transport cost and time can be different. The first route can be from Shanghai to Prince Rupert by sea at a higher rate and that takes 16 days, and then, from Prince Rupert to Montreal by rail. Another route can be from Shanghai to Vancouver by sea at a lower rate and that takes 25 days, and then, one could use the rail to transport goods from Vancouver to Montreal. Mr. Shwenger also said that the most favorable multimodal transport terminals are the base ports in the world—the main cities in the world, such as Shanghai in China and Amsterdam in the Netherlands. To choose the optimal route between origins and destinations, the company also considers port congestion; if the port is in high congestion, it will change to another port as the multimodal transport terminal. He emphasized that when the air cargo mode is involved in the multimodal transportation system, the company will compare different airlines' transport costs and times and then choose the lowest-cost option.

To calculate the total cost of a multimodal transport system, the following costs should be taken into account: customs fees, handling fees, documentary fees and bills of lading fees, and container storage costs, in addition to transport and holding costs. Furthermore, apart from transit and delay times, the total transport time should also include port congestion, loading between transport modes, and delays at ports. To control the risk of multimodal transport is to reduce the times of handling between modes, which means that the less the handling, the less the risks.

7 Conclusion

This thesis aims to find the best solution in terms of cost and time for including air transport modes in the multimodal transportation system. The literature tells us that multimodal transport, especially sea-rail and air-truck combinations, is a widely used transportation method for both small and large cargos/containers. The sea-rail combination is mainly used for transporting large containers with low-value goods that are not time sensitive, while the air-truck combination is mostly for small cargos with high-value goods that are time sensitive. The sea-rail combination is slow but the cost is low, while the air-truck combination is fast but the cost is high. The trade-off between cost and time is obvious in the multimodal transport system.

The literature also tells us that air transport is quite important in the multimodal transport system. Since 1989, the world's air cargo rapidly grew in RTK until 2008, when the economic crisis developed. However, after the drop in 2008, the amount of air cargo continued to increase until today, and it is projected to grow in the future. Moreover, due to the large quantity of trade using the air cargo mode between Asia, North America, and Europe, which the literature illustrated, we conducted our research on those regions. Data of price and time are mostly generated from the secondary database on websites such as freightos.com and worldfreightrates.com. We generated almost all the data of price and time related to transporting one AKE and one ASE cargo between each city pair (among 23 cities with combinations) by air, road, rail, and sea, with the exception of a small portion (20%) of data in rail transport, which is calculated by the ratio of (0.25, 7.2) to air transport—0.25 times the cost of air transport and 7.2 times the time of air transport—when the rail data were not available from the websites. This is an important limitation of the thesis because some data errors, such as the transport time of air cargo, could lead to incorrect rail transport data. The data correlation between the two transport modes (air and rail) is somewhat high in this situation. Therefore, the results of certain optimal plan selections within some OD pairs could also contain errors. However, the data portion of rail that is calculated by the ratio of rail to air is relatively small*,* therefore, the research result is still reliable.

The research was conducted using an intuitive heuristic when choosing the top five plans in terms of cost and time in each city pair, chosen as short-distance and long-distance OD pairs based on the criterion of a maximum short-distance figure of 8,000 km. If the distance between an OD pair is shorter than 8,000 km, then the OD pair is deemed to be a short-distance pairs; otherwise, the pairs are considered to be long-distance city pairs. In choosing the top plans, we first set the total transport cost column as an ascending function in order to find the lowest-cost plan. We then set the total transport time as an ascending function to find the highest-speed plan. The other three alternative plans were chosen from the high-speed but relatively low-cost section in the top 50 fastest plans. The strategy was used in both AKE (small cargo) and ASE (large cargo) situations in four different scenarios (either with air or air modes not required).

A differentiation was made between low-value and high-value products at a starting value of $10/kg, and we assume that all the products are time sensitive, for example, fashion clothing and perishable goods. The reason we differentiate product value is that it is essential to calculate holding costs during the transport transit time.

Table 48. Comparison of plans in four scenarios—result

		AKE—with air	**AKE—air not required**	**ASE—with air**	**ASE—air not required**
Short distance					
Eurasia	Optimal plans	Mostly highest-speed plans	Lowest-cost or alternative plans	Lowest-cost or alternative plans	Highest-speed or alternative plans
	Optimal plan transport modes	Air only	Road or rail only	Air-road or air-sea	Road, sea only, or air-sea
North America	Optimal plans	Mostly highest-speed plans	Mostly highest-speed plans	Alternative plans	Lowest-cost or alternative plans
	Optimal plan transport modes	Air only	Mostly rail only	Air-road	Road or sea only
Long distance					
Eurasia	Optimal plans	Lowest-cost plans or alternative plans	Mostly alternative plans	Alternative or lowest-cost plans	Mostly alternative plans
	Optimal plan transport modes	Air-rail, air road, or air-sea	Air Road, air-rail, or air-road-rail	Air-road, air-sea, or air-road-sea	Air-road, air-sea, or air-road-sea
North America	Optimal plans	Lowest-cost or alternative plans	Mostly alternative plans	Lowest-cost or alternative plans	Alternative or lowest cost plans
	Optimal plan transport modes	Air-road or air-road-rail	Air-rail, air-road-rail, or road-rail	Air-road or air-sea	Road or rail only
Eurasia, North America, Africa	Optimal plans	Half highest-speed and half alternatives	Half highest-speed and half alternatives	Lowest-cost or alternative plans	Alternative plans
	Optimal plan transport modes	Air only, air-rail, or air-road	Air-road, air-rail, or air only	Air-road	Air-road

The above table of results answers all the research questions, in the following four scenarios: AKE—with air, AKE—air not required, ASE—with air and ASE—air not required. It presents four different results of itineraries chosen in Europe, Asia, and North America that demonstrate better economic effects because they balance the trade-offs between transport costs and transport times. For example, in Eurasia (Europe and Asia continent), the most effective plans to transport AKE cargo (small) in short-distance situations are mostly highest-speed plans when the air transport mode is compulsory. However, when transporting ASE cargo (large), the lowest-cost plans and alternatives are often utilized for better economic effect—low transport costs with high transport speeds. The long-distance scenario is quite different. Lowest-cost or alternative plans are frequently used to transport AKE cargo and ASE cargo in Eurasia. Air-rail, air road, and air sea transport mode combinations are more often chosen in transporting AKE cargo over a long distance in Eurasia, while air-road, air-sea, and air-road-sea transport combinations are chosen for ASE cargo transport. The route and transport mode combinations are different when transporting small versus large cargos between city pairs with different distances. In terms of regions, North America uses mostly highest-speed plans, which generally involve air-only transport modes, as optimal plans in AKE cargo short-distance transport. However, to transport ASE cargo within North America in the scenario of an air mode being required, the optimal plans are mostly alternatives, which generally include air-road combinations. Furthermore, for long-distance transport in North America, lowest-cost or alternative plans, which use a combination of air-road or air-road-rail, are frequently chosen as optimal plans to transport AKE cargo. To transport ASE cargo over long distances, lowest-cost or alternative plans, which use mostly air-road or air-sea mode combinations, are chosen as optimal plans—this is the same as AKE cargo transportation. Therefore, the optimal transportation plans differ in different regions depending on the multiple variables of transporting distance and cargo size.

The sensitivity analysis has differentiated low-value products from high-value products, starting from $10/kg and going up to $1,500/kg. The results demonstrate the different situations: when the product value reaches a certain point (different break-even point between various OD pairs), the final optimal plan changes to the highest-speed plan among the five top plans. The reason is that we assumed that the holding cost is 20% of the total product value in one year, and when the product value is high enough, the transit time will have a great effect on the total transport cost because this cost consists of freight costs and transport holding costs.

The six interviews confirm the feasibility of the thesis result. All of the six companies use the air cargo mode in the multimodal transport system when shipping goods between origins and destinations, mostly between Asia and North America.

The six interviewees have pointed out some limitations in the validity of the thesis result, including the validity of data collection of the four transportation modes. The first limitation is the accuracy of air transport transit times between some origins and destinations: if the air transit time is more than 4 days, then the transit time should be considered to be too long. The second problem is the accuracy of rail transit times between origins and destinations. Our thesis calculated the estimated price and transit times between origins and destinations by the ratio of the rail mode to the air mode (from the reference to the U.S. Chamber of Commerce, 2006). The ratio was somewhat out of date; the interviewee from CN railway said that rail transportation is much faster than it was in 2006, and the transit time is only slightly slower than that of road transportation. For example, if road transport requires 5 days to transport goods from origin A to destination B, then the rail transportation will need 6 days to transport the same goods over the same distance.

