Erasmus University Rotterdam

MSc in Maritime Economics and Logistics

2018/2019

Study on economic routes selection under the integrated operation mode of China Railway Express: based on the train transits from Alataw Pass through the new Eurasian Land Bridge

by

Xinyu Gu

Acknowledgements

First of all, I would like to express my sincere gratitude towards my supervisor Prof. Dr. Rommert Dekker for his motivation and guidance given with regards to my thesis. He is my mentor on the road to academic research. His support through email, phone calls and regular meetings helped me a great deal, especially with critical thinking. He has been encouraging me to explore my potentials further and inspiring me to keep on making improvements. Without his inspiration and support, I would definitely not be able to complete this piece of work within limited amount of time.

I would like to thank MEL for giving me the chance to participate in program of Maritime Economics and Logistics. The lectures, company visits, field trips and dinners became unforgettable memories of my life. The cross culture atmosphere in academic helped me to broaden my horizons in shipping. The experience I have earned here is believed to be of vital importance for my future career in shipping industry. I also want to thank my colleagues and the staff in MEL. We went through good and bad together along the way, and built close friendship in this year.

Moreover, I would like to thank my friends and family, who provided great mental and physical support during my master program. Their unconditional love and trust in me helped me through hard time and sleepless nights.

Last but not least, I want to thank myself for the braveness of making the decision to come to the Netherlands to explore further. I want to appreciate the hard work I have done as well as the ups and downs I have experienced so far, which makes me even stronger day by day.

Xinyu Gu

September, 2019

Abstract

With the increasing China-Europe trade volume in goods, the Belt and Road Initiative stimulates trades for countries along the routes. The China Railway Express plays an important role in connection of China and Europe trade, and the number of trains as well as the frequencies is growing throughout years. However, the express mainly is supported by government subsidies to avoid a lossmaking status and there are several problems during the operation. Therefore, it is requested to improve the operation efficiency by reducing operational cost and improving the timeliness.

This research studies the China Railway express from perspectives of economic routes selections for trains exiting from China through Alataw Pass by New Eurasian Land Bridge. By implementation of the integrated operation concept, a multi-objective optimization model in terms of transport cost and duration is established and the problem is solved by a genetic algorithm.

At first, the research introduces background, added value, and literatures relating to the subject. Then, the author analyzes the major problems and limitations of China Railway express, and points out the necessity to implement an integrated operation mode. After that, the research introduces the multi-objective optimization models and genetic algorithms to solve the model. By generating the influence factors in terms of economic route selection, the model of traditional economic route selection is improved. Considering the transport duration and cost, the differences in transport modes, and the possibility of interchanging operations between nodes, a multi-objective optimization model in terms of transportation cost and duration is built. By determining the best combination of transport route and transport modes, the study resulted in the lowest transportation costs for each forty-foot equivalent unit and the shortest overall transport duration. Considering the complexity of the model, this research uses genetic algorithm by encoding each node and transport mode, applies certain crossover and mutation rules to keep the population evolving and find the solution at the end. The whole process is implemented in the MATLAB software. For routes from China to Europe through Alataw Pass, it suggests Zhengzhou as the integration center for the economic route selection where the transport cost and duration is the lowest.

The study fits this goal and lays the basis for future research in this field, which is helpful to improve efficiencies of China Railway Express. That has certain practical significance.

Key words: China Railway Express, integrated logistics, genetic algorithm, multi-objective optimization model

Table of Contents

List of Tables

List of Figures

List of Abbreviations

BRI	Belt and Road Initiative
CR	China Railway
CNY	China Yuan
EU	European Union
FCL	Full Container Load
FEU	Forty-foot Equivalent Unit
GA	Genetic Algorithm
GDP	Gross Domestic Product
KM	Kilometer
LCL	Less Than Container Load
MM	Millimeter
MOP	Multi-Objective Optimization Model
NDRC	National Development and Reform Commission
NSGA	Nondominated Sorting Genetic Algorithm
PRC	People Republic of China
TEU	Twenty-foot Equivalent Unit
TSP	Travelling Salesman Problem
USD	United States Dollars

Chapter 1 - Introduction

1.1 Problem Statement

Under the current isolated operation mode of China Railway Express (CR express), it is neither so productive in respect of cargo aggregation and service quality, nor competitive in cost and operational efficiencies (Dong, 2016). However, the existing research on CR express under the Belt and Road Initiative (BRI) are mainly from qualitative aspects, such as the economic and geopolitical impacts thereof. There is lack of quantitative research for CR express regarding economic route selection. Therefore, this research looks to figure out economic routes of CR express under the integrated operation mode by selecting the proper integration center, which is believed to be more beneficial for the sustainable development of CR express.

1.2 Objectives and Added Value

1.2.1 Objectives

Under the background of BRI and increasing trade flows between China and Europe, although the CR express in different areas has been making great contribution to local economy, however, there are still several problems: severe route duplications, lack of capability to aggregate sufficient cargo, relative low utilization rate, imbalanced two-way cargo, and etc. Without the subsidies from local government, the CR express operates will be at a loss situation. When the subsidies come to due, the local operators should get rid of the original isolated operation mode, instead to implement an integrated operation mode in order to reduce the operational cost and duration. In doing so, the CR express will become much more competitive than before.

Integrated mode being the ultimate and mature level of logistics industry, has been verified to be capable of reducing the overall transport cost. The objective of this paper looks to improve the performance of CR express by proposing the integrated operation mode, determining economic routes by figuring out the integration center, and compare the transport cost before and after routes' optimization.

1.2.2 Added Value

a) Theoretically

This paper conducts qualitative and quantitative analyses of the CR express, and improves the research further based on current research. Although the Chinese Government introduced *Construction and Development Plan of China Railway Express during 2016-2020* mentioned that till 2020, the CR express will be able to achieve a reasonable network layout, efficient and convenient system, safe and smooth flows, and complete infrastructures. However, due to the fact that the start of actual operation for the express train was relatively late, the integrated operation mode has not been fully implemented and there is lack of theoretical support with regards to CR express at current stage. This paper looks to explore further on the theoretical analysis for necessity of integrated operation mode of CR express to fill the gap to a certain extent.

b) Practically

Based on the current situation, the development of CR express will be helpful to upgrade the traditional China/Europe trading structures. The export products from China maybe changed from low profit bulk commodities to “Made in China” products with high profit margins, which is a milestone as a result of the CR express development. Under the background of rapid development, the consignors are able to select the most suitable transport mode based on their requirement. In doing so, the trade flow between China and Europe is expected to increase further. This paper is going to combine the actual operational data for CR express to implement the modeling in order to reduce the transport cost and improve the efficiency, which has considerable practical significance.

1.3 Research Question and Explanations

1.3.1 Research Question and Sub-research Questions

This research looks at answering the question of:

What’s the possible integration center under the integrated operation mode of China Railway Express in order to achieve economic routes through Alataw Pass?

In order to answer the research question, the sub-research questions as below have been developed to help aid the provision of a well-rounded answer to the main research question:

1. What are the benefits for an integrated operation mode of the CR express? (To be answered in Chapter 3)

2. What are the valuable influencing factors with regards to the selection of economic routes? (To be answered in Chapter 4)

1.3.2 Explanations

a) CR Express: the name was officially introduced by National Development and Reform Commission (NDRC) of People's Republic of China (PRC) on 8th Jun 2016 (NDRC of PRC, 2016). It refers to the internationally joint railway transport services that based on fixed schedules, routes, train number, and whole course operations between China and Europe, and other countries which along the BRI (China Railway, 2019).

b) CR Express Operators: it indicates the local China Railway departments of CR express divisions at each city that manage and operate the trains on specific routes. For instance, as for CR express on route "Chongqing-Duisburg" YUXINOU (Chongqing) Logistics Co., LTD is one of the operators.

c) Integration Center: it represents to a city that is going to aggregate the cargo from several CR express operators, and then transfer the cargo to Europe in order to operate CR express efficiently in terms of transport time and duration.

d) Integrated Operation Mode: it's one type of operation modes of CR express that the local operators of CR express are going to aggregate cargo within their geographic areas first. Then, transfer the cargo to one or several integration centers as per the order of authorities (government, industry associations). Ultimately, the cargo to the same destination will be sourced and transported from the integration centers afterwards (Xinsilu, 2018).

e) Alataw Pass: it locates in the Eurasia center, which is in Northwest China the Xinjiang Uygur autonomous region. Moreover, it is an important gateway along the modern Silk Road, and it's the largest dry port in China (Li, 2019).

Figure 1: Geographical Location of Alataw Pass

Source: China Daily (May 8, 2017)

1.4 Background

1.4.1 Country Level

a) Economy Development Presents “New Normal” and Supply-side Reform in China

As a result of the market-based reforms policy since 1978, the rapid and sustained economic development can be seen in China. Until 2010, the growth rate of GDP per year remained around 9% (Riley, 2019). However, the growth rate started to decline since then which floats between 7% and 8% (Bank, 2013). Chinese government noticed that the root cause may not be the economic cyclicality; however, the reform of export processing industrial structure in China leads to the decline (Yu, 2015).

President Xi Jingping first time proposed the idea of “New Normal” during his visitation at Henan province in May 2014. He pointed out there were three trends and characteristics of “New Normal”, which were “the economy has shifted gear from the previous high speed to a medium-to-high speed growth”, “the economic structure is constantly improved and upgraded” and “the economy is increasingly driven by innovation instead of input and investment” (Bernard, 2015). Based on that, President Xi proposed the proceeding of supply-side reform in Nov 2015 at meeting of the Central Leading Group for Financial and Economic Affairs. One of the purposes of supply-side reform is to cut partly the production overcapacity and close down outdated production capacities. In doing so, China is going to transfer part of them to some countries that are still improving their infrastructures. Under the background of “New Normal”, the Belt and Road Initiative will be beneficial for China to enhance the cooperation and connection with emerging economies around the world.

b) Proposal and Promotion of Belt and Road Initiative

President Xi raised the initiative of building the Silk Road Economic Belt and the 21st Century Maritime Silk Road in 2013. BRI aims to promote connectivity of developed economies in Europe, fast growing economies such as Russia, Mongolians well as Poland, and great economic potentials in Southeast Asia, which seize to achieve peaceful, fast growing, cooperative, mutual beneficial and full-open situation. In doing so, China will be able to transfer the domestic production overcapacity much faster.

In 2016, the Chinese Government invested about 14.5 billion United States Dollars (USD) in exploitation of the economic potentials within the 53 countries along the BRI.

By the end of 2018, the total investment by Chinese Government exceeded 90 billion USD with a growth rate of 5.2% per year. So far, 82 overseas economic and trade cooperation zones have been built which brought about 2.2 billion USD of tax revenue to local countries and created about 0.3 million employments at the same time (Xinhua Net, 2019).

The opening structure in China shows that the east regions develop faster than the west and maritime transport grows faster than road transport (CICC, 2015). The BRI will be beneficial for the east China to develop even faster, and the connections between west China and other countries will be increased. Moreover, it's helpful for China to improve further of its logistics system as a whole.

c) The Importance of Increasing Trade Flows between China/Europe

China established diplomatic ties with European Community in 1975 and declared comprehensive strategic partnership with EU in 2003. With the further development of opening policy in China, the gross Europe/China trade volumes have been increasing throughout the years. As per the official figure from Chinese government, until 2019, the Europe/China trade volumes increased 250 folds in 40 years, and in 2018, the bilateral trade value hit a record which up to 68.22 billion USD (The Chinese Governemnt, 2019).

1.4.2 Market Level

a) The Import and Export Commodity Structure between China and Europe

The traditional trade structure between China and Europe since 2004 has been: China mainly export labor-intensive products with low profit margin, such as textiles, garments, toys, raw materials, electric home appliances and etc (Xinhua, 2019). However, China import high profit margin goods, for instance the electronics, machineries, biological instruments and etc.

In recent years, the structure has been changed due to the new achievements made by scientific and technological innovations in China. More and more Chinses IT and pharmaceutical enterprises emerge. Therefore, the products from those companies are expected to be exported to Europe which requires efficient and timely logistics services. The development of CR express will be able to meet their demand of transportation.

The arrival of new retail era and the improvement of economic level in China enforced customers in China to pay attention to their life experience, logistics services. It can be seen that the demand of wine, furniture, fruits, milk from Europe is increasing throughout the years in China.

b) Main Mode of China/Europe Transport

The main modes of transport between China and Europe are: waterway (shipping, Far East – Mediterranean - Suez Canal Route), railway (Siberian Land Bridge and New Eurasia Continental Bridge) and air transport (UNECE, 2018).

Waterway is the dominant transport mode which carried 94.4% of total TEU exported from China to Europe (Liu, 2018). The duration of the one-way transit from China to Europe through sea transport is about 30-35 days. The dense frequencies and sufficient capacity of the shipping lines through Chinese and European ports stimulate the trade flows. Moreover, the fierce competitions between shipping lines inevitably led to price competitions and the Baltic Freight Index (BFI) dropped dramatically. In 2015 for instance, the BFI only reached about half of the break-even point for each TEU.

The railway is mainly carried by CR express. According to the *Construction and Development Plan of China Railway Express during 2016-2020* published by Chinese Government in 2016, the CR express exits from four Chinese inland ports which are Manzhouli, Erenhot, Horgos and Alataw Pass, then switches the tracks and drives further to Europe. With the reveal of the BRI benefits and the increasing profit generated by CR express, the numbers of trains and the frequencies have been increased from year to year. At present, the CR express only carried a small percentage of all export cargo, which is about 0.4% of total export TEU (Liu, 2018). However, considering the improvement of the CR express operation structure, construction of infrastructures along the way and policies support from the countries, the duration and cost of the CR express is expected to decrease gradually in near future.

There are several air routes among major cities in China/Europe, which is helpful for the transport of commodities. However, only high profit margin and strict timeliness cargo is transported by airlines considering the expensive air freight, such as flowers, biologicals, fresh foods, and etc.

c) Subsidies from Chinese Government

The local Chinese governments propose different types and degrees of subsidies in order to have their local CR express operators to be more competitive than the others in respect of aggregation of cargo, freight rates, and utilization rate. As a result, the local operators start the malignant price competition by lowering their price to be aligned with freight rate by sea. In doing so, the freight rate of CR express is not able to be fully adjusted by the market itself.

1.5 Research Design and Structure

1.5.1 Research Design

Generally, this paper makes comprehensive use of qualitative and quantitative analytical methods to conduct necessity analysis of integrated operation mode and set up mathematical model of economic route selection to realize the optimization of multiple objectives, which is solved by Genetic Algorithm (GA) in MATLAB. The detailed research design is as follows:

Chapter 2 gathers literature review regarding main methods the author is going to use: GA, China Railway express and integrated logistics.

Chapter 3 starts with explanations of relevant definitions, such as integrated logistics, economic routes, and multi-objective optimization. Subsequently, analyzes the necessity of integrated operation mode of CR express compared with existing isolated mode considering the current status and problems incurred during operation.

Chapter 4 explains about the influence factors of economic route selection model and the integrated operation scheme for CR express. Based on the traditional economic route selection model, the author establishes a multi-objective optimization model considering the transport cost and duration of CR express, and sets up the relative presumptions, corresponding parameters and relative constraints.

Chapter 5 introduces GA in order to deal with multi-objective optimization model, including encoding the chromosomes, determining the initial population, selecting the fitness function, and establishing crossover and mutation rules in the algorithm.

Chapter 6 places the data in the model, and determines the integration center of CR express as well as the corresponding transport time and cost by MATLAB. Moreover, the author compares the economic benefit and conducts the analysis based on the outcome.