Overall, the research results could answer research questions which displayed in the introduction section.

1) Are there any possible itineraries using multimodal transport methods (air mode included) that create better economic effects and service levels than air-only transport modes in time-sensitive, low-value and high-value products?

Through most of the optimal routes with transportation modes in scenarios illustrated in the discussion section, we could find plenty of examples of optimal routes with multimodal transport method. For example, the optimal route between Singapore and London to transport an AKE cargo of low-value products is from Singapore to Bangladesh by road, then from Bangladesh to Amsterdam by air and from Amsterdam to London by rail.

While to transport high value products, the optimal route between Singapore and London becomes to transport by air.

2) Are there any itinerary differences between transporting small cargos and heavy cargos?

We could answer the question by comparing the two scenarios of transporting an AKE cargo as a small cargo and an ASE cargo as a heavy cargo between each two city pairs in Eurasia, North America or Africa. The difference of transporting a small cargo and a heavy cargo is huge since the weight is different, the transportation cost and transportation transit time are different, thus the optimal itinerary between the two city pairs differs. For example, the optimal route to transport an AKE cargo of low-value products between Singapore and London is from Singapore to Bangladesh by road, then from Bangladesh to Amsterdam by air and from Amsterdam to London by rail. However, the optimal route to transport an ASE cargo between Singapore and London is from Singapore to Rome by air then from Rome to London by sea. (When air transport method is required.)

When it goes to transport a cargo of high-value products, the optimal route between Singapore and London is by air.

3) Are there any itinerary differences between short-distance city pairs and long-distance city pairs in different regions (Eurasia, North America and Africa) with regard to transporting products?

The answer to the question 3) is certain; we have displayed all the different scenarios in terms of distance in each continent. The results turned out to show the differences in each circumstance. For example, when the air transport method is required, the optimal route for transporting an AKE cargo of low-value products between Singapore and Shanghai (Short distance city pairs in Eurasia) is to ship by air, but to ship by road from Singapore to Bangladesh, then by air from Bangladesh to Amsterdam and by rail from Amsterdam to London between Singapore and London (Long distance city pairs in Eurasia).

The optimal route to transport an AKE cargo of low-value products between New York and Montreal (Short distance city pairs in North America) is from Montreal to New York by air. But the optimal route between Los Angeles and Montreal is from Los Angeles to Seattle by air, then from Seattle to Vancouver by rail and from Vancouver to Montreal by road.

The optimal route to transport an AKE cargo of low-value products between Montreal and Shanghai (Long distance city pairs cross continents) is to transport from Montreal to Singapore by air, then from Singapore to Shanghai by road.

Thus there are a lot of itineraries differences between short distance city pairs and long distance city pairs in different regions (Eurasia, North America and Africa) when transporting low-value products.

When it goes to transport a cargo of high-value products, in each three regions, the optimal route changes to be transported by air between city pairs.

4)What are the itinerary differences between different regions, for example, Eurasia and North America, and cross-continent city pairs?

Due to the differences of price and transport transit time in different markets in the world, the optimal itineraries between two city pairs would have huge differences.

8 Implications

8.1 Theoretical implications

Our research has filled the information gap with regard to air cargo in the multimodal transportation system. The previous research mostly focused on rail-sea and road-rail multimodal transportation, and a small portion of papers mentioned the air-truck combination, which mostly appeared in the air transport leakage papers. Conducting research solely on the impact of air cargo transport in the multimodal transportation system is new. Furthermore, with the development of the air transport industry and the maturity of the multimodal transport system, the possibility of combining air cargo modes in the multimodal transport system is a trend nowadays to reduce transportation costs and maintain a relatively fast lead time.

The selection of city covers most major cities across three continents (airports); therefore, the scale of the research is wide enough to observe the world trend of using air cargo modes in multimodal transportation systems. Air cargo size and product value are considered to be two important factors that can influence the economic effects related to economies of scale and the total holding cost in the multimodal transport system. The content of the interviews in this research is a combination of theoretical research and practical experience, and to validate the results, interviews with real companies could be useful references.

In summary, the research is valuable for aviation research as well as for multimodal transport research.

8.2 Managerial implications

The research also posed implications for freight-forwarding and other transportation companies. The interviews revealed that most of the freight-forwarding companies do not use the database to calculate the optimal routes between origins and destinations. Instead, they make decisions based on their own intuition or the existing, familiar transport routes between origins and destinations. For example, if the freight-forwarding companies know the terminals and transit cities on the routes between origins and destinations, they will not risk trying new routes, even though those routes may result in lower costs and higher transport speeds.

The research provided alternative methods and optional plans for freight-forwarding companies to choose when transporting a product from its origin to its destinations in three large continents in the world. The method of combining different routes with various transport modes is useful for those companies to reduce transportation costs. It could also result in more profit while still meeting customers' demands and satisfaction.

9 Limitations

9.1 The data accuracy

The data we have collected are mostly from the secondary database, and in the database, all the data took into account door to door service rather than port to port service, which led to the relatively long transport time between origins and destinations, especially in the air transport mode. Moreover, due to unavailability of data such as railway data in North America, we made an assumption to calculate the estimated transport cost and transit time with the ratio among four modes according to the research of U.S. Chamber of Commerce (2006), thus the bias between calculation results and reality exists.

9.2 The scale of selected cities

We have selected cities over three large continents, which are Eurasia (Europe and Asia), North America and Africa. Those cities are major cities in the world, but in some cases, some cities are not reachable by sea such as Moscow. It can be a limitation of the thesis when we combine the transport modes with various city pairs.

The scale and number of the cities selected in our research are also limited. There could be more cities and combinations in the data processing section.

10 Reference

10.1 References cited in the thesis

Air cargo world. (2015). Retrieved from https://aircargoworld.com/

Athakorn Kengpol, Sopida Tuammee, Markku Tuominen, (2014) “The development of a framework for route selection in multimodal transportation,” The International Journal of Logistics Management, Vol. 25 Issue: 3, pp.581-610

Banomyong, R. (2000). Multimodal transport corridors in South East Asia: a case study approach. Logistics & Operations Management Section, Cardiff Business School Cardiff University .

Beuthe, M. (2007). Transport and its infrastructure. IPCC Report.

CEC (2006) Improving evolution strategies through active covariance matrix adaptation. IEEE Congress on Evolutionary Computation, 2814-2821.

Crainic, T. G. (2007). A brief over view of intermodal transportation. Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation.

Feng, B., Li, Y., & Shen, Z. M. (2015). Air cargo operations: Literature review and comparison with practices. Transportation research, 56, 263-280.

Hao, C., & Yue, Y. (2016). Optimization on Combination of Transport Routes and Modes on Dynamic Programming for a Container Multimodal Transport System. Prodcedia Engineering, 137, 382-390.

Hayuth, Y. (1987). Intermodality: concept and practice: structural changes in the ocean freight transport industry. Lloyd's of London, 149.

Kengpol, A., & Tuammee, S. (2013). The development of a framework for route selection in multimodal transportation. The International Journal of Logistics Management, 25(3), 581-610.

Lowe, D. (2005). Intermodal freight transport. Jordan Hill Oxford, Burlington: Elsevier Butterworth-Heinemamn.

Multimodal transport or port to port conditions. (n.d.). NVOCC terms. Retrieved 2016.

Openflights. (2017). Retrieved from https://openflights.org/data.html

Reis, V., Fabian Meier, J., Pace, G., & Palacin, R. (2013). Rail and multi-modal transport. Research in transportation economics, 17-30.

Rodrigue, J. (2017). The Geography of Transport Systems (Vol. 440).

Roemer, J. (1999). “Singapore registry of accredited multimodal transport operators”, SLA. *International Freight Forwarding Committee Singapore Freight Forwarders Association*.

Rondinelli, D., & BERRY, M. (2000). Multimodal Transportation, Logistics, and the Environment: Managing Interactions in a Global Economy. European Management Journal, 18 (4), 398-410.

U.S. Chamber of Commerce. (2006). Retrieved from https://www.uschamber.com/transportation

UNECE (2009). Terminology on Combined Transport.

Verweij, C. (2011). Synchromodal Transport: Efficient and sustainable transport via network management.

Woxenius, J. (1998). Development of small-scale intermodal freight transportation in a systems context.

Yamada, T., Frazila Russ, B., Castro, J., & Taniguchi, E. (2009). Designing Multimodal Freight Transport Networks: A Heuristic Approach and Applications. Transportation science, 129-143.

10.2 References related to the thesis

ATAG, (n.d.). *The economic & social benefits of air transport*.

ATKEARNEY, (2009). *Rail Freight: Returning to Profitability*. Reversing the impact of the global economic crisis on European rail freight.

Baublys, A. (2009). Models of freight transport system development. *Transport*, 24 (4), pp.283-287.

Bontekoning, Y., Macharis, C., & Trip, J. (2004). Is a new applied transportation research field emerging? --A review of intermodal rail-truck freight transport literature. Transportation research, 1-34.

C. Miller, J. (n.d.). *The optimal Pricing of freight in combination aircraft*.

Chang, T. (2008). Best routes selection in international intermodal networks. Computers & operations research, 35, 2877-2891.

Choosing and developing a multi-modal transport solution. (2008). 1st ed. [London]: Dept. for Transport.

Clarke, M. (2002). Multimodal Transport in the New Millennium. WMU Journal of maritime affairs, 71-84.

Dde Palacio, L. (2004). Future challenges in the air cargo transport. In: *Air Cargo Forum*.

European Commission, (2009). *Road Freight Transport Vademecum*.

Filani, M. (1978). Multimodal Transport Operations in international cargo movement: Implications for transport policies and development in tropical Africa. *GeoJournal*, 2 (5).

Ganbat, E. and Kim, H. (2015). Empirical Study of Multimodal Transport Route Choice Model in Freight Transport between Mongolia and Korea. *Journal of Navigation and Port Research*, 39 (5), pp.409-415.

Gather, M. and Lüttmerding, A. (2010). *Railway logistics and rail cargo*. Proceedings of the 5th SoNorA University Think Tank Conference (Erfurt).

H., L., S., & Y. (2003). Multimodal freight transport network planning. Journal of the eastern Asia society for transportation studies, 5, 666-681.

Hall, R. W. (2001). Truck scheduling for ground to air connectivity. Journal of air transport management, 7, 331-338.

Hansman (PI), J., Hansen (PI), M., Peterson (PI), E. and Trani (PI), A. (2014). *The Impact of Oil Prices on the Air Transportation Industry*. Ph.D. Massachusetts Institute of Technology, University of California at Berkeley, Virginia Tech.

Hao, E. (2010). *Overview of the Cargo Industry and Airports: A Case Study of Memphis International Airport*. Airport Systems Planning and Design.

Impact of advanced air transport technology. (1980). 1st ed. Washington, D.C.: Congress of the United States, Office of Technology Assessment.

Islam, D. Z., Dinwoodle, J., & Roe, M. (2005). Towards supply chain integration through multimodal transport in developing economies: The case of Bangladesh. Maritime Economics & Logistics, 382-399.

J. Wang, J., & C. Cheng, M. (2010). From a hub port city to a global supply chain management centre: a case study of Hong Kong. Journal of transport geography, 104-115.

Janic, M. (2011). Assessing some social and environmental effects of transforming an airport into a real multimodal transport node. Transportation research part d, 137-149.

Jansen, B., Swinkels, P., Teeuwen, G., Van Antwerpen de Fluiter, B., & Fleuren, H. (2004). Operational planning of a large-scale multi-modal transportation system. European journal of operational research, 41-53.

Jong Kim, B., & Kim, W. (2006). An equilibrium network design model with a social cost function for multimodal networks. Ann Reg Sci, 473-491.

Kasilingam, R. (2003). Transporting air cargo into the future. In: *Air cargo supply chain management and challenges*.

Liedtke, G. (2012). Estimation of the benefits for shippers from a multimodal transport network. Logistics research, 113-125.

Logistics management institute, (1998). *Air Cargo Operations Cost Database*.

M., L., & Y. (2010). A Linear Programming Model for Short Sea Shipping and Multimodal Inland Transportation in Myanmar. Logistics research centre, 37-43.

Macharis, C., & Bontekoning, Y. (2004). Opportunities for OR in intermodal freight transport research: A review. European Journal of Operational Research, 400-416.

OLIVER WYMAN, (2016). *AIRLINE ECONOMIC ANALYSIS*. FOR THE RAYMOND JAMES GLOBAL AIRLINE BOOK.

Popescu, A., Keskinocak, P. and al Mutawaly, I. (2010). *The Air Cargo Industry*. 1st ed. p.30.

Shiehwan Lee, (2008). Liability of the Air Cargo Carrier in Montreal Convention and New IATA Air Waybill. *KOREA INTERNATIONAL COMMERCIAL REVIEW*, 23 (4), pp.51-69.

Smith, D. G. (1994). Resolving schedule failures in multimodal transport networks from movement of time-sensitive shipments. Journal of Marketing.

State of California Department of Transportation, (2010). *Air Cargo Mode Choice and Demand Study*.

SteadieSeifi, M., Dellaert, N., Nuijten, W., Van Woensel, T., & Raoufi, R. (2014). Multimodal freight transportation planning: A literature review. European journal of operational research, 1-15.

Stephen G. Wood. (1998). Multimodal Transportation: An Perspective on Carrier Liability and Bill of Lading 46 Am. J. Comp. L. Supp, 403-420

Telesetsky, A. (2013). 10. Organisation for Economic Co-operation and Development (OECD). *Yearbook of International Environmental Law*, 23 (1), pp.578-582.

UNTACD, (2015). *Review of maritime transport*.

Xu, G. (1999). *Multimodal transport and trade facilitation: implications in the Chinese context*. M.Sc. World Maritime University.

Zhang, A., Lang, C., Hui, Y., & Leung, L. (2007). Intermodal alliance and rivalry of transport chains: The air cargo market. Science direct transportation research part E, 234-246.

Zhang, J., Liao, F., Arentze, T., & Timmermans, H. (2011). A multimodal transport network model for advanced traveler information systems. Procedia social and behavioral science, 313-322.

Appendices

Appendix 1 **Multimodal transport concepts:**

Multimodal transport contract
"A single contract for the carriage of goods by at least two different modes of transport." Which means a multimodal transport operator (MTO) is to deal with the transport of goods by using more than one mode of transport, and they are operating under one document for the entire cargo journey. Door-to-door service is often induced.

Multimodal transport operator[4]
"Any person who concludes a multimodal transport contract and assumes responsibility for the performance thereof as a carrier."

Subcontractor
A subcontractor is composed by direct and indirect agents, as well as their relating servants and agents.

Merchant
"Includes the consignor, shipper, consignee, Goods receivers, any person, corporation, or other legal entity having interest in the Goods, or anyone acting on behalf of the person of transacting the goods."

Freight forwarder
In the past, the function of freight forwarder was agent by dealing with paper documents, while recent year, it has become the more active to take opportunity acting as carrier such as NVOCC, thus freight forwarders are bearing more responsibility.

Carrier
"Means the party on behalf of negotiable bill of lading or unnegotiable waybill has been issued."

Goods
"Means the cargo on an attached or referenced manifest, including any Container of cargo not supplied by or on behalf of Carrier."

Carriage[5]

---

[4] "Singapore registry of accredited multimodal transport operators", SLA

[5] Multimodal transport or port to port conditions

“Means the whole or any part of the operations and services undertaken by Carrier in regards of the Goods.”

Package
“Means the object referred to in the ‘No. of Pkgs.’ column on the face of the document and in the absence of designation in such column shall be deemed the Container.”

Container
“Includes any container, trailer, transportable tank, flat or pallet or any similar article used for the transportation of Goods.”

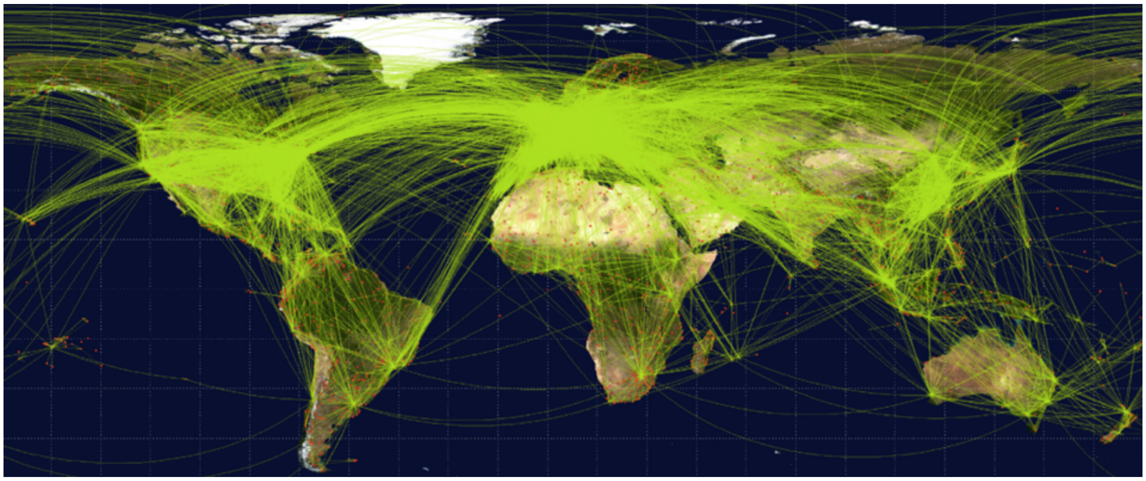
Vessel
“Includes any vessel, ship, craft, lighter, vehicle and other means of transport used for the Carriage or where the Goods are loaded.”