1.5.2 Research Structure

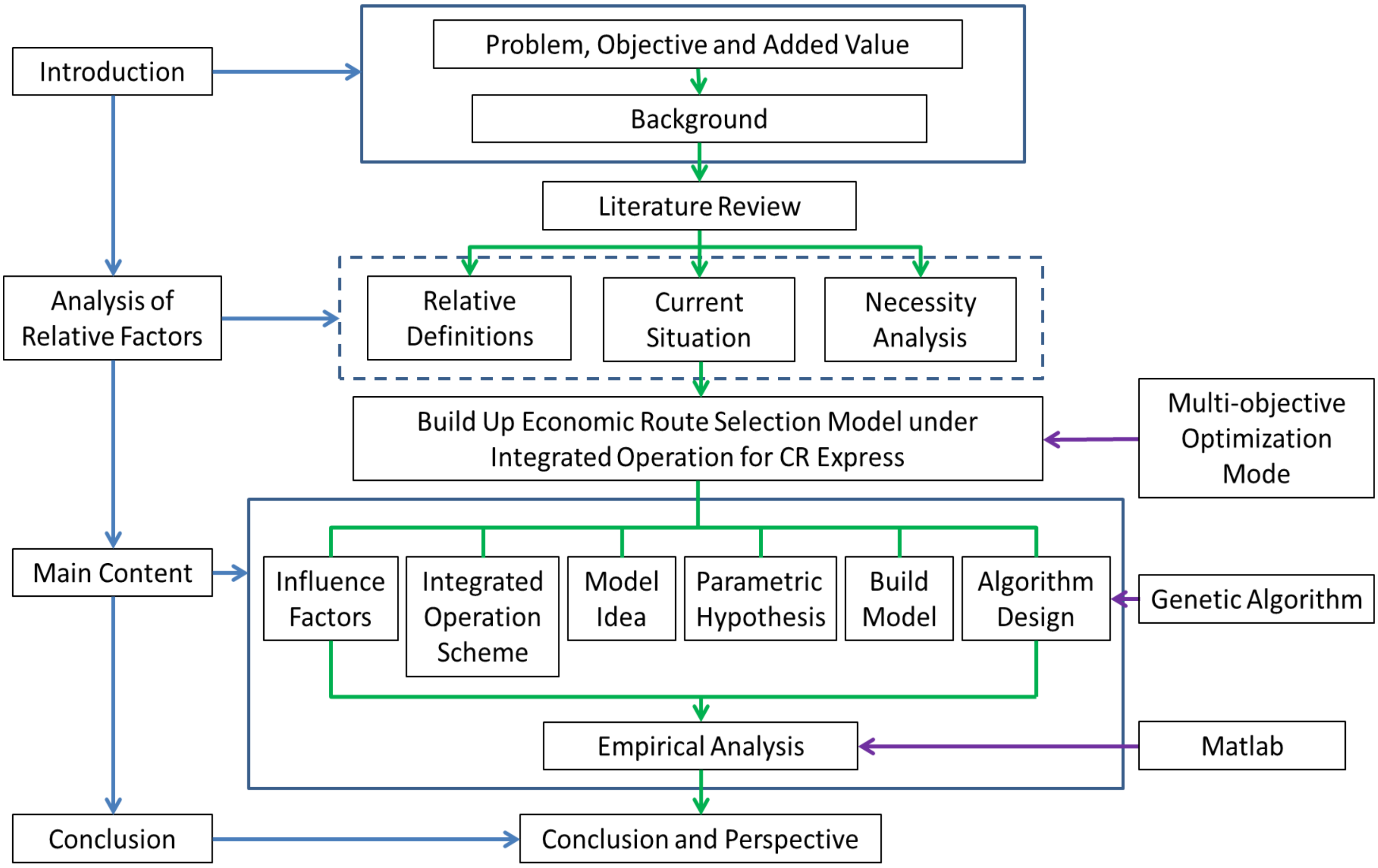

Figure 2: Research Structure

Source: Own elaboration

Chapter 2 - Literature Review

2.1 Application of Genetic Algorithm in Economic Route Selection

Genetic Algorithm by definition is a computational model that mimics biological evolution to figure out the optimal solution. On top of that, it is a metaheuristic inspired by the process of natural selection which based on the concept of Darwin's theory of evolution (Wikipedia, 2019). With the increasing number of nodes and routes with regards to the economic route selection problem, the number of solutions in GA shows a geometric explosion. Therefore, the traditional route optimization method such as enumeration method and weighting method could not properly or efficiently solve the model. However, the GA can solve the model easily.

Holland (1960) introduced the concept of GA. Afterwards, his colleagues Dejong, Goldberg extended the concept further and introduced a mature GA in 1989 (Wikipedia, 2019).

Tom & Han (2003) introduced heuristic algorithm to generate large amounts of alternative routes based the lowest cost of public traffic system. Later, they used the GA to select the most economic route from those alternatives.

Anderson, Phillips, Sicker & Grunwald (2004) introduced the non-separator mixed GA to upgrade the algorithm to a more simple and flexible way while solving the route selection under the condition of multi-objective optimization, especially while implementation in the calculations involving 50-483 parameters.

Li & Zhao (2012) designed integer coding GA in order to solve the route selection problems in terms of integral linear programming. The optimization objective is to achieve the lowest total cost of transport, transshipment and punishment. The constraints are transport capacity and delivery time. The precondition is to include the controllable and uncontrollable situations under the transport cost.

Deng (2015) used GA to select the route for unmanned aerial inspection. While selecting the chromosome, the observation points are polar coordinate coded. In doing so, the overall optimization capability has been improved. Moreover, the efficiency and safety operation of the unmanned aerial is improved as well.

Tian (2016) used GA and ant colony algorithm to solve the traveling salesman problem regarding optimized combinations of travel time, expenses and tourism experience. He used MATLAB to formulate the best tourism route.

Li (2016) used GA to get the optimal solution for complicated vehicle distribution model in the process of cold-chain logistics to achieve the lowest CO_2 emission.

The GA proved to be a suitable model to solve the complicated economic route selection problem. In this research, the GA method will be used to select economic routes under the integrated operation of CR express.

2.2 China Railway Express

The first work of CR express is Chongqing-Sinkiang-Europe International Railway which started operation in 2011. Subsequently, the China-Asia and China-Europe international railway operated successively. During the operation, many problems occurred which mainly focus on the cost of operation, duration of the transport and cargo aggregation. Currently, the existing research regarding the CR express is mainly focused on qualitative analysis, such as strategy planning, geopolitical and economic impacts, and policy making.

Xu (2015) analyzed the common and different operation mode of CR express at different regions, such as the operation structure, capability to aggregate cargo, entry and exit port, and etc. Based on the outcome, he combined the BRI to explore further on the route selection of the CR express.

Wang (2015) analyzed the current situation of CR express and summarized the amount of the express, the cargo quantity, cargo types, and operation structures. Moreover, he provided some suggestions regarding each problem, such as the reform of operation structure, adjustment of industrial structure, implementation of governmental subsidies and etc.

Li (2015) analyzed the problems of CR express considering the transport timeliness, arrangement of outward/backhaul shipments, cooperation mode, cost, and etc. He proposed to use market optimization method and accelerate the construction of infrastructures to solve these problems.

Xu & Lu (2015) stated that due to administrative interference from government and too direct support of financial subsidy, the competition between local CR express operators in terms of aggregations of cargo is disordered, which lead to malignant price competitions. As a result, the operation of CR express in some regions is at loss condition without the subsidies from government due to the severe imbalance between revenue and cost. Moreover, in view of the isolated operation mode, the Chinese operators are at inferior positions during negotiations with foreign countries. In doing so, it is very difficult for the operators to get preferential freight rate and favorable political support for CR express from those countries.

Chen (2015) proposed the malignant price competition in CR express has to be stopped, the local operators should work together and keep a partnership based on the viewpoint of “1+1 > 2”.On the one hand, the local operators may differentiate their services by introducing railways of distinctive features for local economies development, and operate on different routes and working period. On the other hand, they should try their best to maintain the price integrity and let the market to adjust the price.

Zheng (2016) pointed out the strategic problems for each region where the CR express is operating, such as isolated operation mode, route duplications and vicious competitions. Based on which he assumed the operation structure of “point to point” and “point plus point to more”.

Chen (2016) studied on new challenges and opportunities for Wuhan-Sinkiang-Europe Railway, and conducted SWOT analysis of it compared to other CR express. Based on that, he concluded the development direction, emphasis and notes for the Wuhan-Sinkiang-Europe Railway.

Huang (2016) studied about the customs clearance and information feedback processes during the CR express operation. The author found that there is large amount of time wasted during the customs clearance in China and in other countries as well. The information feedback also presents retardation. These problems have a negative impact on the customers’ choice of ways of transportation, meaning they are less likely to choose the CR express for transportation. It’s also harmful for the “faster and safer” brand effect of the CR express.

Above studies of CR express point out the several challenges based on the current status, such as route duplications, vicious price competitions, and isolated operation mode.

2.3 Integrated Logistics

Integrated logistics is one of the major trends for the logistics development since 2000, and it represents a higher and mature level of logistics services. Moreover, logistics integration aims to achieve a total optimal goal by emphasizing the cooperation and coordination between subsystems.

Young & Jackson (1997) mentioned that integrated logistics doesn’t mean a fixed and definite idea. The content, scope and structure of the concept is changing along with the world development. One of the features of integrated logistics is to enforce the efficiency and coordination of logistics procedures.

Liu (1999) defined the concept of integrated logistics. The author pointed out that integrated logistics happens between many enterprises or different departments within one company. The purpose is to reduce logistics cost and improve the efficiency. Moreover, consider the processing, supply and sales procedures as a whole in raw material, semi-finished products and finished products which requires the coordination and cooperation along the logistics links. The author also explained further for the purpose and procedures of integrated logistics.

Quayle (1999) pointed out that the purport of integrated logistics is to take a systematic view to combine each function and activities of logistics. In doing so, people are able to reduce the connective procedures and increase the efficiency. The overall logistics cost will be able to be reduced by cooperate each function in the chain.

Wu (2003) believed the core of integrated logistics is logistics management, which means that in order to achieve optimization as a whole, we should use the managing experience during the logistics procedures and listen to the advises from professional logistics managers and technicians. The main management process of integrated logistics is to manage the circulation of products. During the process, we need to consider all influence factors of logistics, and implement a systematized scientific concept to achieve the optimal goal as a whole.

Jiang (2004) mentioned the major four purposes of integrated logistics are: quick response, customer satisfaction, system optimization and cost saving. In order to realize the goal, the operators should integrate resources at each link, and implement system management in all logistics procedures from purchase of raw material to sales of products. By integrated operation of each links, the operators are able to choose the optimum binding point by adjusting trade-off relation of each factor in order to achieve the total optimization. In doing so, the logistics cost will be reduced and the efficiency will be improved at the same time.

It can be seen that in order to achieve the cost and time efficient operation of CR express, it’s vital to introduce the idea of integrated logistics into the research.

2.4 Summary

From above literatures, it can be seen that logistics integration is essential to improve logistics efficiency and reduce transport cost. CR express is an important platform for China to open to outside world, and the state of operation is not optimal due to the high running cost. At present, there are only a few scholars implement the concept of integrated operation in order to figure out economic routes to reduce the operation cost of CR express. Many of them are focused on qualitative research on this subject.

Nowadays, the solutions for complex system problems rely on mathematical modeling. This method also achieved fruitful research outcomes in many other areas such as spacecraft development, military activities, logistics distribution mode, fire prevention and control, and etc. However, the mathematical modeling is rarely implemented to figure out economic routes for CR express. In order to address this problem, this paper is going to build a quantitative model by mathematical method considering the transport cost and duration by implementing the concept of integrated logistics.

Chapter 3 – Necessity Analysis for Integrated Operation Mode of China Railway Express

3.1. Definitions and Descriptions

3.1.1. Integration and Integrated Logistics

The concept of integrated operation on CR express was first introduced by Dong Qianli (2011). In literature "Logistics Integration Theory & Implementation Mechanism", he explained about the integrated logistics theory in detail.

a) Integration

Integration means aggregation and composition. By definition of Oxford Dictionary, integration is an action or process or outcome of combining two or more things in an effective way in order to achieve a specific goal. It also means to aggregate beneficial factors to realize the overall optimization. In other words, it represents a certain behavior, process or outcome that a party combines two or more elements as per certain rules to achieve some goals.

b) Integrated Logistics

Logistics integration refers to a synthesis process to combine logistics unit, links and processes as per certain rules and purpose. Moreover, integrated logistics is also a process of resource integration according to the requirement of logistics system and the purpose of increasing value of the logistics services.

The realization of integrated logistics relies on modern technology. The theory and realization processes are based on development of society, science and technology. The content of integrated logistics includes integrations of information, technologies, processes, systems, regulations, environment and etc. The structure of integrated logistics process is shown in Figure 3.

Taking Dole Food Company as an example, it is the largest fruit and vegetable provider around the world (Wikipedia, 2019). Dole owns a logistics company Dole Ocean Cargo Express running 23 containerships, and it provides integrated logistics services, including cooperation with 3rd party logistics, warehouses, and terminals. To elaborate more, Dole implements integrated logistics which enables it to control mature period of goods as per the required delivery time by temperature control at warehouses and during the delivery process, and monitor the quality of the goods throughout transportation in order to prolong the shelf time. When cargo damage occurs, Dole is able to track back to the exact period when it happened. Therefore, integrated logistics is essential for Dole to deliver the goods timely and efficiently to many parts of the world (Dole, 2016).

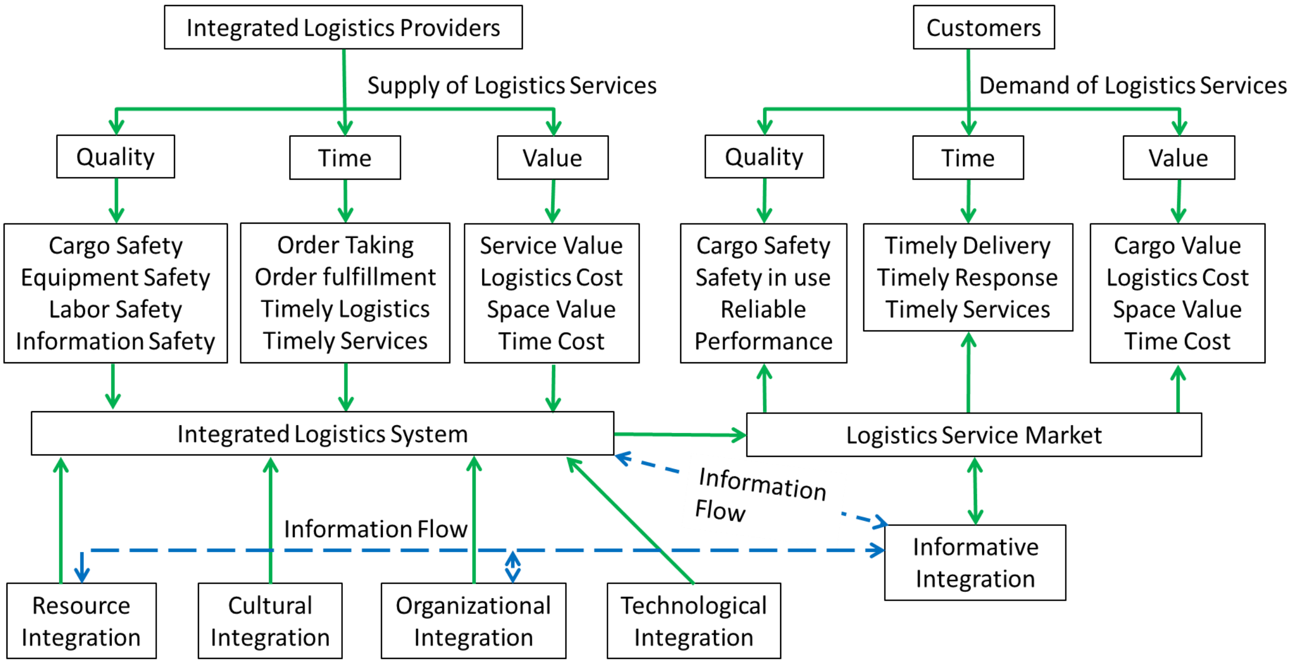

Figure 3: Structure of Logistics Integration

Source: Own elaboration and content based on Dong (2011)

3.1.2. Economic Route

The economic route is usually understood as the route that is charged at the lowest cost, which is partly correct. This research considers the selection of economic route from an economic point of view, meaning the route selection process, the assessment criteria also include transport cost, time cost, labor cost and external cost (pollution, CO2 emission, noise, accidents, and congestion) and etc (Shang, 2015)

Cost is the monetary expression of the value of production factors consumed by enterprises or individuals to produce commodities or provide services in the production and business activities (Yu, 2005). Although the concept of cost varies according to the booming commodity economy, there are some characters remain the same: Firstly, the emergence of cost is due to the demand of certain product; secondly, the payment of cost is through cash or exchange of goods. Last but not least, the calculation of cost is through monetary measurement.