Appendix 2 Top world air cargo ranking

WORLD AIRPORT RANKING: TOTAL CARGO 2014 (METRIC TONNES)				
RANK	CITY, COUNTRY	CODE	TOTAL CARGO	Y-o-Y % CHANGE
1	HONG KONG, CHINA	HKG	4,415,983	6.0
2	MEMPHIS, USA	MEM	4,258,531	2.9
3	SHANGHAI, PEOPLE'S REPUBLIC OF CHINA	PVG	3,181,654	8.6
4	INCHEON, SOUTH KOREA	ICN	2,557,681	3.8
5	ANCHORAGE, USA	ANC	2,492,754	3.0
6	DUBAI, UNITED ARAB EMIRATES	DXB	2,367,574	(3.1)
7	LOUISVILLE, USA	SDF	2,293,231	3.5
8	TOKYO, JAPAN	NRT	2,133,542	5.6
9	FRANKFURT, GERMANY	FRA	2,131,976	1.8
10	TAIPEI, CHINESE TAIPEI	TPE	2,088,727	6.2
11	PARIS, FRANCE	CDG	2,086,487	0.8
12	MIAMI, USA	MIA	1,998,779	2.8
13	SINGAPORE	SIN	1,880,100	0.4
14	BEIJING, PEOPLE'S REPUBLIC OF CHINA	PEK	1,848,251	0.2
15	LOS ANGELES, USA	LAX	1,816,269	3.7
16	AMSTERDAM, NETHERLANDS	AMS	1,670,676	6.7
17	LONDON, UNITED KINGDOM	LHR	1,588,655	4.9
18	GUANGZHOU, PEOPLE'S REPUBLIC OF CHINA	CAN	1,454,044	11.0
19	CHICAGO, USA	ORD	1,377,664	12.1
20	NEW YORK, USA	JFK	1,303 889	0.6

Source: Air cargo world, 2015

Appendix 3 World airlines routes



Source: Openflights.org, 2017

Appendix 4 AKA - AIR-Average cost and time

	1 MODE AVERAGE			2 MODES AVERAGE			3 MODES AVERAGE			4 MODES AVERAGE			TOGETHER AVERAGE		
CITY PAIR	PRICE	COST	TIME	PRICE	COST	TIME	PRICE	COST	TIME	PRICE	COST	TIME	PRICE	COST	TIME
AKE CARGO-SHORT-EURASIA															
SH-SGP	1601.00	2229.44	6.50	9240.61	10281.14	53.69	9415.30	10589.00	89.99	10073.01	11443.05	122.65	8792.89	9771.53	108.14
SGP-SH	11934.00	11999.26	7.50	5785.60	6273.24	56.04	6847.20	7655.61	92.91	7928.43	9028.78	126.46	7840.48	8916.90	123.71
MB-ISTB	4577.00	4668.36	10.50	6993.01	7369.97	43.32	7862.66	8555.50	76.92	8875.27	9881.09	110.96	8792.89	9771.53	108.14
ISTB-MB	3883.00	3983.07	11.50	5771.56	6223.34	51.92	6975.05	7775.07	86.88	8159.43	9267.41	121.29	8062.59	9143.48	118.43
LD-AMSD	2794.50	2872.81	9.00	4193.36	4514.83	42.41	6020.14	6717.85	77.90	7564.26	8586.94	113.55	7437.09	8433.12	110.63
AMSD-LD	2865.00	2943.31	9.00	6052.60	6529.42	41.99	7154.75	7895.68	77.48	8496.89	9552.67	113.06	8387.64	9417.86	110.15
AKE CARGO-SHORT-NORTH AMERICA															
MTL-NYC	7304.00	7338.81	4.00	5823.73	6069.31	28.22	6411.64	6862.63	51.83	7212.75	7873.51	75.94	7097.23	7727.14	72.39
NYC-MTL	918.00	944.10	3.00	2756.00	2982.84	26.07	3970.92	4395.72	48.82	5085.54	5716.37	72.50	4920.36	5520.94	69.02
NOL-LA	1161.00	1195.81	4.00	3848.79	4080.29	26.60	4930.65	5359.11	49.24	5951.46	6577.46	71.94	5800.22	6397.14	68.60
LA-NOL	865.00	899.81	4.00	4800.95	5039.57	27.42	5712.89	6149.16	50.14	6648.75	7282.89	72.88	6510.45	7115.46	69.53
VCV-STL	7304.00	7338.81	4.00	5620.35	5906.38	32.87	6324.45	6811.08	55.93	7163.93	7840.87	77.80	7042.14	7690.95	74.56
STL-VCV	548.00	565.40	2.00	2648.45	2908.27	29.86	3986.87	4430.32	50.96	5143.51	5768.79	71.86	4971.37	5569.85	68.78
AKE CARGO-LONG-EURASIA															
SH-AMSD	11934.00	11999.26	7.50	8082.44	8433.71	40.37	8718.32	9374.27	75.33	9621.01	10584.53	109.35	9548.09	10485.68	106.54
AMSD-SH	1410.50	1471.41	7.00	4577.95	5129.24	51.61	6081.52	6889.03	88.34	7366.86	8493.17	123.77	7260.96	8361.01	120.86
SGP-LD	5066.50	5170.92	12.00	6652.01	7031.93	43.66	7867.01	8541.95	77.57	9059.55	10029.61	111.48	8962.06	9908.00	108.71
LD-SGP	2576.50	2707.02	15.00	4125.83	4650.60	54.76	5796.20	6704.95	88.12	7256.41	8445.49	122.57	7136.54	8304.09	119.79
TKY-HMB	4448.50	4509.41	7.00	8632.89	8988.48	40.87	9307.76	9956.24	76.51	10248.21	11220.29	111.75	10170.74	11115.23	108.80
HMB-TKY	3502.00	3562.91	7.00	6224.09	6666.98	41.13	7345.71	8070.76	76.05	8559.14	9596.04	111.13	8459.49	9469.91	108.23
AKE CARGO- LONG-NOTH AMERICA															
MTL-LA	7304.00	7338.81	4.00	5658.52	5944.74	32.89	6211.46	6702.44	56.43	6973.11	7660.44	78.99	6863.39	7521.73	75.66
LA-MTL	5671.00	5705.81	4.00	2746.15	2974.15	26.20	3952.11	4362.32	47.14	5040.26	5635.55	68.41	4879.96	5448.03	65.28
MIA-VCV	1849.00	1901.21	6.00	2420.52	2644.25	25.71	3797.49	4218.77	48.41	4988.44	5608.89	71.31	4810.94	5401.96	67.92
VCV-MIA	7304.00	7338.81	4.00	5578.42	5820.46	27.82	6319.21	6765.88	51.33	7199.62	7850.45	74.80	7071.86	7692.62	71.34
NYC-STL	1487.00	1539.21	6.00	3784.85	4047.51	30.19	5016.00	5489.26	54.39	6132.40	6816.10	78.57	5966.73	6619.44	75.01
STL-NYC	1056.00	1143.01	10.00	3953.60	4161.05	23.84	5173.69	5571.65	45.74	6284.57	6882.91	68.76	6119.62	6688.56	65.39
AKE CARGO-LONG-EURASIA & NORTH AMERICA & AFRICA															
SH-MTL	13803.00	13868.26	7.50	8752.07	9116.52	41.88	9257.78	9882.22	72.27	10108.95	10990.02	101.21	10047.85	10909.54	98.57
MTL-SH	4586.00	4651.26	7.50	6461.33	6898.05	50.19	7462.97	8223.99	84.64	8510.06	9554.16	115.37	8433.81	9456.29	113.09
SGP-LA	1646.50	1759.62	13.00	7944.71	8317.98	42.90	8498.89	9128.07	72.51	9459.29	10337.43	100.92	9390.05	10250.04	98.83
LA-SGP	2928.00	2958.45	3.50	6985.39	7644.96	44.20	7915.36	8754.20	78.04	8943.78	10070.39	109.40	8868.94	9973.24	107.06

Appendix 5 ASE - AIR-Average cost and time

	1 MODE AVERAGE			2 MODES AVERAGE			3 MODES AVERAGE			4 MODES AVERAGE			TOGETHER AVERAGE		
CITY PAIR	PRICE	COST	TIME	PRICE	COST	TIME	PRICE	COST	TIME	PRICE	COST	TIME	PRICE	COST	TIME
ASE CARGO-SHORT-EURASIA															
SH-SGP	19754.50	20375.87	10.00	52940.66	57108.36	68.99	56433.52	64147.77	126.44	62205.13	73472.03	184.19	61721.76	72687.76	179.47
SGP-SH	63669.00	64290.37	10.00	52165.25	56155.36	64.09	56318.25	63831.78	120.41	62245.75	73323.63	177.59	61754.10	72532.82	172.92
MB-ISTB	71450.00	72071.37	10.00	51756.21	56227.77	71.96	56996.40	64856.57	126.05	63875.34	75070.71	179.46	63306.08	74222.34	175.09
ISTB-MB	27092.00	27744.44	10.50	33408.73	38900.84	89.13	42566.81	51618.83	147.09	51565.99	64017.04	202.47	50799.79	62961.00	197.93
LD-AMSD	27797.00	28356.23	9.00	39427.51	43852.35	71.21	49194.10	57303.60	129.95	58445.24	70237.12	188.97	57659.87	69139.78	184.14
AMSD-LD	21739.00	22298.23	9.00	34345.27	37785.25	55.36	45445.11	52316.52	110.63	55172.77	65604.44	167.89	54344.44	64474.93	163.21
ASE CARGO-SHORT-NORTH AMERICA															
MTL-NYC	52164.00	52412.55	4.00	44435.95	47627.48	51.36	53448.71	59230.70	93.05	63618.16	71925.37	133.69	62113.78	70042.98	127.61
NYC-MTL	40500.00	40748.55	4.00	37231.93	40088.68	45.98	48433.82	53780.98	86.05	59247.99	67109.04	126.51	57641.44	65129.24	120.50
NOL-LA	20387.00	21350.12	15.50	43654.96	47034.01	54.38	55007.48	60665.55	91.06	65203.23	73187.72	128.50	63622.96	71251.16	122.76
LA-NOL	20332.00	21295.12	15.50	42748.94	45842.16	49.78	52654.91	58070.83	87.16	62530.98	70244.89	124.14	61047.05	68416.28	118.60
VCV-STL	52164.00	52412.55	4.00	46387.15	49682.06	53.03	55491.70	61257.69	92.79	65322.21	73488.04	131.42	63869.23	71676.92	125.65
STL-VCV	40500.00	40748.55	4.00	36884.27	39818.51	47.22	47514.96	52886.45	86.45	57722.20	65534.06	125.72	56218.90	63671.42	119.94
ASE CARGO-LONG-EURASIA															
SH-AMSD	63669.00	64290.37	10.00	47471.95	51837.05	70.25	53636.39	61622.32	128.31	60855.89	72474.08	186.79	60250.52	71562.03	182.00
AMSD-SH	36219.50	36840.87	10.00	39972.31	43549.87	57.47	48006.59	55035.18	112.85	56057.40	66623.07	169.94	55374.91	65640.90	165.27
SGP-LD	30271.50	31017.14	12.00	46256.46	49937.77	59.25	53558.02	60710.21	115.01	61225.35	71968.87	172.45	60582.77	71025.36	167.75
LD-SGP	26797.00	27449.44	10.50	39930.40	43960.88	66.80	47791.44	55388.52	124.34	56126.28	67328.36	182.68	55419.02	66314.81	177.90
TKY-HMB	66965.00	67399.96	7.00	61259.75	64153.93	46.58	65367.95	71368.88	96.97	71639.91	80872.21	149.81	71107.33	80061.52	145.44
HMB-TKY	44700.50	45135.46	7.00	48738.09	57094.52	134.48	54871.98	67384.58	199.44	62636.06	78975.87	261.99	61972.44	77980.89	256.78
ASE CARGO- LONG-NOTH AMERICA															
MTL-LA	52164.00	52412.55	4.00	45442.24	48556.34	50.12	55263.34	60933.80	91.26	64763.30	72966.45	132.02	63340.20	71163.37	125.90
LA-MTL	40500.00	40748.55	4.00	37478.70	40272.45	44.96	48018.05	53295.35	84.93	58288.39	66052.38	124.95	56749.55	64140.77	118.95
MIA-VCV	40500.00	40748.55	4.00	36748.95	39635.38	46.45	47923.75	53260.58	85.89	58705.23	66518.07	125.74	57117.81	64566.29	119.87
VCV-MIA	52164.00	52412.55	4.00	44692.87	47914.59	51.85	54244.34	60000.96	92.64	64415.12	72654.76	132.60	62919.53	70791.03	126.68
NYC-STL	20387.00	21350.12	15.50	43654.96	47035.73	54.41	53894.96	59688.81	93.24	63949.65	72091.86	131.04	62451.11	70243.87	125.41
STL-NYC	20332.00	21295.12	15.50	42157.42	45306.35	50.68	52510.97	57951.93	87.56	62371.12	70094.14	124.29	60890.31	68272.28	118.80
ASE CARGO-LONG-EURASIA & NORTH AMERICA & AFRICA															
SH-MTL	62484.50	63230.14	12.00	54163.44	57205.68	48.96	62019.09	68160.47	99.09	70033.16	79616.82	154.23	69432.39	78758.46	150.09
MTL-SH	34349.00	35063.58	11.50	49021.60	52439.14	54.97	55458.52	62037.96	105.84	63615.26	73649.64	161.49	63002.65	72776.66	157.30
SGP-LA	43298.00	43813.96	8.30	65952.54	69414.88	55.72	68163.36	74887.13	108.16	74257.28	84433.66	163.77	73810.03	83728.81	159.63
LA-SGP	20482.00	20699.48	3.50	41772.13	45276.58	58.06	51831.61	58756.76	114.09	61131.76	71545.55	167.59	60420.16	70567.99	163.31