It's not encouraged to increase the investment for a certain criteria in order to reduce its cost spending. However, the investment should be based on the economic efficiency. Taking the time cost as an example, the company increased the investment on time in order to shorten the time to market and to accelerate the speed of product delivery. However, the company may gain neither any competitive advantage nor the expected profit margin, which fell into the “acceleration trap” and led to investment failure at the end (Cui, 2007). The key economic measurable indicator of time is time cost which means to increase or decrease the impact of time on cost. Therefore, while selecting the economic route, it should be considered comprehensively including transport cost, time cost, labor cost, and external costs, not only the cost spending.

3.1.3. Multi-objective Optimization Model

Since economic route selection for CR express is influenced by many factors, while designing the model, it’s not practical to optimize single objective, instead, it is required to optimize multiple objectives in a model. As a result, the integrated operation mode of CR express should be a multi-objective optimization model.

The multi-objective model is an important model in operational research, which has been broadly used in many areas, such as military affairs, projects and social sciences (Hu, 2012). This model was designed by Charnes and Cooper (1962) in order to study multiple objectives functions under certain constraints. Pareto, Von, Kuhn, Tucker and Koopman explored further on the multiple objective problems and extended the model to many other sciences (Guo, 2017).

a) Description of Multi-objective Optimization Problem

When the single objective optimization model cannot meet the needs of model designers, the multi-objective optimization model (MOP) emerges. The single model by name can optimize one objective only. The formula is as below:

$$\max \quad \mathrm{z} = \mathrm{f}(x) \tag{3-1}$$

$$\mathrm{s.t.} \quad \mathrm{g}(x) \le 0 \qquad i = 1,2, \dots m \tag{3-2}$$

$\mathrm{f}(x)$ is the objective function, $\mathrm{g}(x)$ is the constraint function, x is the decision variable, and $\mathrm{x} \in R^n$.

Multi-objective problem is a condition that decision makers want to achieve multiple objectives, and choose the relative optimal solution by weighing the preference structure of the constraints. The formula is as following:

$$
\begin{cases}
\min & f_1(x_1, x_2, \ldots x_n) \\
 & \ldots \\
\min & f_i(x_1, x_2, \ldots x_n) \\
\max & f_1(x_1, x_2, \ldots x_n) \\
 & \ldots \\
\max & f_m(x_1, x_2, \ldots x_n) \\
\text{s.t.} & g_j(x_1, x_2, \ldots x_n) \geq 0 \quad j = 1,2, \ldots p \\
 & h_k(x_1, x_2, \ldots x_n) \geq 0 \quad k = 1,2, \ldots q
\end{cases} \tag{3-3}
$$

$f_i(x_1, x_2, \ldots x_n)$ $(i = 1,2, \ldots m)$ is objective function, $x_1, x_2, \ldots x_n$ are decision variables, $g_j(x_1, x_2, \ldots x_n)$ and $h_k(x_1, x_2, \ldots x_n)$ are constraint functions, p, q, n are nonnegative integers. If $p = q = 0$ the multiple objective problems are called unconstrained multi-objective optimization, instead is called constrained multi-objective optimization.

b) Non-dominated Solution

During the process of finding the optimal solution, the difference between single and multiple objective problems is huge. For single objective optimization, the solution is usually within the feasible region determined by the constraints. For the multiple ones, sometimes it can be found that it's difficult to compare the objectives directly or the objectives contradict each other, and it turns out to be hard to find an optimal solution to satisfy all the objectives. These solutions are called non-dominated solutions or Pareto solutions (Ling, 2017). The definition is as follows: assume that there are two solutions 1Q and 2Q. If 1Q is best for any objective, it is called 1Q dominates 2Q, while if not, 2Q is called non-dominated solution or Pareto solution. The common character of Pareto solutions is that one objective will be weakened by the optimization of the other objective.

c) Preference Structure

The existence of Pareto solutions enforced people to select one of them as the optimal solution for multiple objective problems. It's required to make a choice from those non-dominated solutions according to the preference of each objective, where the preference index is introduced. For example, people can set up the expected optimal level for each objective to set up the corresponding preference index as excellent, good, general, weak and extremely weak. Moreover, people may sort these objectives as per the preference sequence and set up preference index for each objective. The preference index for each objective formed the preference structure of objectives. Preferences are determined by the decision maker considering the optimized requirement of objectives. Then the decision maker will select the final solution from the preference structure.

d) Solution

According to several literatures, the common solutions dealing with multiple objective problems are as Figure 4. There are two ways to deal with the solutions, which are traditional decision making approach and intelligence algorithm (Gong, 2008). The traditional approach is to handle the structure problems of single extremum, such as linear and integer programming. The intelligence algorithm is to solve unstructured problems with multi-extremum.

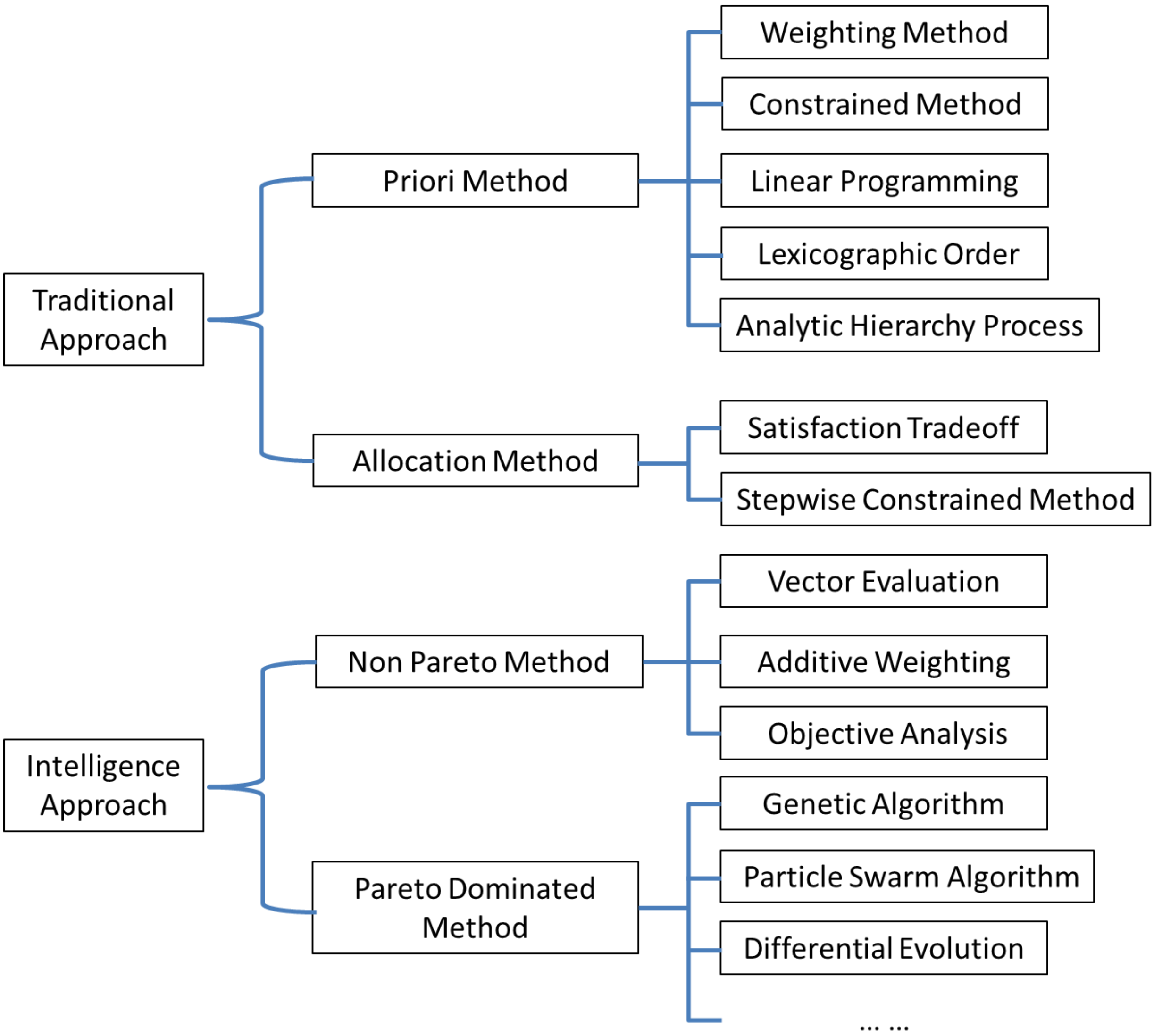

Figure 4: Common Solutions for Multi-objective Problems

Source: Own elaboration and data based on You (2002)

There are several literatures studied deeply regarding multi-objective optimization model and the solutions, which provide idea and methods to set up MOP for the economic route selection of CR express.

3.2. Status and Existing Problems of China Railway Express

3.2.1. Status

a) Numbers of CR Express

The first work of CR express is Chongqing-Sinkiang-Europe International Railway which started operation in 2011. This route is to solve the transport problem at Chongqing in order to implement investments from overseas. After a long time negotiation and effort of Chongqing local government, the railway operated via Alataw Pass to Duisburg, Germany since March 19, 2011, and the total distance is 11,000 kilometers. As the development of BRI since 2013, the number of CR express trains has been increasing substantially. The statistics from NDRC shows there are 65 CR express routes by August 2018, and there have been 48 cities in China that operate CR express till 40 cities in 14 European countries (NDRC, 2018). The total number of CR express exceeds 14,000 by March 2019 (Ministry of Commerce of the PRC, 2019).

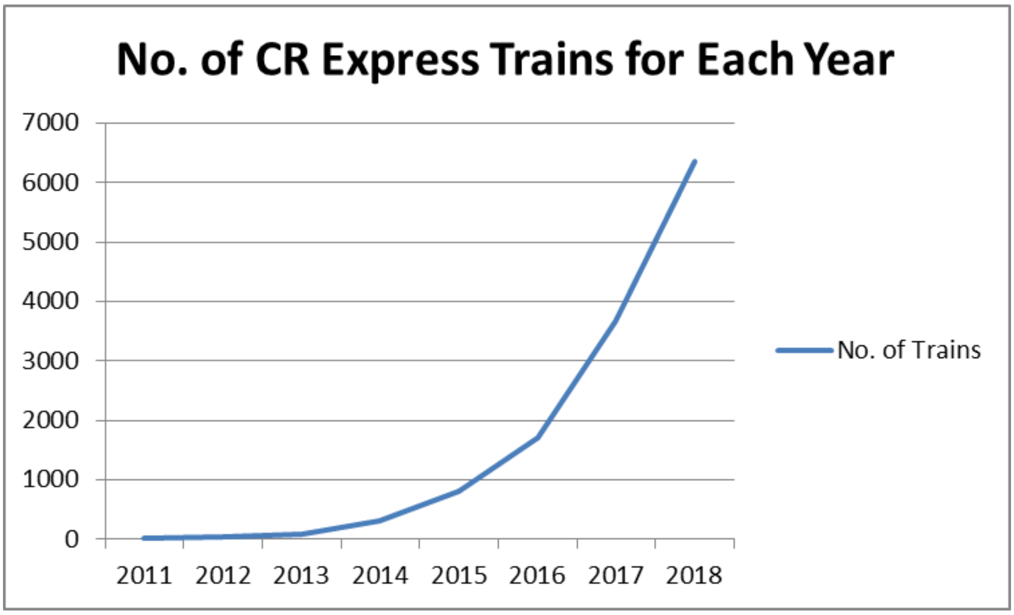

Figure 5: Number of CR Express Trains for Each Year
Source: National Development and Reform Commission of PRC (2018)

There are four entry/exit ports for CR express in China: Alataw Pass, Horgos, Erenhot, and Manzhouli. The Alataw Pass and Horgos correspond to the west CR express pass, Erenhot corresponds to middle routes and Manzhouli is to east pass. The traffic volume of each entry/exit port in 2018 is shown in Table 1. It can be seen that compared with Alataw Pass, Horgos has extremely low value in terms of capacity and import & export value, however, the reason is not clear.

Table 1: Traffic Volume for Each Entry/Exit Port at End of 2018

Ports	No. of Trains / Growth Rate	Capacity / Growth Rate	Import & Export Value / Growth Rate
Alataw Pass	2605 / 6.69%	18.03 Million Tons / 8.9%	$77.9 Billion / 7.3%
Manzhouli	1801 / 38.2%	3.4 Million Tons / 33.4%	$8.7 Billion / 15.63%
Erenhot	1052 / 80%	0.7 Million Tons / 114.4%	$2.8 Billion / 10.5%
Horgos	404 / 146%	2 Million Tons / 133%	$13.7 Billion / -

Source: Own elaboration and data based on GangGangTong (2019)

b) Service Quality of CR Express

The initial purpose for local governments to develop CR express is from political considerations. To elaborate more, the local governments would like to attract investments from overseas to increase export and develop local economy by offering huge amount of subsidies to CR express operators to keep profit and loss balance. Having seen the positive economic effect of CR express, several cities (including Chongqing, Chengdu, Zhengzhou, Wuhan, Changsha and etc) started their international railways named after their cities. All of a sudden, reports about Chongqing/Wuhan/Zhengzhou-Sinkiang-Europe and Changsha-Manzhouli-Europe are widespread. In these reports, there are some doubts about the CR express, such as the efficiency, empty containers, no return cargo, subsidies and etc. However, as per the development of CR express brand and support/guidance from government policies, these doubts are gradually solved and the quality of the CR express has been increasing in these years. Nowadays, a variety of cargo is transported by CR express such as clothing, shoes, auto parts, mechanical parts, food and drinks. Compared to 8 years before, the cargo was solely electronic products for instance computers. Moreover, the CR express operators provide diversity of services, such as truckload transport, temperature controlled transport, clothes hanging transport, and other personalized services according to specific needs of customers (Int.Business Daily, 2019). In doing so, the added value of CR express can be increased dramatically.

3.2.2. Existing Problems

Since 2011, the CR express has been seen making good progress in promoting local economic development so far. However, during the process, there are some problems that need to be resolved.

a) Utilization Rate

Utilization rate refers to the ratio between the numbers of forty feet equivalent units (FEU) that are fully loaded with cargo and the total numbers of FEUs on each CR express train. The problem regarding utilization rate has been existing chronically since the start of CR express. Some of the operators only load one computer for one container in order to increase the utilization rate. Till now, this problem for outward trip still remains by now. However, in view CR express increases its timeliness and economic benefits gradually, and more and more enterprises choose CR express to transport their goods to Europe and central Asian region, the utilization rate has been increased substantially. Based on the data on Dec 2018, the utilization rate for CR express from China was 97% (Xinhua, 2019). However, for the return trip this problem is much more severe, which was about 71% only by the end of 2018. There are two main reasons:

Firstly, many of the CR express routes are duplicated. Especially for routes exiting from Alataw Pass, there are 5 routes that are duplicated at "China-Kazakhstan-Russia-Belarus-Poland", which are Chongqing-Duisburg Route, Chengdu—Lodz, Yiwu-Madrid, Wuhan-Hamburg, and Zhengzhou-Hamburg line. The duplicated routes increase the transport cost, and their operators will be very difficult to get preferential policies in terms of international freight cost and customs during international business negotiations.