Appendix 6 AKA - ALL-Average cost and time

CITY PAIR	1 MODE AVERAGE			2 MODES AVERAGE			3 MODES AVERAGE			4 MODES AVERAGE			TOGETHER AVERAGE		
	PRICE	COST	TIME	PRICE	COST	TIME	PRICE	COST	TIME	PRICE	COST	TIME	PRICE	COST	TIME
AKE CARGO-SHORT-EURASIA															
SH-SGP	553.06	728.83	20.20	6312.44	7048.23	67.34	8194.84	9278.14	95.53	10073.01	11443.05	122.65	9868.21	11206.43	119.69
SGP-SH	3524.09	3729.45	23.60	4135.79	4765.13	72.33	6039.57	6903.66	99.31	7928.43	9028.78	126.46	7723.31	8797.96	123.50
MB-ISTB	2141.03	2365.54	25.80	4814.50	5265.74	51.86	6858.04	7579.22	81.28	8875.28	9881.07	110.96	8655.81	9626.67	107.68
ISTB-MB	1938.69	2194.96	29.45	4096.49	4631.65	61.50	6136.86	6964.61	91.53	8159.38	9267.33	121.28	7939.47	9012.81	117.99
LD-AMSD	1359.68	1503.88	16.57	3043.95	3440.25	50.90	5315.82	6037.07	82.37	7564.18	8586.83	113.55	7319.37	8307.50	110.13
AMSD-LD	1279.34	1384.67	12.11	4158.72	4627.38	50.53	6256.96	7009.14	81.94	8496.89	9552.67	113.06	8253.67	9274.93	109.65
AKE CARGO-SHORT-NORTH AMERICA															
MTL-NYC	3157.19	3267.88	12.72	4152.42	4466.05	36.04	5679.68	6167.66	56.08	7212.75	7873.51	75.94	6907.84	7534.11	71.97
NYC-MTL	466.23	560.51	10.84	2025.21	2308.92	32.60	3552.52	4010.14	52.59	5079.01	5709.92	72.51	4780.12	5376.42	68.53
NOL-LA	750.63	1087.55	38.72	2847.68	3147.80	34.49	4407.92	4868.97	52.99	5966.15	6592.03	71.93	5643.09	6236.46	68.19
LA-NOL	930.88	1051.37	13.85	3544.96	3853.23	35.43	5106.39	5577.76	54.17	6664.87	7299.15	72.89	6340.09	6941.78	69.15
VCV-STL	3189.32	3439.47	28.75	4073.52	4453.99	43.72	5624.69	6153.70	60.80	7170.81	7846.99	77.71	6857.60	7505.06	74.41
STL-VCV	288.91	331.97	4.95	2053.10	2381.91	37.79	3599.32	4074.61	54.62	5139.71	5764.66	71.82	4835.56	5430.89	68.42
AKE CARGO-LONG-EURASIA															
SH-AMSD	5098.74	5377.18	32.00	5604.53	6048.35	51.01	7619.30	8316.73	80.06	9621.01	10584.53	109.35	9403.27	10335.89	106.14
AMSD-SH	736.94	1018.86	32.40	3304.90	3909.38	65.58	5359.90	6200.42	94.39	7366.86	8493.17	123.77	7147.97	8241.31	120.55
SGP-LD	2245.60	2502.55	29.53	4648.23	5106.63	52.68	6887.10	7600.88	82.03	9059.55	10029.61	111.48	8823.08	9765.30	108.28
LD-SGP	2245.60	2502.55	29.53	2878.08	3407.87	64.60	5076.92	5973.79	93.01	7256.41	8445.49	122.57	7019.57	8176.70	119.37
TKY-HMB	2628.50	2826.46	22.75	6507.84	6927.77	48.26	8378.02	9061.37	79.94	10248.21	11220.29	111.75	10061.02	11002.72	108.55
HMB-TKY	2045.25	2293.24	28.50	4778.36	5250.06	47.99	6677.08	7423.24	79.41	8559.14	9596.04	111.13	8370.88	9377.12	107.94
AKE CARGO- LONG-NOTH AMERICA															
MTL-LA	3148.19	3293.08	16.65	4019.65	4398.23	43.51	5378.20	5923.50	62.67	6338.21	7016.67	77.97	6679.39	7335.89	75.45
LA-MTL	2505.37	2734.35	26.32	2086.80	2373.34	32.93	3563.53	4004.45	50.67	5040.26	5635.55	68.41	4747.71	5312.33	64.89
MIA-VCV	795.95	989.38	22.23	1824.36	2110.64	32.90	1824.36	2110.64	32.90	4988.44	5608.89	71.31	4673.68	5260.91	67.49
VCV-MIA	3177.57	3349.86	19.80	4035.54	4352.20	36.39	5617.58	6101.33	55.59	7199.62	7850.45	74.80	6885.02	7502.58	70.97
NYC-STL	1079.50	1213.08	15.35	2820.78	3163.28	39.36	4476.59	4989.69	58.97	6132.40	6816.10	78.57	5802.37	6452.03	74.66
STL-NYC	1077.88	1224.46	16.85	2972.95	3230.10	29.55	4629.47	5057.13	49.15	6284.57	6882.91	68.76	5954.81	6519.23	64.87
AKE CARGO-LONG-EURASIA & NORTH AMERICA & AFRICA															
SH-MTL	7105.75	7477.73	42.75	6874.46	7293.49	48.16	8496.70	9144.00	74.66	10108.95	10990.02	100.68	9969.98	10829.57	98.42
MTL-SH	2616.00	2892.27	31.75	5045.25	5559.52	59.10	6793.86	7564.41	87.98	8633.37	9620.03	115.35	8475.03	9440.67	112.96
SGP-LA	1213.50	1422.33	24.00	6138.07	6561.92	48.71	7765.44	8413.87	74.60	9459.29	10337.43	100.92	9313.37	10171.74	98.65
LA-SGP	1680.25	1847.75	19.25	5314.87	5988.44	54.21	7156.65	8011.67	81.91	8960.12	10089.03	109.42	8804.42	9907.04	107.01

Appendix 7 ASE - ALL-Average cost and time

	1 MODE AVERAGE			2 MODES AVERAGE			3 MODES AVERAGE			4 MODES AVERAGE			TOGETHER AVERAGE		
CITY PAIR	PRICE	COST	TIME	PRICE	COST	TIME	PRICE	COST	TIME	PRICE	COST	TIME	PRICE	COST	TIME
ASE CARGO-SHORT-EURASIA															
SH-SGP	7134.28	8928.49	28.88	36643.66	42048.43	90.77	49440.13	57765.55	136.99	62205.13	73472.03	184.19	60779.07	71718.15	179.06
SGP-SH	21008.06	22962.27	31.45	36355.99	41595.28	84.39	49401.98	57534.80	130.51	62245.75	73323.63	177.59	60816.31	71567.03	172.47
MB-ISTB	31025.88	33410.38	38.38	35340.23	41180.14	93.98	49674.77	58171.55	136.31	63875.34	75070.71	179.46	62299.53	73195.34	174.76
ISTB-MB	12192.12	14893.53	43.48	23203.76	30368.98	116.38	37398.87	47136.75	158.98	51565.99	64017.04	202.47	49985.50	62134.22	197.74
LD-AMSD	11879.86	13692.70	29.18	28065.41	33846.80	93.04	43294.36	52065.73	140.54	58445.24	70237.12	188.97	56742.33	68194.84	183.70
AMSD-LD	10896.10	12809.92	30.80	24643.00	29155.67	72.62	40037.29	47473.87	119.82	55172.77	65604.44	167.89	53470.98	63566.63	162.67
ASE CARGO-SHORT-NORTH AMERICA															
MTL-NYC	23017.79	24217.03	19.30	31951.34	36120.19	67.09	47493.21	53757.38	100.81	63618.16	71925.37	133.69	60392.49	68287.01	127.05
NYC-MTL	18090.13	19289.37	19.30	27181.69	30886.87	59.63	43172.76	48964.12	93.20	59247.99	67109.04	126.51	56026.02	63470.53	119.81
NOL-LA	12153.69	14671.79	40.53	32208.53	36629.84	71.15	48039.37	54330.10	101.24	63853.89	71995.82	131.03	60645.18	68411.63	124.99
LA-NOL	10191.63	12865.07	43.03	30863.25	34855.81	64.25	46710.17	52569.42	94.30	62530.98	70244.89	124.14	59320.24	66658.64	118.10
VCV-STL	24803.04	27081.91	36.68	34299.51	38561.08	68.58	49665.04	55880.37	100.03	65322.21	73488.04	131.42	62209.73	69986.34	125.15
STL-VCV	18326.25	19407.43	17.40	26383.15	30214.93	61.67	42052.67	47874.50	93.69	57722.20	65534.06	125.72	54606.63	62021.24	119.33
ASE CARGO-LONG-EURASIA															
SH-AMSD	27585.40	30078.65	40.13	32878.97	38581.01	91.77	46925.20	55557.69	138.79	60855.89	72474.08	186.79	59296.28	70580.29	181.57
AMSD-SH	16500.86	18955.27	39.50	28003.11	32711.89	75.60	42140.81	49750.10	122.31	56057.40	66623.07	169.94	54495.45	64729.95	164.76
SGP-LD	13739.71	16444.22	43.53	32367.86	37177.67	77.41	46974.00	54707.19	124.47	61225.35	71968.87	172.45	59635.44	70044.38	167.23
LD-SGP	12542.48	15127.38	41.60	27737.56	32978.84	87.39	41915.63	50112.49	134.56	56126.28	67328.36	182.68	54537.56	65404.02	177.44
TKY-HMB	35012.00	36456.68	23.25	45613.61	49227.53	58.16	58665.04	65085.89	103.99	71639.91	80872.21	149.81	70297.19	79238.66	145.24
HMB-TKY	23606.50	25361.87	28.25	36708.18	47292.27	170.33	49657.71	63202.84	216.16	62636.06	78975.87	261.99	61293.14	77342.03	257.39
ASE CARGO- LONG-NOTH AMERICA															
MTL-LA	25017.79	27288.90	36.55	33493.32	37594.87	66.01	49280.80	55429.43	98.95	64763.30	72966.45	132.02	61627.27	69414.46	125.32
LA-MTL	18740.00	20024.68	20.68	27355.51	30976.54	58.28	42721.43	48436.29	91.97	58288.39	66052.38	124.95	55144.21	62491.93	118.25
MIA-VCV	17174.88	18653.74	23.80	26376.50	30126.21	60.35	42540.86	48322.14	93.04	58705.23	66518.07	125.74	55490.46	62898.25	119.22
VCV-MIA	24507.17	26170.37	26.77	32294.87	36483.53	67.41	48245.70	54479.48	100.32	64415.12	72654.76	132.60	61211.67	69051.67	126.17
NYC-STL	12153.69	14702.86	41.03	32208.53	36632.42	71.20	48082.73	54370.32	101.19	63949.65	72091.86	131.04	60757.61	68527.01	125.04
STL-NYC	10191.63	12896.14	43.53	30403.08	34479.72	65.61	46599.25	52472.23	94.52	62371.12	70094.14	124.29	59187.50	66539.86	118.33
ASE CARGO-LONG-EURASIA & NORTH AMERICA & AFRICA															
SH-MTL	33240.50	34747.32	24.25	42954.57	46648.07	59.44	57104.87	63632.14	105.29	67697.86	77005.35	151.85	66731.16	75797.84	147.86
MTL-SH	19933.50	21657.80	27.75	38970.56	43101.56	66.45	51286.26	58266.17	112.75	63736.10	73547.37	160.14	62592.63	72167.86	156.20
SGP-LA	24631.75	26334.41	27.40	51239.14	55588.75	70.00	62453.34	69622.51	115.54	72031.31	81971.57	161.31	71212.40	80914.69	157.41
LA-SGP	11877.50	13679.47	29.00	33312.10	37804.32	74.70	47797.47	55194.96	121.01	64943.20	75343.78	169.02	63599.38	73759.61	165.15