Secondly, the China-Europe trade surplus has long been in existence. In 2018, the EU had a trade deficit with China of 185 billion euros in terms of trade in goods (Eurostat, 2019). China export more than import from Europe, and 74% of the imports is transported by sea transportation (Sun, 2018). Therefore, the demand of land transportation is relatively small.

b) Timeliness

The outstanding competitive advantage of CR express compared with extreme low freight cost of sea transport and expensive air freight rate is the timeliness. The punctuality (1 day) of CR express is nearly 100%. The transport duration is one third of sea transport and it could reach to Europe fastest in 12 days. The freight rate of CR express has reduced 30% compared to the beginning, and it is only one fifth of the air freight (National Railway Administration of PRC, 2017).

c) Deficit

The overall deficit condition of CR express operation is not improved due to three reasons:

1. Government subsidy: facing the competitions between various operators, local

governments have been providing large amount of subsidies to operators to attract more cargo since the start of CR express. However, the freight rate competition between local operators became more vicious that the CR express freight was even close to the fright rate of sea transport which is not helpful for CR express to decrease cost and promote efficiency. Nowadays, Chinese government has noticed this problem, and has planned to reduce the subsidy year by year to enhance the regulatory role of the market in economy in terms of price adjustment. Since 2018, Treasury of P.R.C. has required local governments to lower the subsidy level that based on the freight rate of CR express, the subsidies should not exceed 50% of the freight in 2018, less than 40% in 2019, and in 2020 it should be less than 30% of through rate (Treasury of PRC, 2019).

2. Isolated operation mode of CR express: there is no collaboration and cooperation between CR express operators currently and route duplication is very common. In the current operation mode wastes capacity of CR express and puts CR express in a weak position for business negotiations with other countries in terms of gaining beneficial international freight rate and preferential customs policies.

3. Infrastructures: some countries along the CR express line lag far behind in terms of infrastructures and informatization level, which has a negative on effect of multimodal transport considering the efficiency of container handling, storage and transshipment.

These researches studied the problems of route duplication and isolated operation mode for CR express, and expect to reduce operational cost and duration by operating under an integrated mode of CR express.

3.3. Analysis of Necessity for Integrated Operation Mode

There are three links that both the isolated and integrated operation mode should go through: aggregate cargo, trunk transport and terminal distribution. Since the terminal distribution is usually carried by international logistics companies of certain country instead of CR express, this research will not include about the terminal distribution.

3.3.1. Isolated Operation Mode

Considering that 70% of CR express trains exit via Alataw Pass, this research studied the CR express from Alataw Pass to Europe through the New Asia Europe Land Bridge (Xinhua, 2018). Based on the current routes, the following seven lines are compliant with this requirement: Chongqing-Duisburg, Wuhan-Hamburg, Chengdu-Lodz, Changsha-Duisburg, Zhengzhou-Hamburg, Xiamen-Hamburg, and

Yiwu-Madrid. The location of seven Chinese cities is illustrated in Figure 6. There are several other cities in China that the CR express are not normalized operated, such as Kunming, Guiyang, Lanzhou, Xining, Lanzhou, Kuerle and etc. However, this research didn't include the CR express in those cities since these trains are limited and randomly operated. Therefore, only seven cities are within the scope, and the operation mode is shown in Figure 7.

Figure 6: Location of Seven Cities

Source: Own elaboration

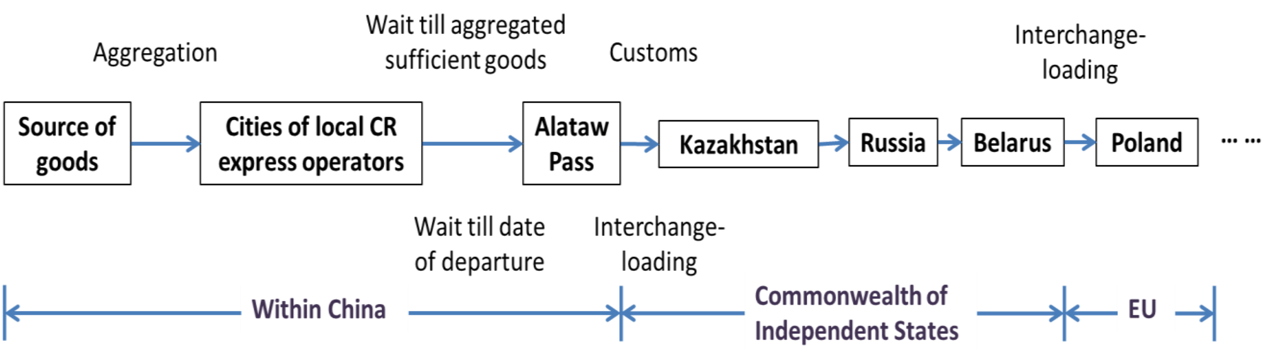

Figure 6: Isolated Operation Mode of CR Express

Source: Own elaboration

Under the isolated operation mode, some routes are seriously duplicated which reduce the utilization of capacity and increase the transport cost. Meanwhile, itis difficult to aggregate sufficient cargo for each train and extends the transport duration.

In doing so, the local operators have less negotiation power with foreign countries to obtain beneficial freight rates and supportive customs policies.

a) Cargo Aggregation

The capacity of each CR express train is 41 FEUs before departure from each city, and these cities are generally supposed to aggregate cargo from nearby cities to reach the required FEUs (Cross Border, 2019). Sometimes, cargo is coming from nearby provinces to be transported through inland waterway, railways and road. Therefore, the aggregation from sources of cargo till cities where CR express is operating spends some time. Ideally, the CR express is fully loaded when it's scheduled to depart; however, it is more common for CR express to operate at partial load.

b) Customs and Interchange-loading

It is required a series of procedures before CR express exists from Alataw Pass: the frontier inspection, inspection & quarantine, interchange-loading and customs declarations. The Chinese gauge is 1435mm standard gauge; however, Kazakhstan is a broad gauge country which is 1520mm. Thus, the CR express needs interchanging loading at the Alataw Pass. From April 20th, 2018, the export & import inspection and quarantine procedures at Alataw Pass are included in customs declarations. Moreover, since August 1st, the declaring items of CR express have been decreased from 229 to 105, which shorten the clearance duration of CR express dramatically (Sinkiang Daily, 2018).

c) CR Express in Kazakhstan

Similar to China Railway, the domestic trains are operated and managed by Kazakhstan Express, which is a state owned company (KTZ Express, 2019). The haul distance of CR express in Kazakhstan is about 1913 kilometers. The railway system in Kazakhstan is relatively old and lacks maintenance, and the speed of CR express is lower than in China which is about 40 kilometer per hour. The freight rate is 0.55 USD per FEU per kilometer (Ministry of Commerce of PRC, 2015).

d) CR Express in Russia

One sixth of New Asia Europe Land Bridge is in Russia. The haul distance of CR express in Russia is about 2687 kilometers, and the freight rate is 0.55 USD per container per kilometer. (Jorph, 2015)

a) CR Express in Belarus

The haul distance in Belarus is about 612 kilometers and the freight rate is 0.55 USD per container per kilometer (21st Century Economics, 2019).

b) CR Express in Poland

Due to Poland is at a key location as the center for the CR express network, from where the routes are separated to the Netherlands, Germany and Czech Republic. The haul distance in Poland is about 683 kilometers, and the freight rate is 1 USD per container per kilometer (Jorph, 2015).

3.3.2. Integrated Operation Mode

As show in Figure 7, there are duplicated routes under isolated operation mode: "Alataw Pass-Kazakhstan-Russia-Belarus-Poland". In this research, the integrated operation mode is basically implemented within China. The international route still follows "Alataw Pass-Kazakhstan-Russia-Belarus-Poland".

The main difference between isolated and integrated operation mode is at cargo aggregation procedure. The integrated mode remains the current trains or routes; however, it integrates the operation meanings that the current local operators are still responsible for cargo aggregation within its geographic scope (nearby cities or provinces). But the local operators are not necessarily to wait until the scheduled departure date of the CR express to integration center; instead, they should transport the cargo to integration center directly by various means of transport as shown in Figure 8. From the integration center, the cargo will be sourced and further transported to Europe via Alataw Pass according to the schedule.

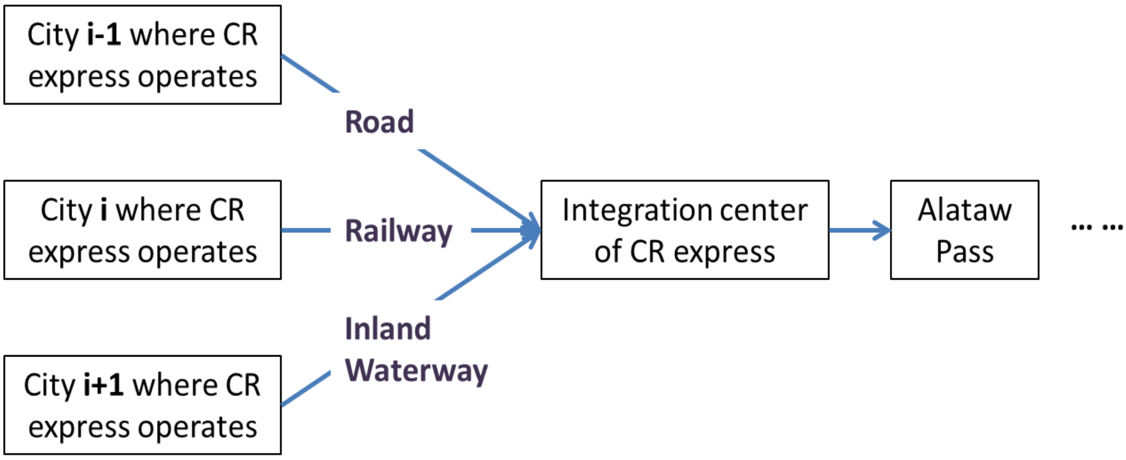

Figure 7: Integrated Operation Mode of CR Express
Source: Own elaboration

3.4. Preliminary Summary

In chapter 3, the ideas of integrated operation mode, economic routes and multi-objective models are discussed. Then, the author studied the current problems of CR express which are believed to be caused by the isolated operation mode. Lastly, the author compared the isolated operation mode of CR express with integrated one, and addressed the first sub-research question: the integrated mode will be beneficial for CR express to improve the competitiveness by reduction of route duplications and promotion of negotiation power with international countries. In the following chapters, the integration center is going to be determined by implementing relative influence factors in the multi-objective model.

Chapter 4 – The Establishment of Economic Route Selection Model under Integrated Operation Mode

4.1. Analysis of Influencing Factors of Economic Routes Selection

The combination of economic routes and means of transport is a key point for planning of the CR express integrated operation proposal since it is the two key factors which determine the quality of integrated operation mode. Therefore, it is necessary to analyze the impact of each influencing factor on economic routes selection under multi-objective optimization model. Then, select the objectives of the model to make it more practical. In doing so, an optimized CR express scheme under integrated operation mode will be established, and the company as well as the operators will be able to obtain greater benefits. The influencing factors is

4.1.1. Influencing Factors

a) Transport Cost

By definition, transport cost is the major part (about 40%) of logistics expenses involved in moving products or assets to another place, and it is one of the determining factors of economic route selection (Cui, 2016). Transport cost is consists of the transit cost, transfer cost incurred due to switching means of transport, cargo damage cost, cargo aggregation cost (Wang, 2015)

1. Transit cost. It refers to the cost generated by one transport cost due to transfer of inventory or assets to another location (Farlex Financial Dictionary, 2012). It is determined by means of transport and transport distance.

2. Transfer cost. It is determined by the transport mode has been selected, and it means the cost incurred due to switching the means of transport at certain nodes considering there is no current transport mode in the following node, or the logistics expenses will be reduced in doing so. Generally, the transfer cost is the highest for railway-waterway transfer, the second highest is for railway-road transfer, and the lowest is for road-waterway transfer (Unknown, 2017).

3. Cargo damage cost. There is no absolute safe for container transport since there are many factors may cause cargo damages, such as the impact due to characteristics of cargo itself, operations, packings, environment, and etc. The damages include container fall off, sweaty and wet damage, concealing the report of dangerous cargo, and etc.

4. Loss due to empty containers. Basically, the loss due to empty containers can be

seen in waterway and railway transport since the capacity of these two transport modes are relatively large, it’s inevitable there will be empty containers to be carried on ships or trains, and the cost of carrying those empty containers is paid by operators which is a loss for them.

5. Cargo aggregation cost. Due to the cargo source for CR express is widely distributed; cargo aggregation cost is incurred due to delivery of cargo to local operators. In order to attract more cargo, some pf the local operators offer to pay for the cost.

b) Transport Duration

Transport duration is consists of transit time and non-transit time. Transit time is determined by means of transport and distance. Non-transit time is determined by time of customs, interchange-loading operations. The outstanding competitive advantage of CR express is the timeliness. By decreasing the transport duration of CR express, customers’ satisfaction will be improved. Generally, the transport duration of same commodity from short to long is: Air > Road > Railway > Waterway (Cui, 2016).

c) Volume of Freight Traffic

Considering the transport cost, bulk cargo gives priority to sea transport in terms of transport mode selection. However, waterway transport takes much more time that may exceed shelf time or reduce the market preemption of the goods. Basically, bulk cargo that is in large volume and relatively low unit price such as iron ore and coal is usually carried by ships or railway transportation; however, cargo that is precious and in small volume is carried by road or air transportation.

d) CO_2 Emission

As the concept of “Energy saving, low carbon life” is becoming more and more welcomed in society, many people are concerned about green traffic nowadays. 80%-90% of CO2 emission in logistics is caused by freight transport (Fan, 2011). It is requested to reduce the CO2 emission during freight transport to protect the environment and keep the economy developing sustainably. Based on literatures, the CO2 emission of different means of transport per ton-kilometer from more to less is: Air > Road > Railway > Waterway (Khan, 2016). Moreover, transport distance also has an impact on CO_2 emission. Generally, the longer the transport distance, the more the emission will be. There are two types of engines that CR express trains are equipped with, diesel engines and electric engines. However, the emissions quantity is not reordered and converted in the freight rate so far.

e) Security Level

Another factor should be considered is the security in the container transportation chain since it is the basic guarantee of whole process. Security level varies according to transport duration, transport cost and freight volume. The cost of security level is usually converted as premium in insurance cost. The accident rate can be reduced by selecting the proper means of transport under different situations. Basically the transport security level from high to low is: Air > Railway > Waterway > Road (Wang, 2004).

4.1.2. Considerations about Modeling

Considering the problems of CR express mentioned in chapter 3.2.2, the model optimization objectives are transport cost and duration, and details are listed as below:

a) Transport cost: The transport cost includes transit costs, transfer cost, cargo damage costs and empty container costs. Caro aggregation cost is not included in the model since the cost does not change in either isolated or integrated operation mode of CR express.

b) Transport duration: The effectiveness of timeliness is influenced by rapidly growing scale of CR express, difficulties to aggregate cargo in various regions, and infrastructures problems in some countries. This research is based on integrated operation mode of CR express to figure out optimized economic routes that transport duration is much shorter.

c) Volume of freight traffic: The unit of this model is set as USD/FEU, and the optimization model does not set up a specific freight volume for simplification.

d) CO2 Emission: It has been taken seriously be Chinses government, however, in view the development of CR express is relatively low, it will not be considered as an optimization objected at this stage.

e) Security Level: Although it is an important factor in logistics, however, it is hard to qualify the influence of security level. Thus, security level is not included in the model.

4.2. The Integrated Operation Scheme of China Railway Express

Generally, the local CR express trains are not fully loaded during operations, based on which the direct trains start from places of origins to the integration center following the economic route according to the result of model computing, then the CR express will further transport to several destinations. In doing so, the unit transport cost will be decreased, and the utility rate will be increased at the same time.

The integrated operation mode is believed to be executable within China since China has basic conditions of realizing brand integration for CR express, the integration center and overall planning of organization. In other countries, it may not fit the requirements to build up integration center at the moment due to various infrastructures conditions and complicated geopolitical situations

For simplifications, this research is based on full container load (FCL). The integrated operation of FCL means that the agent and the destination of cargo in each container is the same. Thus, the integration center could dispatch containers to same destinations together and it not necessary for deconsolidation service of each container.

4.3. The Ideal of Modeling

4.3.1. The Traditional Model of Economic Route Selection

There is no general model handling economic route selection since there are many influencing factors. The most common economic route selection model is the linear programming model. As shown in (4-1), the traditional model made by the author herself is determined by the minimum cost due to selection of transport mode and choice of nodes. The total transport cost is consisting of transit cost and transfer cost at each node.   The base element of the model is a network with nodes i, links and with transport modes.

a) The decision variables are:

$P_{i,i+1}^{k}$ represents from node i to node i+1 whether cargo is carried by means of transport k.

The value of this parameter is either 0 or 1. If cargo is carried by k then this value equals to 1, otherwise is 0.

r_i^{kh} represents whether or not to switch the means of transport from k to h at node i.

The value of this parameter is either 0 or 1. If transport mode is changed from k to h then $r_i^{kh} = 1$. If it stays the same, $r_i^{kh} = 0$.

b) The data are explained is as below:

$C_{i,i+1}^{k}$ represents the unit transport cost from node i to node i+1 under transport means k.

R_{i}^{kh} represents the transfer cost of switching the means of transport from k to h at node i.

c) The objective function is as follows:

$$\min \mathrm{C} = \sum_{i \in I} \sum_{k \in K} P_{i,i+1}^{k} \times C_{i,i+1}^{k} + \sum_{i \in I} \sum_{h \in K} \sum_{k \in K} R_{i}^{kh} \times r_{i}^{kh} \qquad (4\text{-}1)$$

Such that:

$$\sum_{k \in K} \sum_{h \in K} r_{i}^{kh} = 1\,, for\ all\ i. \qquad (4\text{-}2)$$

$$P_{i-1,i}^{k} \times P_{i,i+1}^{h} = r_{i,}^{kh}\ for\ all\ i,k \qquad (4\text{-}3)$$

$$\sum_{k \in K} P_{i,i+1}^{k} \leq 1 \qquad (4\text{-}4)$$

The constraint function (4-2) means that at node i there is at most once transfer of transport mode. The constraint function (4-3) indicates that the transportation between nodes is consecutive. The constraint function (4-4) represents between two nodes, there is only one means of transport. This model lacks of consideration in terms of configurations of transport costs and transport duration. Therefore, it is difficult to find the most reasonable economic routes by this model.

4.3.2. Improvement of the Traditional Model

The most prominent problems of CR express are transport cost and timeliness. It has been a long time that the transport cost of CR express exceeds the expectations before start of operation, and the cost is hard be reduced. The transport duration has been gradually increased since the number of CR express is growing throughout the years. The increasing transport duration is mainly caused by limited storage capacity at ports and yards. Therefore, this research improves the traditional model from the view of decreasing transport cost and duration.

According to the objective mentioned in *Construction and Development Plan of China Railway Express*, it is requested to a construct comprehensive service system of CR express of which the layout is reasonable, infrastructures are perfect, transport volume is stable, transport services are efficient and convenient, and security is guaranteed throughout the processes. In order to achieve the goal, China is supposed to improve the trade channels further, enhance the infrastructural construction of logistics hubs, strengthen the resources integration and innovate continuously on modes of transport services. This research designs the models from the view of resources integration while considering the consistencies, timeliness and transport cost between nodes. Only when these premises are met, the overall operation quality of CR express is supposed to be improved fundamentally, and the profits of each operator are expected to increase substantially.

Basically, this research is from the stance of CR express as a whole that aims to figure out optimized economic routes of CR express by selecting the proper integration center, and the decisive factors are total transport cost and duration. The model is a multi-objective one, which looks to minimize the transport cost and duration, and the principle of this model is to combine the selection of economic routes and means of transport. Constrains of this model are set up based on the limitation of transport capacity and transport consistencies. The transport cost includes transport costs of each route, the transfer costs between nodes, cargo damage costs and loss due to empty container transport. The transport duration consists of transport time of each route, the transfer time between nodes, waiting time and other time incurred.

4.4. Establishment of the Modeling

4.4.1. Assumptions

The practical situation of container transport is complicated, and it is difficult to establish a model. Therefore, the model could be simplified by abstraction and assumption of some factors and links.

a) A shipment of goods carried by 40 feet containers are transported from place of origin O to place of destination D.

b) There are numbers of i nodes between O and D.

c) There is at most once transfer of means of transport between adjacent nodes i and j. i and j refers to cities which operate CR express.

d) The transport cost and speed of one means of transport remains the same even though the road sections and durations are changed.

e) Cargo damage incurred is in proportional to transport distance, and it is relevant to means of transport. The cargo damage caused during transfer of means of transport is included in the transfer cause, and it is not relevant to transport distance and means of transport.

f) Each FEU is carried as a whole, which cannot be partly transported. Moreover, there is only one transport mode between adjacent nodes.

g) There is no new node or route in terms of route optimization.

4.4.2. Symbol Description

a) Indices

I represents the set of all nodes between O and D. $\{i, j\} \in \mathrm{I}$ means one of the nodes.

K represents the set of all means of transport between nodes. $\{k, h\} \in \mathrm{K}$ indicates one of the means of transport, including road, railway, waterway and air transport.

b) Decision Variables

r_i^{kh} represents whether or not to switch the means of transport from k to h at node i. The value of this parameter is either 0 or 1. If means of transport is changed from k to h then $\mathrm{r_j^{kh}} = 1$, otherwise, $\mathrm{r_j^{kh}} = 0$.

$\mathrm{P_{i,j}^k}$ represents whether cargo is carried by transport mode k from node i to node j. The value of this parameter is either 0 or 1. If cargo is carried by transport mode k then this value equals to 1, otherwise is 0.

c) Parameters

$L_{i,j}^k$ represents the distance from node i to node j by means of transport k.

R_i^{kh} represents the transfer cost of switching the means of transport from k to h at node i.

$V_{i,j}^k$ represents the average speed of means of transport k from node i to node j.

t_j^{kh} represents the unit transfer time from means of transport k to h at node i.

μ_i^k represents the utility rate when cargo departs from node i carried by means of transport k.

C_{loss}^k represents the loss incurred caused by the utility rate by means of transport k, which has positive correlation with transport cost for empty containers.

$C_{i,j}^k$ represents the unit transport cost from node i to node j per FEU.

t_1 represents the waiting time at each node.

t_2 represents other time incurred on routes.

C represents the unit cost of cargo from O to D.

T represents the total actual time for cargo to be carried from O to D.

Q represents the total cargo quantity from O to D.

S represents the cargo damaged rate (value of damaged cargo per transport distance) by one means of transport during carriage of cargo.

Θ represents the fixed cargo damage rate. In general, the fixed rate between two nodes is 0.3% (Zhou, et al., 2018).

V represents the unit value of each cargo.

4.4.3. Objective Functions

a) Unit transport cost

The unit transport cost is mainly determined by the choice of means of transport.

$$\sum_{i,j\in I}\sum_{k\in K} P_{i,j}^k \times C_{i,j}^k \tag{4-5}$$

b) Transfer cost

The transfer cost is incurred due to switch of means of transport, in other words, if the means of transport does not change, there is no transfer cost. This cost is related to methods of transport.

$$\sum_{i\in I}\sum_{h\in K}\sum_{k\in K} R_i^{kh} \times r_i^{kh} \tag{4-6}$$

c) Cargo damage cost

The cargo damage cost in this research is mainly related to transport distance and choice of means of transport. If the damage rate does not exceed the fixed rate $\theta = 0.3\%$, there is not cargo damage cost incurred. Otherwise, the cargo damage cost is calculated based on the unit value of this cargo times the exceeded damaged rate.

$$max\left(\sum_{i,j\in I} P_{i,j}^{k} \times L_{i,j}^{k} \times \mathrm{S} - \theta, 0\right) \times \mathrm{V} \tag{4-7}$$

d) Loss due to empty containers

In this research the loss is related to means of transport and utilization ratio, and the ratio varies as per transport modes. The ratio of empty containers determines the transport cost incurred to operators in order to meet the lowest requirement for container carriage, although there is no profit to deliver the empty containers.

$$\left(1 - \mu_i^k\right) \times C_{loss}^{k} \tag{4-8}$$

e) Transit time

The transit time on the route is determined by the choice of transport means and the distance between nodes.

$$\sum_{i,j\in I}\sum_{k\in K} P_{i,j}^{k} \times \frac{L_{i,j}^{k}}{V_{i,j}^{k}} \tag{4-9}$$

f) Transfer time

The transfer time depends on the change between two means of transport.

$$\sum_{i\in I}\sum_{h\in K}\sum_{k\in K} r_i^{kh} \times t_i^{kh} \tag{4-10}$$

g) Waiting time

Waiting time is constant, meaning the period waiting for start-up of CR express which is determined by the local frequencies of CR express, and the parameter is t_1.

h) Other time

Other time is constant as well, including the time of interchange-loading, customs, inspection and quarantine, and etc. The corresponding parameter is t_2.

$$\min \mathrm{C} = \sum_{i,j\in I}\sum_{k\in K} P_{i,j}^{k} \times C_{i,\mathrm{j}}^{k} + \sum_{i\in I}\sum_{h\in K}\sum_{k\in K} R_i^{kh} \times r_i^{kh} + max\left(\sum_{i,j\epsilon I} P_{i,j}^{k} \times L_{i,j}^{k} \times S - \theta, 0\right) \times V + \left(1-\mu_i^k\right) \times C_{loss}^{k}$$

$$\min \mathrm{T} = \sum_{i,j\in I}\sum_{k\in K} P_{i,j}^{k} \times \frac{L_{i,\mathrm{j}}^{k}}{V_{i,j}^{k}} + \sum_{i\in I}\sum_{h\in K}\sum_{k\in K} r_i^{kh} \times t_i^{kh} \times Q + t_1 + t_2 \qquad (4\text{-}11)$$

s.t.

$$\sum_{k\in K}\sum_{h\in K} r_i^{kh} \le 1, \forall(\mathrm{i},\mathrm{j}) \in \mathrm{I}, \mathrm{k} \in \mathrm{K} \qquad (4\text{-}12)$$

$$P_{i-1,i}^{k} \times P_{i,i+1}^{k} = r_i^{kh}, \forall(\mathrm{i}-1,\mathrm{i},\mathrm{i}+1) \in \mathrm{I}, (\mathrm{k},\mathrm{h}) \in \mathrm{K} \qquad (4\text{-}13)$$

$$\sum_{k\epsilon K} P_{i,j}^{k} \le 1, \forall(\mathrm{i},\mathrm{j}) \in \mathrm{I}, \mathrm{k} \in \mathrm{K} \qquad (4\text{-}14)$$

$$\mathrm{Q} \le Q_{i,j}^{k}, \forall(\mathrm{i},\mathrm{j}) \in \mathrm{I}, \mathrm{k} \in \mathrm{K} \qquad (4\text{-}15)$$

$$P_{i,j}^{k} \in \begin{cases}1, \\ 0,\end{cases} \forall(\mathrm{i},\mathrm{j}) \in \mathrm{I}, \mathrm{k} \in \mathrm{K} \qquad (4\text{-}16)$$

$$r_i^{kh} \in \begin{cases}1, \\ 0,\end{cases} \forall\ \mathrm{i} \in \mathrm{I}, (\mathrm{k},\mathrm{h}) \in \mathrm{K} \qquad (4\text{-}17)$$

The above constraints indicate:

(4-12) means that at node i there is at most once change of means of transport.

(4-13) describes the transport consistencies between nodes.

(4-14) represents that there is only one transport mode between two nodes.

(4-15) indicates the volume of freight traffic cannot exceed the maximum capacity at each node.

(4-16) demonstrates the choice of means of transport from node i to node j.

(4-17) shows the choice of switching transport modes from one to the other at node i.

4.5. Preliminary Summary

This chapter analyzed the influencing factors of economic routes selection at first, and chose the objectives as well as parameters of the model based on the current status of CR express. In this section, the answer for sub-research question regarding valuable influence factors are transport cost and duration. Ultimately, the multi-objective model was established referring to the traditional economic route selection model by adding the transport cost and transport duration as the optimal objections.

Chapter 5 – The Algorithm Design of Economic Route Selection Model under Integrated Operation Mode

5.1. Multi-objective Optimization Algorithm

Further to chapter 3.1.3, multi-objective optimization is also known as multi-objective programing which is concerned with mathematical optimization problems involving at least two objective functions to be optimized simultaneously, and it has been applied in many scientific fields, including logistics, engineering and investments where optimal decisions need to be taken in the presence of trade-offs between conflicting objectives (Wikipedia, 2019).

Table 2: Methods of Solving MOP and Corresponding Characteristics

Classification	Methods	Characteristics
Traditional	Mathematical Programming	
Heuristic	Heuristic algorithm	Simple to operate and realise; not sure if all constraints could be met, so it is necessary for specialists to evaluate the outcome.
Evolutinary	Artificial Intelligence	Higher technique required; time-consuming process; depends on the choice of initial solutions and controlling parameters
	Genetic Algorithm	Fitness and timeliness is stronger; probability to relize global optimum is much higer
	Partical Swarm	Strong robustness; requires large amount of computations; long running time of the algorithm, but the quality is poor.
	Ant Colony	Fast calculating speed, and easy to get the covergence result, however, reletively hard to figure out the locally optimal solution

Source: Own elaboration and content based on (Meetei, 2014)

By comparing and contrasting the advantages and disadvantages of above methods, and considering the actual situation of economic route selection problems in terms of CR express, GA is chosen to address the problem for this research.

5.2. Genetic Algorithm

5.2.1. Fundamental Theory of Genetic Algorithm

Genetic algorithm is a metaheuristic inspired by the natural selection theory which imitates the selection, inheritance, crossover and mutation process of evolution. This algorithm starts with initializing a population as the first generation. The individual solution in the population given as a string is known as a chromosome includes a set of linked characteristics which is being named as gene. A set of value of the optimization variables is kept in every single chromosome. In every generation, the fitness values of chromosome are specified by calculating them using an objective function and genetic operators, which are crossover and mutation that are implemented with a chance (incurred by a pre-specified probability) to generate different solutions. The processes of this algorithm keep going until a stopping criterion is satisfied (Shiripour, et al., 2014). A standard flow of genetic algorithm is show in Figure 8.

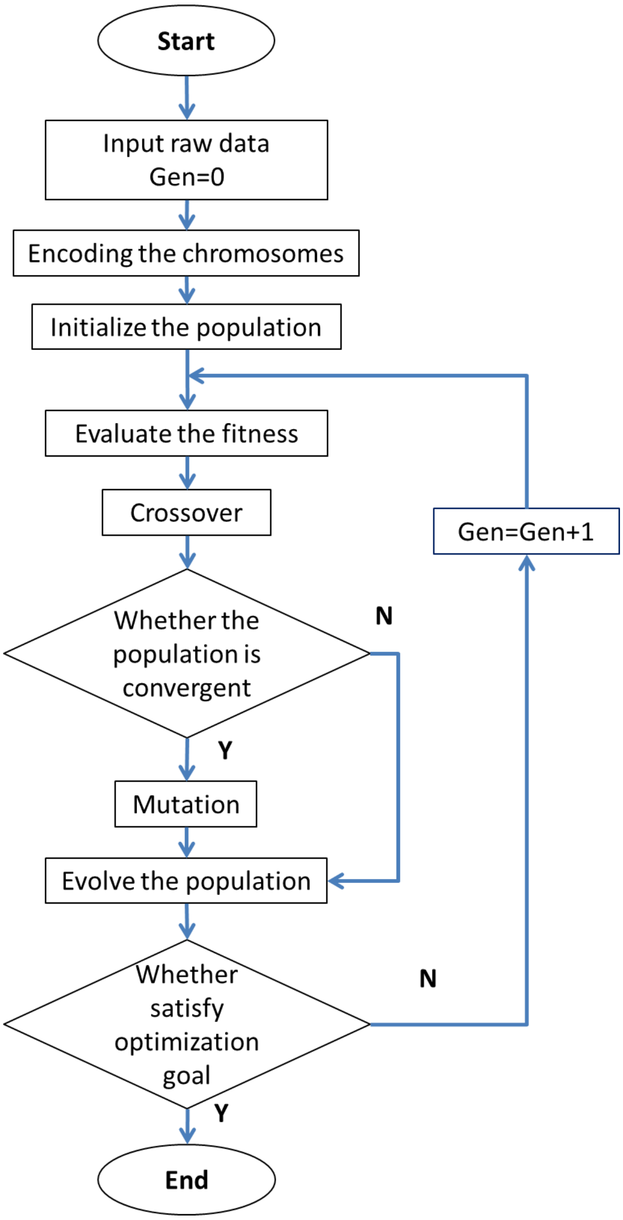

Figure 8: Flow Chart of Standard Genetic Algorism
Source: Own elaboration and data based on from Raval (2017)

5.3. The Algorithm Design of Economic Routes Selection Model under Integrated Operation Mode

The key elements of GA design for this research are composed of chromosome encoding, fix of fitness function and initial population, genetic operators including crossover and mutation.