Appendix 8 Interview questions

Customer

1 What type of customers are you dealing with mostly?

- Are they manufacturers, retailers or wholesalers?
- What are the most important industrial sectors?
- How many of them are sensitive to both transport cost and transport time?
- Do you sometime have the choice between air cargo and other modes (sea, road)?

Products

2 Different types of goods to be transported by what kind of transport method?

- Low value products, time sensitive
- Low value products, not time sensitive
- High value products, time sensitive
- High value product, not time sensitive

3 What is the boundary between low-value product and high-value product?

- Any criteria to divide product between low-value products and high value products?
- What are example of such products?

Transportation

4 Air cargo

- On what market is air cargo used (North America, Europe, Asia)?
- Do you do business with integrators (FedEx, UPS or DHL) or airlines?
- Most used type (Dimension, size and weight)

5 Multimodal transport

- Is multimodal transportation a method that you use (or consider) to move goods between origins and destinations?
- What type of goods are mostly using multimodal transport?
- Is air cargo involved in the multimodal transport system?
- In what kind of scenario does air cargo get involved in multimodal transport?
- If it is not used, why is it? Could it be used?

Routes and cost/time

6 Optimal route selection between origins and destinations

- Using algorithm or heuristics?
- Situations in different regions? Such as North America, Eurasia and cross continents transportation?
- Any favourable multimodal terminals or hubs in each region?
- Any preferable existing itineraries with different transport mode in each region?
- What is the most popular multimodal transport mode combination in each region?

7 Total cost constituent, total transport time constituent

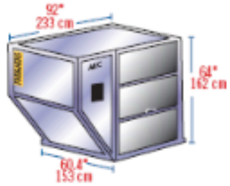
- Total cost consists of transport cost and holding cost during transit time and delay time? What's more?
- Total transport time consists of transit time and delay time? Anymore?

8 Criteria considered other than cost and time

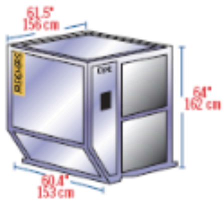
- Such as environment protection? CO_2 emission?
- Potential transport risk? Multimodal transport risks?
- How to measure those risks? Any algorithm or procedure (check list)?

Appendix 9 Air cargo types

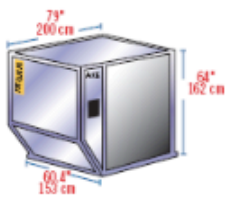
LD-1
IATA ULD Code: AKC Contoured Container
Also known as: AVC, AVD, AVK, AVJ
Forkable: AVY
Classification: LD-1
Rate Class: Type 8
Suitable for: B747, B767, B777, MD-11
Internal volume: 4.8 cu. m (169.5 cu. ft)
Maximum gross weight: 1588 kg (3501 lb)



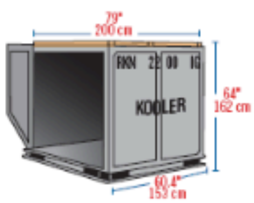
LD-2
IATA ULD Code: DPE Contoured Container
Also known as: APA, DPA
Forkable: DPN
Classification: LD-2
Rate Class: Type 8D
Suitable for: B767
Internal volume: 3.4 cu.m (120 cu. ft)
Maximum gross weight: 1225 kg (2700 lb)



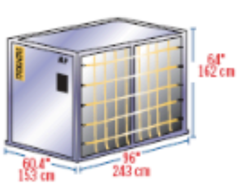
LD-3
IATA ULD Code: AKE Contoured Container
Also known as: AKE, AVA, AVB, AVC, AVK, DVA, DVE, DVP, XKS, XKG
Forkable: AKN, AVN, DKN, DVN, XKN
Classification: LD-3
Rate Class: Type 8
Suitable for: A300, A310, A330, A340, B747, B767, B777, DC-10, MD-11, L1011
Internal volume: 4.3 cu. m (152 cu. ft)
Maximum gross weight: 1588 kg (3500 lb)



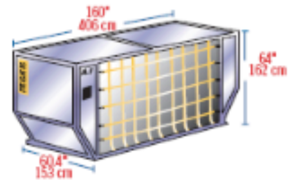
Insulated LD-3
IATA ULD Code: RKN
Classification: LD-3
Rate Class: Type 8
Suitable for: A300, A310, A330, A340, B747, B767, B777, DC-10, MD11, L1011
Internal volume: 3.0 cu.m (109 cu. ft)
Maximum gross weight: 1588 kg (3500 lb)
Temperature Control Range: -20C to +20C



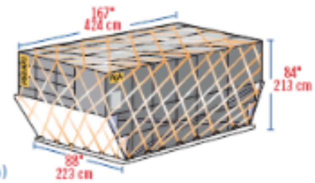
LD-4
IATA ULD Code: ALP Rectangular Container
Also known as: ALD, AWD, AWZ, DLP
Forkable: ALB, ALC, AWB, AWC
Classification: LD-4
Rate Class: Type 8
Suitable for: B767, B777
Internal volume: 5.7cu. m (201 cu. ft)
Maximum gross weight: 2449 kg (5399 lb)



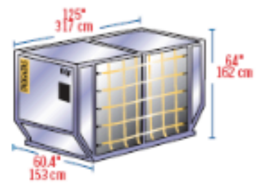
LD-6
IATA ULD Code: ALF Contoured Container
Also known as: AWD, AWF
Forkable: AWC
Classification: LD-6
Rate Class: Type 6W
Suitable for: A300, A310, A330, A340, B747, B777, DC-10, MD-11, L1011
Internal volume: 8.9 cu. m (314 cu. ft)
Maximum gross weight: 3175 kg (7000 lb)



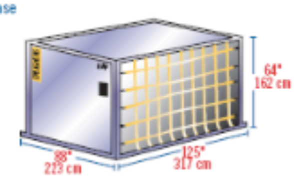
LD-7
IATA ULD Code: XAW P1P Pallet with fixed angle wings and net
Classification: LD-7
Rate Class: Type 5
Suitable for: Wide body. All aircraft
Maximum volume with overhang: 14.0 cu. m (494 cu. ft)
Maximum gross weight: 5000 kg (11023 lb)



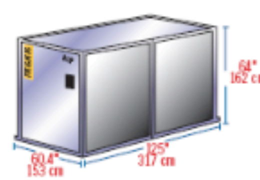
LD-8
IATA ULD Code: DQF
Also known as: ALE, ALN, DLE, DLF, DQP, MQP
Classification: LD-8
Rate Class: Type 6A
Suitable for: B767
Internal volume: 6.85 cu. m (242 cu. ft)
Maximum gross weight: 2450 kg (5401 lb)



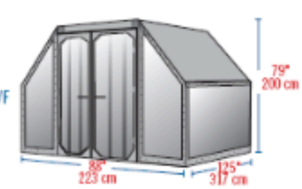
LD-9
IATA ULD Code: AAP Enclosed Pallet on P1P base
Also known as: AA2, XAG, XAV
Classification: LD-9
Rate Class: Type 5
Suitable for: A300, A310, A330, A340, B747, B767, DC-10, MD-11, L1011
Internal volume: 9.1 cu. m (321 cu. ft)
Maximum gross weight:
4624 kg (10194 lb) lower deck
6000 kg (13227 lb) main deck