5.3.1. Chromosome Encoding

Encoding is an essential problem that needs to be dealt with first in GA, and it is a key element in the algorithm since it has a huge impact on error rate, resolving speed and range of optimal solutions. Encoding is a process of transferring the feasible solutions from. The common encoding methods are binary encoding, integer, and Gray code. Binary encoding is the most popular one.

Table 3: Popular Encoding Methods

Methods	Characteristics	Example
Binary	Decoding algorithm is simple; the total length of the code has an influence on the accuracy and timeliness; the crossover and mutation process could be simplified; the code is composed with 0 and 1.	1011 1100 1101
Integer	The form is in natural number, which is easy to be understood.	11 12 13
Gray Code	It is superior in terms of search capabilities and timeliness; Similar to binary encoding is an ofering of the binary numeral system such that two successive values differ in only one bit.	1110 1010 1011

Source: Own elaboration and content based on Theelepel (2016)

Two layers of coding are utilized in this research. Assume there are numbers of J nodes and N sides between nodes in the transport network of CR express, therefore, the length of code is $L = J + N$. The first layer is code SO with length of J. It introduces natural number coding method and represents each of the nodes. The second layer is code M with length of N. It implements integer coding methods and indicates transport codes of each side.

a) Integration Center

Select one of the nodes as the integration center in the first layer, based on which we construct the routes from other nodes to the center and then further to Lodz (Poland).

In doing so, a set of routes will be constructed.

b) Encoding Transport Modes

The set of transport mode is $\mathrm{m} = \{1,2,3\}$, whereas 1 represents road transport, 2 indicates railway transport and 3 refers to waterway transport. Based on the set of routes in previous section, each route corresponds to one side in the map, and then the set of possible transport modes can be known. The number i in terms of code M is the rage of integer code which is between 1 to mi. mi indicates the number of transport modes for side i, and the corresponding transport mode is $\mathrm{methdID} = \mathrm{Mset}$i. Mseti indicates the set of possible transport modes for side i.

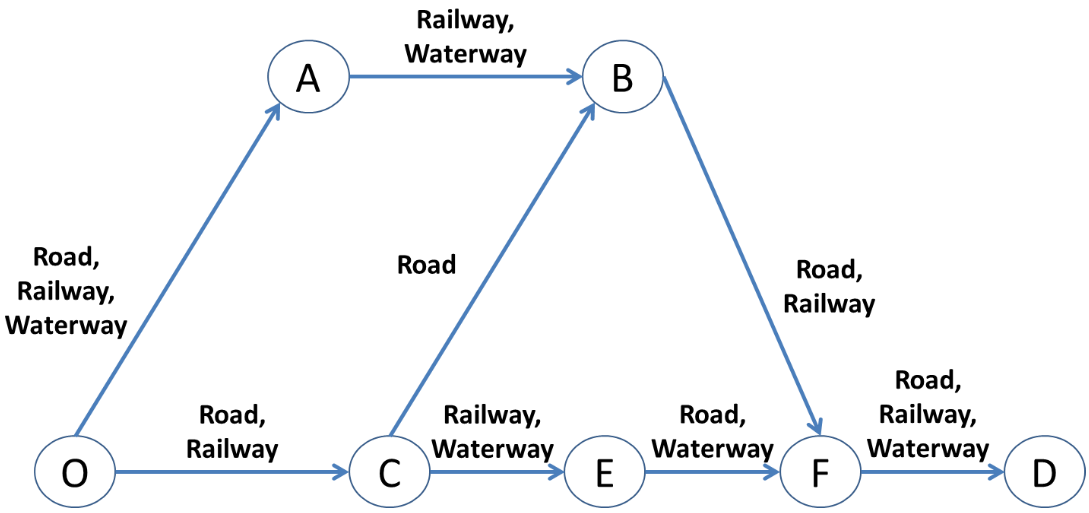

Figure 9: Example of Transport Network

Source: Own elaboration

As the example shown in Figure 9, assume O-A is the 1st side, then $\mathrm{Mset1} = \{1,2,3\}$, O-C is the 2nd side, then $\mathrm{Mset2} = \{1,2\}$; A-B is the 3rd side, then $\mathrm{Mset3} = \{2,3\}$. Moreover M(1)=2 represents that the means of transport for the side 1 is $\mathrm{methdID} = 2 = \mathrm{Railway}$, M(3)=1 indicates that the transport mode for the side 3 is $\mathrm{methdID} = 2 = \mathrm{Railway}$.

5.3.2. Fitness Function

Based on the evolutionary rule of survival in nature, the individuals with higher fitness are more likely to pass genetically from one generation to another. Moreover, the fitness of each chromosome is judged by the value of the fitness function, and the higher the value the stronger the fitness is. Therefore, fitness function is to measure the possibility of one chromosome to be passed on to future generation (Zhu & Mo, 2017). Generally, the objective function is considered as the fitness function in GA to compute the fitness value for each chromosome (Shiripour, et al., 2014).

The fitness function is the inverse of the objective function in this research, and selection methods are introduced to identify the chromosomes with higher fitness value since they have more chances to be selected to create new offspring. There are four major selection methods as listed in table 4.

Table 4: Selection Methods

Name	Characteristics
Roulette Wheel Selection	Easy to operate, however, the select bias is relatively large.
Stochastic Universal Sampling	The position of the first pointer is given by a randomly generated number.
Local Selection	Divide the population into several small groups of population that exist certain repeatability.
Truncation Selection	It is an artificial selection method and is used by breeders for large populations/mass selection.

Source: Own elaboration and content based on (Pohlheim, 2005)

Considering operational simplicity, this research introduced roulette wheel selection method. According to the fitness of each chromosome, the probability of survival could be calculated by formula (5-1).

$$p_i = \frac{fitness(x_i)}{\sum_{i=1}^{n} fitness(x_{i)}} \qquad (5\text{-}1)$$

p_i refers to the probability of survival of chromosome i;

$fitness(x_i)$ represents the fitness of chromosome i;

n indicates the number of chromosomes in population.

First step is to generate r randomly ($0 \leq \mathrm{r} \leq 1$). Then, select the chromosome at the corresponding position on probability section. For example, assume there are four chromosomes (p_1, p_2, p_3 and p_4) in the initial population, and the corresponding probabilities of survival are 0.24, 0.22, 0.20 and 0.34 (sum of probabilities equal to 1) calculated by formula (5-1). If r equals to 0.4, chromosome p_2 would be selected and this process keeps going as shown in Figure 11.

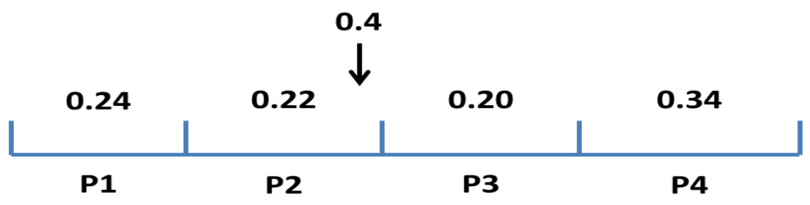

Figure 10: Example of Roulette Wheel Selection
Source: Own elaboration

5.3.3. Proposal of Initial Population

Population represents a set of chromosomes, and it is also a subset of solutions in the current generation. Generally, there are two primary methods to initialize a population of the first generation, which are random initialization and heuristic initialization (Tutorialspoint, 2019).

Heuristic initialization is to divide all the chromosomes or solutions into No. n equal size groups. Based on a specific probability, select one chromosome from each group, and form the initial population which is composed of No. n chromosomes (Yu, et al., 2016). The chance of being selected for each chromosome is the same in terms of random initialization. Firstly, select one chromosome and recombine the genes. After selection of No. n chromosomes, the initial population is fixed.

In this research, there are two hundreds of chromosomes in the first generation. In doing so, the ideal result is able to be obtained, and the speed of calculation is relatively fast.

5.3.4. Genetic Operators "Mutation and Crossover"

Crossover is a natural process in which two parent chromosomes mate to generate a child chromosome (Shiripour, et al., 2014). As for the two parent chromosomes, they are going to switch the genes at specific position as per crossover rate Pc. Crossover methods vary as per the coding scheme of the chromosome. The binary crossover method is shown in Table 5.

Table 5: Selection Methods

Crossover Methods	example & illustration		Original Code
	Crossover Position	After Crossover	
Single Point Crossover	Assume crossover at the 2th code bit	Child 1: 000011 Child 2: 101100	
Double Point Crossover	Assume at the 2nd and 5th code bit	Child 1: 000011 Child 2: 101100	Parent 1: 001100 Parent 2: 100011
Shuffle Crossover	Use the same 1-point crossover technique in addition to shuffle	Child 1: 101100 Child 2: 000011	
Uniform Crossover	Assume at even bits (or even bits)	Child 1: 010101 Child 2: 101010	Parent 1: 000000 Parent 2: 111111

Source: Own elaboration and content based on (Umbarkar & Sheth, 2015)

Mutation indicates random variations into the population. In GA, the mutation operation could be performed by changing the gene at specific position based on a mutation rate Pm. Mutation methods change according to the chromosome coding scheme, and the primary method is binary mutation method (Pohlheim, 2006).

a) Genetic operator SO

There are J nodes, thus the lengthen of code is J. Genes of one chromosome are sequenced from 1 to J. Assume that $J = 5$, a chromosome could be $\{1,3,2,5,4\}$.

1. Crossover: double point crossover method is introduced in terms of genetic operator SO. There are 3 steps in total. Firstly, randomly select two parent chromosomes as the parents. Secondly, generate two random natural numbers r_1 and r_2. Thirdly, exchange two gene segments of two parent chromosomes to reproduce two children chromosomes, and recombine them in case any conflicts between them, such as change the non-crossover gene segment to the missing gene. For example, the two parents chromosomes are $\{1,\mathbf{3},\mathbf{2},\mathbf{5},4\}$ and $\{1,\mathbf{2},\mathbf{4},\mathbf{5},3\}$. r_1=2 and r_2=4. After crossover, the two chromosomes are {1,**2,4,5**,4} and {1,**3,2,5**,3}. After recombination procedure, the children chromosomes are $\{1,2,4,5,\mathbf{3}\}$ and $\{1,3,2,5,\mathbf{4}\}$.

2. Mutation: mutate two genes at one single chromosome. Generate two natural numbers r_1 and r_2, and then exchange the genes at r_1 and r_2 bits. For example, r_1=1 and r_2=4. After mutation, the chromosome is changed from $\{1,3,2,5,4\}$ to $\{1,\mathbf{5},2,\mathbf{3},4\}$.

b) Genetic operator M

There are m sides for genetic operator M, and the length is n. Assume n=4, a chromosome could be $\{1,2,3,1\}$.

1. Crossover: double point crossover method is introduced, and the rule is similar to genetic operator SO.

2. Mutation: mutate one gene at one single chromosome. To elaborate more, generate one natural number r_1 which means the gene at bit r_1 is going to mutate by random variation. For example, r_1=2. After mutation, the chromosome is changed from $\{1,2,3,1\}$ to $\{1,\mathbf{1},3,1\}$.

5.3.5. Design of Algorithm Flow

Considering the CR express from each local city is designed to transport to integration center first, and then further dispatch to Europe, therefore, the integration center procedure is introduced in the flow. Combined with a standard genetic algorithm and the desired objections of the model, the algorithm flow for this research is illustrated in Figure

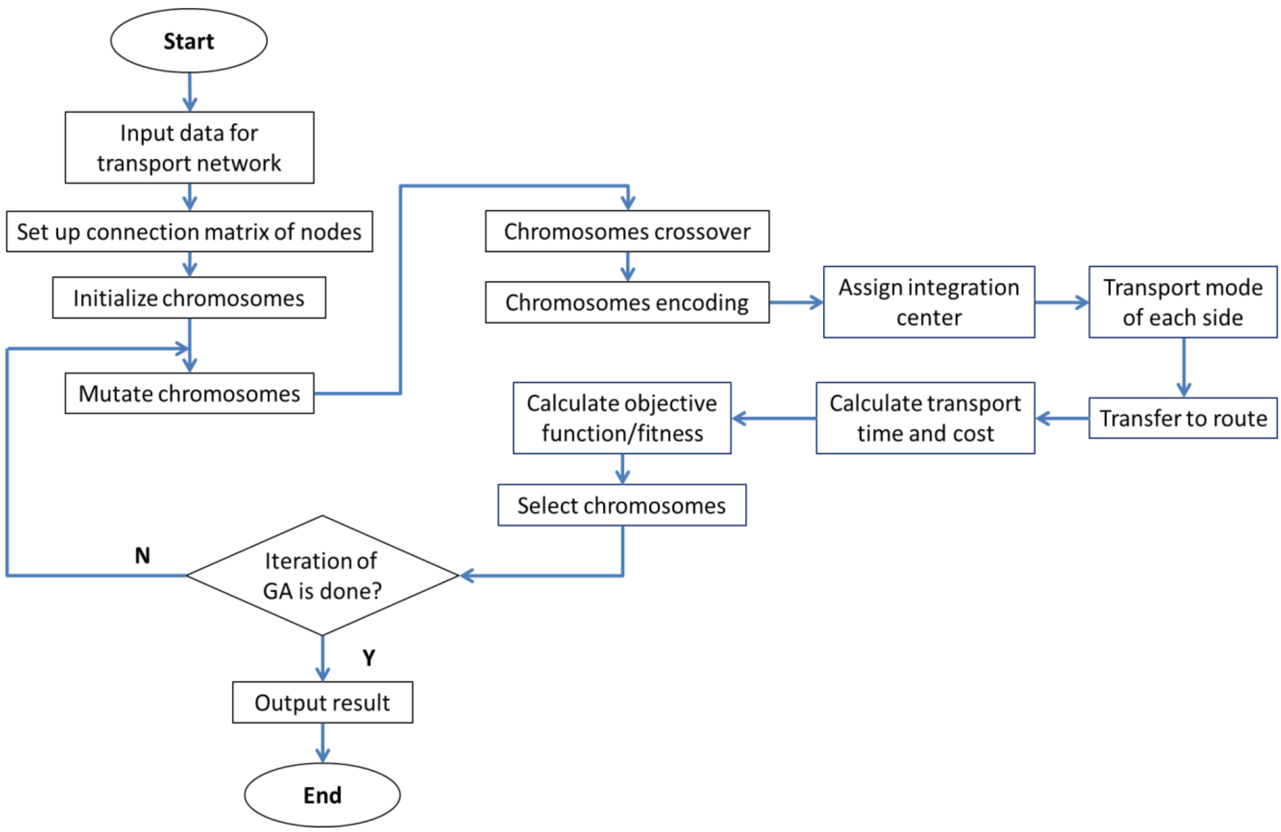

Figure 11: Algorithm Flow for Economic Route Selection under Integrated

Operation of CR Express

Source: Own elaboration

5.4. Preliminary Summary

In this chapter, the major methods to deal with multi-objective problems were illustrated. By comparison of the characteristics, genetic algorithm was selected to solve the model proposed in Chapter 4. On top of that, basic theory of genetic algorithm and the standard GA flow was explained. Ultimately, the tailored algorithm with regards to integrated operation of CR express was fixed.

Chapter 6 – Empirical Analysis of Alataw Pass Based on Genetic Algorithm

6.1. Description of the Problem

As mentioned in chapter 1, each operator of CR express runs their own train to Europe via Alataw Pass at current stage. Assume the cargo volume for each train is the same, which is 41 FEUs and the cargo value of each FEU is about 2 Million CNY. Now, the CR express trains are going to transport to the integration center (city) first and then to be dispatched further to Europe. There are different transport modes between nodes and integration center (road, railway and waterway) that can be selected. Air transport is excluded since the cargo quantity is quite large.

This chapter is going to utilize the multi-objective optimization model mentioned in chapter 4 to select economic routes of CR express by generating relevant information of the transport network. In doing so, the operational efficiency will be improved and transport duration will be shortened as well.

6.2. Data Collection and Calculation

6.2.1. Nodes

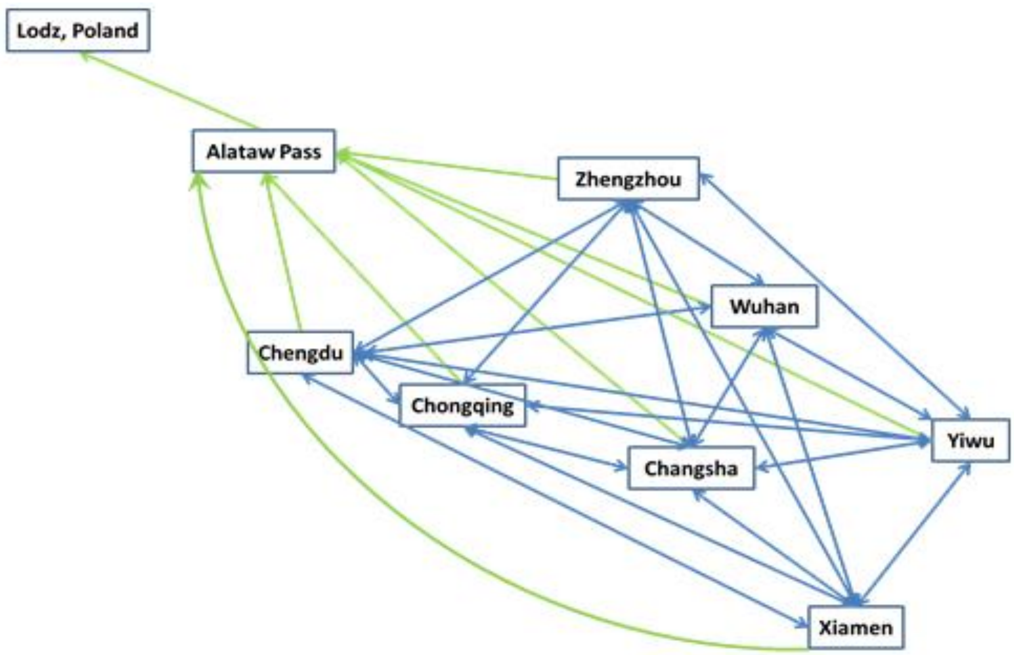

Figure 12: Route Map between Nodes
Source: Own elaboration

As indicated in chapter 3.3.1, this research focuses on the 7 routes of CR express that via Alataw Pass including Chongqing-Duisburg, Wuhan-Hamburg, Chengdu-Lodz, Changsha-Duisburg, Zhengzhou-Hamburg, Xiamen-Hamburg, and Yiwu-Madrid. In view there are duplicated segments at Alataw Pass-Kazakhstan-Russia-Belarus-Poland, this research selects Lodz, Poland as the transport node in Europe. The road map is shown in Figure 13 and the geographic location of the seven cities is given in Figure 6.

6.2.2. Length of Route

Considering the distance between specific nodes varies as per transport modes, the distance by railway transport is listed in Table 6, and Table 7 shows distances by road transport. Waterway transport can be found only between Chongqing and Wuhan, and the length of route is about 1283km according to Yangtze River GPS net (Yangtze River Navigation Bureau, 2019).

Table 6: Length of Route by Railway Transport – kilometer

Railway	Wuhan	Zhengzhou	Changsha	Chongqing	Chengdu	Xiamen	Yiwu	Lodz
Wuhan	0	585	393	876	1187	1076	725	10200
Zhengzhou		0	898	1403	1522	1827	1186	9600
Changsha			0	1040	1714	712	1587	11163
Chongqing				0	302	1861	1584	10092
Chengdu					0	1919	2163	9965
Xiamen						0	1055	12733
Yiwu							0	10607
Lodz								0

Source: Own elaboration and data based on (Xinhua Silk Road, 2019)

Table 7: Distance of CR Express at Specific Nodes

Origin	Entry/Exit Port	Domestic (km)	International (km)	Total Distance
Wuhan	Alataw Pass	4305	5895	10200
Zhengzhou	Alataw Pass	3705	5895	9600
Changsha	Alataw Pass	5268	5895	11163
Chongqing	Alataw Pass	4197	5895	10092
Chengdu	Alataw Pass	4070	5895	9965
Xiamen	Alataw Pass	6838	5895	12733
Yiwu	Alataw Pass	4712	5895	10607

Source: Own elaboration and data based on (Xinhua Silk Road, 2019)

Table 8: Length of Route by Road Transport – kilometer

Road	Wuhan	Zhengzhou	Changsha	Chongqing	Chengdu	Xiamen	Yiwu	Lodz
Wuhan	0	514	345	867	1132	982	713	-
Zhengzhou		0	805	1153	1187	1485	1065	-
Changsha			0	893	1187	876	1310	-
Chongqing				0	397	1712	1571	-
Chengdu					0	2006	1836	-
Xiamen						0	791	-
Yiwu							0	-
Lodz								0

Remark: "-" indicates there is no road transport between the nodes

Source: Own elaboration and content based on (Editorial Committee, 2006)

6.2.3. Cost of Transport

a) Transit Cost

1. Railway Transport

Since Jan 20th, 2018, China Railway Bureau has adjusted domestic railway transit cost in order to put forward market-oriented reform of railway freight rate and further expand market of railway container transport. The current pricing rule specifies the transit cost, additional fee of railway electrification, railway construction funds and other charges (Xinhua News, 2018). The domestic railway transit cost is charged based on below formula:

$$\text{Transit Cost} = \text{basic cost}_1 + \text{basic cost}_2 \times \text{distance} \qquad (6\text{-}1)$$

For each FEU, the transit cost is shown as per Table 9, miscellaneous charges such as electrification fee and construction fund is illustrated in Table 10, and the handling fee of railway stations is listed in Table 11. As for the devanning and stuffing fee, it refers to the cost incurred due to the process of unloading cargo from a container, and loading cargo into an empty container which is then sealed. Each container is charged once for the devanning and stuffing fee based on full container load.

Table 9: Transit Cost of Each FEU

Basic Price 1 (CNY/FEU)	Basic Price 2 (CNY/(FEU· km))
532	3.357

Source: Own elaboration and data based on (China Railway, 2018)

Table 10: Miscellaneous Charges of Each FEU - CNY/(FEU·km)

Item	Empty Freight Rate	Utilized Freight Rate	Pricing Formula
Electrification Fee	0.204	0.408	freight rate x charged weight x electrified distance
Construction Fund	0.561	1.122	freight rate x charged weight x tariff distance

Remark: Charged weight equals to numbers of FEU

Source: Own elaboration and data based on (Yan, 2012)

Table 11: Handling Fee at Railway Station - CNY/FEU

	Loading/Unloading Handling Fee	Devanning/Stuffing Fee
FEU	292.5	300

Source: Own elaboration and data based on (Fu, et al., 2017)

As the frequency of CR increases after operational integration of CR express, the negotiation power of CR express also improves dramatically. The freight rates of CR express for overseas route under different modes are shown in Table 12. The exchange rate was 1 USD = 6.9 CNY at the year based on data source.

Table 12: Freight Rate under Isolated/Integrated Operation Mode

	Freight under Isolated Mode (USD/(FEU· km))	Freight under Integrated Mode (USD/(FEU· km))	Distance (km)
Kazakhstan	0.55	0.4	1913
Russia	0.55	0.4	2687
Belarus	0.55	0.4	612
Poland	1	0.8	683

Source: Own elaboration and data based on (Chang, 2016)

Generally, CR express trains cannot aggregate sufficient cargo at every city, which caused CR express cannot be not fully loaded for every shipment. The utilization rate of CR express is the highest at Chongqing which is about 90% for route Chongqing-Lodz (Economic Information Daily, 2018). As for other routes, the utilization rate is lower, and for simplification, it is set as 80% for calculation. Based on the above, the transit cost between nodes by railway is shown in Annex 1.

2. Road Transport

Pricing Rule of Domestic Road Container Transport is introduced for calculation of transit cost by road transport. The transit cost is consisted of container transport fee, per container charge and other fees. The other fee mainly refers to storage charges which is included in the transfer cost, so it is not discussed in this section. The transit cost between nodes by road transport is shown in Annex 2.

$$\text{Transit Cost} = \text{container transport fee} + \text{per container charge} + \text{others} \qquad (6\text{-}2)$$

Table 13: Transit Cost by Road Transport – CNY/FEU

Item	Freight Rate	Pricing Formula
Container Transport Fee	9 CNY/(FEU· km)	freight rate x charged number of FEU x tariff distance
Per Container Charge	46 CNY/FEU	freight rate x charged number of FEU

Source: Own elaboration and data based on (Yan, 2012)

3. Waterway Transport

The formula for transit cost of waterway transport is illustrated as below:

$$\text{Transit Cost} = \text{daily fuel consumption} \times (\text{distance} \div \text{speed}) + \text{port charge} + (\text{un})\text{loading rate} \times \text{number of FEU} + \text{charter fee} \qquad (6\text{-}3)$$

The parameters such as daily consumption, speed, charter rates are related to type of ship. Based on draught limit of ports along Yangtze River (below 10.5 meters), the maximum capacity of ship is about 150 TEU between Chongqing and Wuhan and there are two types of ships meet the requirement as shown in Table 14 (Changjiang Waterway Bureau, 2012).

Table 14: Ship Type Parameters

Type	Capacity (TEU)	Speed (km/h)	Daily Consumption (CNY)	Daily Charter Fee (CNY)
1	100	11	6,000	2,000
2	150	11	11,000	3,000

Source: Own elaboration and data based on (An, 2014)

Considering it is inland waterway transport, the transit time at Three Gorges Dam should be considered in the calculation which is about five hours' transit time from Wuhan to Chongqing via the dam (An, 2014). The port charge for one call is about five thousand CNY, loading/unloading fee in included in transfer cost, and the loading/unloading time is considered as a part of transfer time. In this research, the 100TEU ship is selected considering the traffic volume. Therefore, the transit cost between Chongqing and Wuhan is calculated and shown in Annex 3.

b) Transfer Cost

As mentioned in chapter 4.1.1, there is certain transfer cost due to switch of transport modes. Considering trucks can easily get to port and railway station, the transfer cost between road and railway or waterway is relatively low; however, switch of transport mode between railway and waterway is much more difficult, therefore the transfer cost is much higher (Guo, 2017). The cost in literatures are calculated in tons, therefore, the author convert the cost in Table 15 considering the capacity of each FEU is about 50 tons.

Table 15: Transfer Cost between Transport Modes – CNY/FEU

Transport Mode	Railway	Road	Waterway
Railway	-	150	1330
Road	150	-	260
Waterwaty	1330	260	-

Source: Own elaboration and data based on (Wen, 2016)

c) Cargo Damage Cost

Based on formula (4-7) in chapter 4.4.2, cargo damage cost can be calculated as per the transport mode and corresponding cargo damage ratio as listed below (Zhang, et al., 2017):

$$s = \begin{cases} 0.1‰ - \text{cargo damage ratio per 100 kilometer by waterway transport} \\ 0.15‰ - \text{cargo damage ratio per 100 kilometer by road transport} \\ 0.05‰ - \text{cargo damage ratio per 100 kilometer by railway transport} \end{cases}$$

d) Loss Due to Empty Containers

This research is mainly concerned about empty containers from China to Europe. However it is rare for road transport to carry empty containers and waterway transport is only between Chongqing and Wuhan, the loss due to empty container by inland waterway is limited. Therefore, the loss refers to railway transport only in this study. As per China Railway and NDRC, the charge for each empty container by railway equals to 40% of one fully loaded container since May 16, 2012 (NDRC, 2011). Based on above, the loss due to empty containers is considered as the charge of carrying an empty FEU, which is about 2800 USD per FEU (Fu, et al., 2016).

6.2.4. Duration of Transport

a) Transit Time

$$\text{Transit Time} = \text{haul distance} \div \text{speed} \quad (6\text{-}4)$$

The average speed by road, railway and inland waterway transport is shown in Table 16.

Table 16: Average Speed of Different Transport Modes

Transport Mode	Railway	Road	Waterway
Average Speed (km/h)	45	80	11

Source: Own elaboration and data based on (Wen, 2010)

b) Transfer Time

The transfer time between transport modes is illustrated in Table 17 excluding the influence of external conditions and other factors.

Table 17: Transfer Time between Transport Modes – h/FEU

Transport Mode	Railway	Road	Waterway
Railway	-	2	2
Road	2	-	1
Waterway	2	1	-

Source: Own elaboration and data based on (Guo, 2017)

c) Waiting Time

Assume the waiting time at node i is uniformly distributed, then the waiting time at i is $(2f_i)^{-1}$, f_i represents the frequency of CR express at node i. If the frequency is 2 trains per week, $f_i = 2/7$. The frequency at each city is listed in Table 18.

Table 18: Frequencies of Local CR Express per Week

	Wuhan	Zhengzhou	Changsha	Chongqing	Chengdu	Xiamen	Yiwu
Frequency	2	5	3	5	4	2	2

Source: Own elaboration and data based on (Ye, et al., 2014)

After selection of economic routes and introduced integrated operation, the frequencies of CR express will be increased. The waiting time of local CR express trains is listed in Annex 4.

d) Other time

As indicated in chapter 4.4.2, there is extra working time for interchange-loading, inspection and quarantine, and customs procedures. According to selected route in this research, CR express is required interchange-loading at borders since China and Poland are standard gauge (1435 mm) countries, however Russian, Kazakhstan and Belarus are broad gauge countries (1520mm) (Xinlang Net, 2014). Since the efficiency of interchange-loading varies as per countries, and there are many factors may influence the interchange-loading time. For simplifications, other time is set up as four days in our calculations.

6.3. Test of Algorithm and Outcome

6.3.1. Test of Algorithm

The model is tested by GA in MATLAB (https://github.com/UoS-CODeM/GA-Toolbox). Initial population equals to 200, mutation rates PM=0.1% PC=0.7%. After 100 times of iterations, the variation of fitness between parent and children is lower than 0.01, and the solutions tend to be convergent steadily which can be seen in Figure 14, 15 and 16.

From the Pareto front figure 16, it can be seen that there is only one economic route by giving certain nodes and data where the transport cost per FEU and transport duration is the lowest.