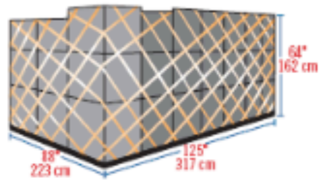
LD-11
IATA ULD Code: ALP Rectangular Container
Also known as: ALD, AW2, AWB, AWD, AWZ, DLP, DWB, MWB
Refrigerated version: RWB, RWD, RWZ
Classification: LD-11
Rate Class: Type 6
Suitable for: A300, A310, A330, A340, B747, B777, DC-10, MD-11, L1011
Internal volume: 7.2 cu. m (253 cu. ft)
Maximum gross weight: 3176 kg (7002 lb)



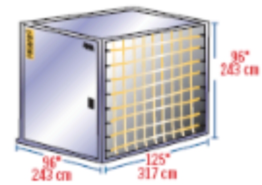
A-2
IATA ULD Code: DAA
Classification: A-2
Suitable for: B747, B747F, DC8, DC10, A300/F
Internal volume: 12.6 cu. m (444 cu. ft)
Maximum gross weight: 6033 kg (13300 lb)



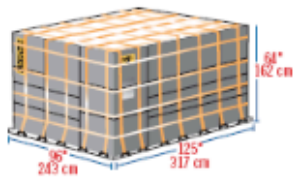
88" PALLET
IATA ULD Code: P1P
Classification: 88" Pallet with net
Suitable for: B747, B767, B777, DC-10
Maximum volume: 11.9 cu. m. (420 cu. ft)
Maximum gross weight: 747/DC-10: 6033 kg (13300 lb)
767: 5103 kg (11227 lb)
777/DC-10: 4626 kg (10501 lb)
Can be loaded to 96" (162 cm) and
118" (300 cm) on freighters



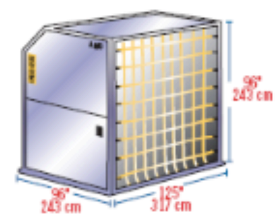
AQ6
IATA ULD Code: AMA Rectangular Container
on P6P Base
Also known as: AMF, AMG, AMK, AMP,
AQA, AQD, AQ6
Classification: M-1
Rate Class: Type 2
Suitable for: B747F, B747Combi
Internal volume: 17.5 cu. m (618 cu. ft)
Maximum gross weight: 6804 kg (15000 lb)



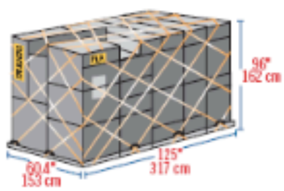
96" PALLET
IATA ULD Code: P6P 10ft flat pallet with net
Also known as: P6A, P6C, P6Q, PMA, PMC,
PMP, PQP
Classification: LD-9
Rate Class: Type 2BG
Suitable for: A300, A310, A330, A340, B747,
B767, B777, DC-10, MD-11, L1011
Maximum volume: 21.2 cu.m (747 cu.ft.)
Maximum gross weight: 6,804 kg (15000 lb)
Can be loaded to 96" (162 cm)
and 118" (300 cm) on freighters



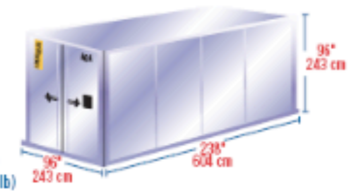
AQ7
IATA ULD Code: AMD Contoured Container
on P6P Base
Also known as: AQA, AQ7
Classification: M1H
Rate Class: Type 2H
Suitable for: B747F, B747Combi
Internal volume: 19.9 cu. m (702 cu. ft)
Maximum gross weight: 6800 kg (14991 lb)



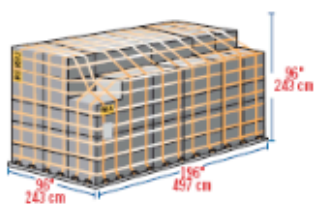
HALF PALLET
IATA ULD Code: PLA half pallet with net
Also known as: PLB, FLA, P9A, P9B, P9P, P9R, P9S
Classification: HP
Rate Class: Type 6
Suitable for: Lower deck: B747, B777
Main deck: B707F, B727F, B737F
Maximum volume: 7.2 cu. m (254 cu. ft)
Maximum gross weight: 3175 kg (6999 lb)



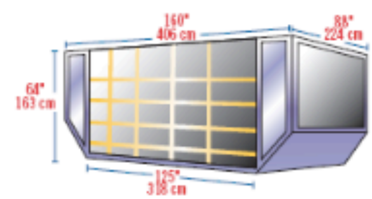
M-6
IATA ULD Code: AGA 20ft Box Container
Also known as: ASE
Classification: M-6
Rate Class: Type 1
Suitable for: B747F, B747Combi
Internal volume: 33.0 cu. m (1165 cu. ft.)
Maximum gross weight: 11340kg (25000 lb)



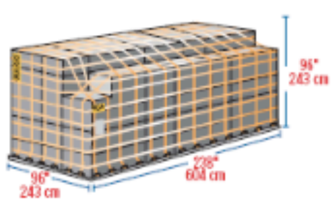
16 FT PALLET
IATA ULD Code: PRA 16ft flat pallet with net
Also known as: PMA, P4A, P4M, PZA
Classification: MDP
Rate Class: Type 1P
Suitable for: B747, B747Combi
Maximum volume: 26.8 cu. m (946cu. ft)
Maximum gross weight: 11300 kg (24991 lb)



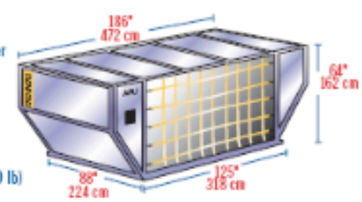
LD-26
IATA ULD Code AAF
Classification: LD-26
Suitable for: B747, B777, DC-10
Maximum gross weight:
747/DC-10: 6033 kg (13300 lb)
777/DC-10: 4626 kg (10501 lb)



20 FT PALLET
IATA ULD Code: PGA 20ft flat pallet with net
Also known as: PGA, PGE, PGF, PSA, PSG, P7A,
P7E, P7F, P7G
Classification: M-6
Rate Class: Type 1
Suitable for: B747F, B747Combi
Maximum volume: 33.2 cu. m (1174cu. ft.)
Maximum gross weight: 11340 kg (25000 lb)



LD-29
IATA ULD Code: AAU Contoured Container
on P1P base
Classification: LD-29
Rate Class: Type 5
Suitable for: B747
Internal volume: 14.2 cu. m (501cu. ft)
Maximum gross weight: 6033 kg (13300 lb)



Source: Interfreight logistics, IATA, ATA

Appendix 10 Air cargo code meanings

First letter [edit]

The meaning of the first letter is

- A Certified Aircraft Container
- D Non-Certified Aircraft Container
- F Non-Certified Aircraft Pallet
- G Non-Certified Aircraft Pallet Net
- J Thermal Non-Structural Igloo
- H Horse Stalls
- K Cattle Stalls
- M Thermal Non-Certified Aircraft Container
- N Certified Aircraft Pallet Net
- P Certified Aircraft Pallet
- R Thermal Certified Aircraft Container
- U Non-Structural Container
- V Automobile Transport Equipment

Second letter [edit]

The second letter describes the base size of the container.

- A 2,235 x 3,175 mm (88 x 125 in)
- B 2,235 x 2,743 mm (88 x 108 in)
- E 1,346 x 2,235 mm (53 x 88 in)
- F 2,438 x 2,991 mm (96 x 117 3/4 in)
- G 2,438 x 6,058 mm (96 x 238 1/2 in)
- H 2,438 x 9,125 mm (96 x 359 1/4 in)
- J 2,438 x 12,192 mm (96 x 480 in)
- K 1,534 x 1,562 mm (60.4 x 61.5 in)
- L 1,534 x 3,175 mm (60.4 x 125 in)
- M 2,438 x 3,175 mm (96 x 125 in)
- N 1,562 x 2,438 mm (61.5 x 96 in)
- P 1,198 x 1,534 mm (47 x 60.4 in)
- Q 1,534 x 2,438 mm (60.4 x 96 in)
- R 2,438 x 4,938 mm (96 x 196 in)
- X Miscellaneous sizes largest dimension between 2,438 mm and 3,175 mm (96 in and 125 in)
- Y Miscellaneous sizes largest dimension 2,438 mm (96 in)
- Z Miscellaneous sizes largest dimension >3,175 (>125 in)

Source: Wikipedia, 2017