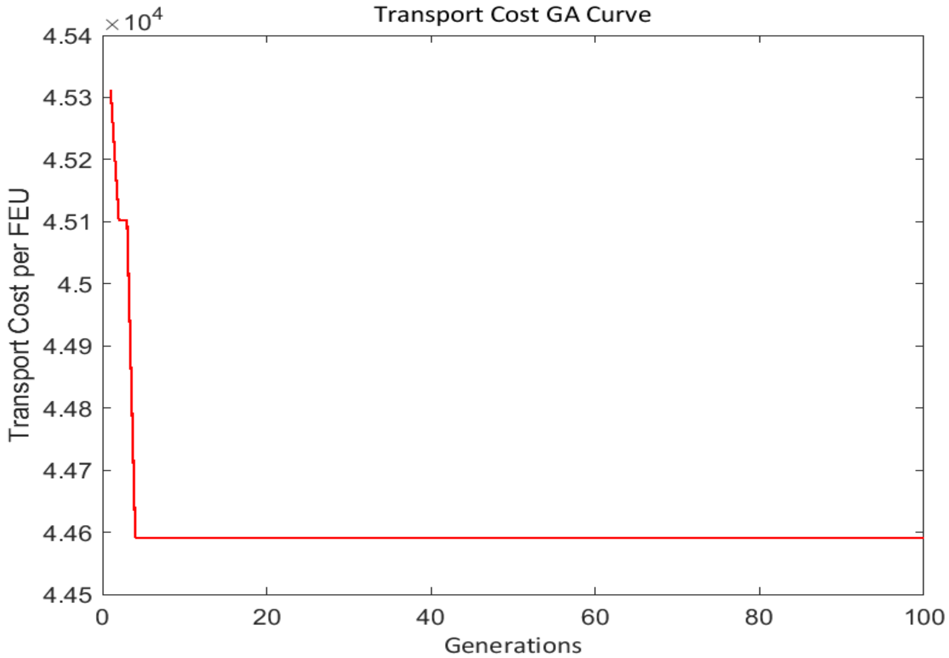

Figure 13: Transport Cost Iterations Figure per FEU
Source: Own elaboration

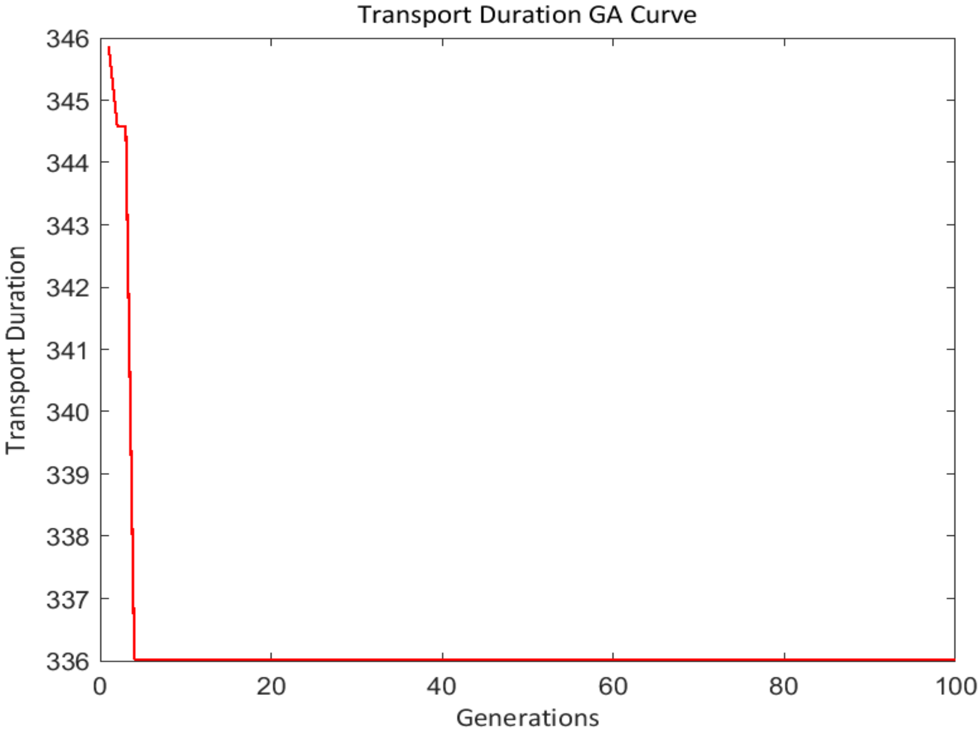

Figure 14: Transport Duration Iteration Figure

Source: Own elaboration

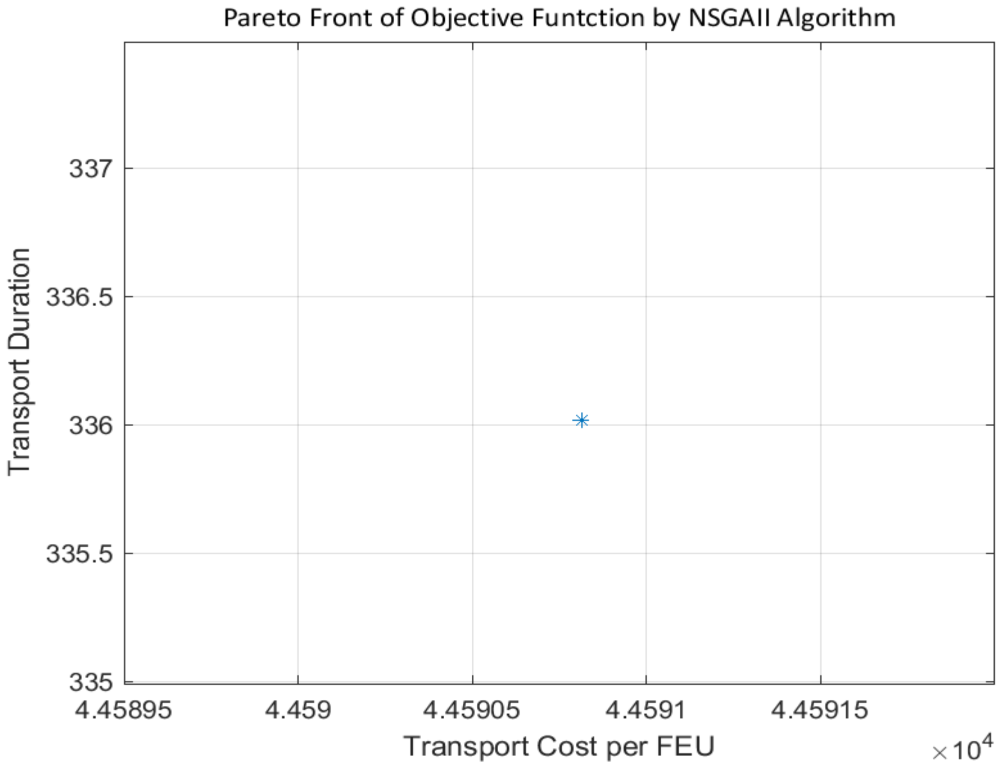

Figure 15: Pareto Front

Source: Own elaboration

6.3.2. Outcome of Isolated and Integrated Operation Mode

a) Isolated Operation Mode

Under the isolated operation mode, the transport cost and duration is shown in Table 19. As mentioned in chapter 6.2.3 and chapter 6.2.4, the cost includes transit cost, transfer cost, cargo damage cost and loss due to empty containers, whereas the transport duration contains transit time, transfer time, waiting time and others.

Table 19: Transport Cost and Time under Isolated Operation

Operation Mode	Route	Transport Mode	Transport Cost (USD/FEU)	Total Transport Duration (h)
Isolated	Wuhan-Lodz	Railway	7226.18	364.67
	Zhengzhou-Lodz	Railway	6814.52	326.13
	Changsha-Lodz	Railway	7886.88	372.07
	Chongqing-Lodz	Railway	6918.61	337.07
	Chengdu-Lodz	Railway	7064.94	338.44
	Xiamen-Lodz	Railway	8964.03	420.96
	Yiwu-Lodz	Railway	7505.41	373.71
SUM			52380.57	2533.05

Source: Own elaboration

b) Integrated Operation Mode

As per the result of NSGA-II in MATLAB, Zhengzhou is selected as the integration center for CR express trains to Europe via Alataw Pass. In other words, the local operators of CR express are supposed to transport their goods to Zhengzhou if they are not able to aggregate sufficient cargo to fully load local CR express trains. In doing so, the operation of CR express is more efficient in terms of the transport cost per FEU and transport duration.

Table 20: Transport Cost and Duration under Integrated Operation

Operation Mode	Route	Transport Mode	Transport Cost (USD/FEU)	Total Transport Duration (h)
Integrated	Wuhan-Zhengzhou-Lodz	Railway	6187.09	325.98
	Zhengzhou-Lodz	Railway	5966.64	309.33
	Changsha-Zhengzhou-Lodz	Railway	6226.75	332.94
	Chongqing-Zhengzhou-Lodz	Railway	6646.41	344.16
	Chengdu-Zhengzhou-Lodz	Railway	6745.31	346.81
	Xiamen-Zhengzhou-Lodz	Railway	6998.76	353.58
	Yiwu-Zhengzhou-Lodz	Railway	6466.08	373.71
SUM			45237.04	2386.51

Source: Own elaboration

Due to integration at Zhengzhou, the total transport cost per FEU is decreased by 13.64% (which is obtained from: $\frac{52380.57-45237.04}{52380.57}$), and total transport duration is reduced by 7.14% ($\frac{2533.05-2386.51}{2533.05}$). Generally, the transport costs under integrated operation mode for all routes are decreased; however, transport duration for Chongqing and Chengdu is increased compared to that under isolated operation mode. Therefore, for Chongqing and Chengdu, they may consider keeping both operation modes and selecting the desired one according to actual situations. Xiamen is the city which benefits the most from integrated operation of CR express that the transport cost is decreased for 21.93% ($\frac{8964.03-6998.76}{8964.03}$) and the duration is declined by 16% ($\frac{420.96-353.58}{420.96}$).

As for the cost component listed in Table 20, the major parts are international and domestic transport costs. Taking Wuhan-Zhengzhou-Lodz route for an example, the total transport cost is about 6187.09 USD per FEU. To elaborate more, 2642.8 USD (43.2%) is for international transport referring to the formula (6-1) and parameters in Table 7 and 12. On top of that, 2194.28 USD (35.79%) is for domestic transport considering the formula (6-1) and data in Table 6-7. Meantime, 1097.13 USD (17.73%) is for handling and miscellaneous cost by Table and 9-11. The other 202.88 USD (3.28%) is cargo damage cost calculated by formula (4-8). For other routes, the cost components are more or less the same to this route. The loss due to empty container is excluded from the above calculation since the cost is fixed as 2800 USD, and it will be used to calculate the total cost of one CR express train carrying 41 FEUs considering the utilization rate of the specific route.

6.3.3. Sensitivity Analysis

The sensitivity analysis is performed by adjusting the unit FEU charge by road transport and the basic price 2 of railway transport respectively, while holding the other variables constant. As per the recent research conducted by Shiqi Li et al. (2019), the long term elasticity of CR express freight rate (basic price 2) may be decreased up to 13.56% which is 2.902 CNY per FEU·km in order to promote the market share of CR express by 13.6 to 68.8%. However, as for road transport, it is believed to be able to influence market share when the unit FEU charge is reduced by 40% which is 5.4 CNY per FEU·km. Note that this is still more than the railway costs. The adjusted transport cost by railway and road is shown in Annex 5 and 6. Therefore, the author applies the new transport cost to the model in the sensitivity analysis.

From the result in MATLAB, it can be seen that the integration center remains the same as Zhengzhou in both cases and the outcome does not change after adjustment of the transport cost by road. However, the transport cost by railway is reduced further after adjustment of the basic price 2 of railway transport which can be seen in Table 21. The transport duration for these routes is the same since the speed of CR express is held constant.

Table 21: Transport Cost and Duration after Adjustment

Operation Mode	Route	Transport Mode	Transport Cost (USD/FEU)	Total Transport Duration (h)
Integrated	Wuhan-Zhengzhou-Lodz	Railway	5553.76	325.98
	Zhengzhou-Lodz	Railway	5294.72	309.33
	Changsha-Zhengzhou-Lodz	Railway	5534.17	332.94
	Chongqing-Zhengzhou-Lodz	Railway	5920.52	344.16
	Chengdu-Zhengzhou-Lodz	Railway	6011.56	346.81
	Xiamen-Zhengzhou-Lodz	Railway	6244.90	353.58
	Yiwu-Zhengzhou-Lodz	Railway	5754.51	373.71
SUM			40314.13526	2386.51

Source: Own elaboration

Compared to the isolated operation, the total transport cost is reduced by 23.04% ($\frac{52380.57-40314.135}{52380.57}$) and Xiamen benefits the most in terms of transport cost which is reduced by 30.33% ($\frac{8964.03-6244.9}{8964.03}$). Looking at these results, it can be seen the less the transport cost by CR express, it is more likely to choose the integrated operation mode. Generally, for the cities that far from Lodz, they are more likely to profit from the integrated operation with regards to transport cost than those which are closer to Lodz.

Overall, it can be said that the outcome (in terms of route) under integrated operation of CR express remains quite similar despite the adjustment of prices of transport by road and railway transport.

6.3.4. Capability Analysis of Zhengzhou

From policy perspectives, Beijing, Shanghai, Guangzhou, Shenzhen, Zhengzhou and some other 18 cities are selected to be built as railway container distribution hubs as per *Medium and Long-term Railway Network Plan (2005-2030)*. Zhengzhou as one of the eighteen container hubs is supported by Chinese Government. Since Zhengzhou locates at the center of China geographically, the construction of

Zhengzhou railway container hub will not only meet the ever-increasing demand of freight transportation especially in central China, but also constitute a comprehensive and convenient railway container transport network together with Dalian, Qingdao, Guangzhou and Urumchi (IGLN, 2010).

On May 10th in 2014, President Xi proposed the idea to construct Zhengzhou as an international logistics channel to connect China to other countries while visiting Zhengzhou container inland port, and expected Zhengzhou to contribute more on Silk Road economic belt (Gong, 2017).

From the perspective of logistics capacity, Zhengzhou is the intersection point for seven main train routes in China, including Longhai railway, Beijing-Guangzhou railway, Beijing-Hong Kong railway, Beijing-Kunming railway, Beijing-Fuzhou railway, Zhengzhou-Xi'an railway and Zhengzhou-Xuzhou railway. North Zhengzhou Railway Station is the largest marshalling station in Asia, and it provide efficient consolidation services, maintenance, technical checkups, and repair services for freight trains (Daily Headlines, 2019). East Zhengzhou Railway Station is the largest less-than-carload freight station in China. Moreover, the capacity of Zhengzhou railway container distribution hub is expected to reach 1.2 million TEU per year by 2020. There have been two loading and unloading tracks in the station, and six more tracks are under construction now.

Zhengzhou container inland port has certain scale after 5 years' construction, and the consolidation as well as distribution capability has been improved dramatically. With the improvement of infrastructures and information system, Zhengzhou container inland port is speeding up on developing the world leading logistic hub and distribution center along Silk Road economic belt (Zhengzhou Inland Hub, 2018). In doing so, Zhengzhou is believed to be capable to be the integration center of CR express.

6.4. Supporting Policies and Measures of China Railway Express under Integrated Operation Mode

a) Set Up the Integration Platform

The isolated operation mode of CR express results in waste of transport capacity, route duplications, and the logistics cost of CR express overruns hugely. It is of vital importance to set up the integration platform which is able to coordinate with local CR express operators and participate in international business negotiations representing the interest of CR express as a whole.

On top of that, it will be able to increase brand cohesiveness of CR express, and unify the brand logo, organization structure, price mechanism and service standards at the same time. In doing so, CR express will be able to in dominant position in terms of bargaining with other countries due to large traffic volume it aggregated.

b) Set Up Cooperative Scheme with Local Operators

The integrated operation mode is expected to have broad impacts on cities that operate CR express trains export via Alataw Pass, including local economy, culture, logistics, and industrial structure. Since there are many factors are involved, it's not possible to rely on Zhengzhou itself to proceed. Therefore, it is necessary to set up cooperative scheme with local operators and implement Belt Road Initiatives efficiently.

c) Explore International Collaboration System

There are about 30 countries involved in Silk Road economy belt that relate to CR express, and sometimes it is hard to coordinate their interests due to conflicts of economic development, logistics infrastructures, political structures, social culture and etc. China as the sponsor nation of CR express is supposed to positively explore the collaboration system at a national level. In doing so, it is able to realize integrated operation of CR express by enhancing communication and cooperation between countries.

Under the premise of ensuring safe transport, it is necessary to establish mutual recognition mechanism of customs procedures between countries in order to improve customs clearance efficiencies. On top of that, by using the unified waybill, establishing unified regulations and standard, decreasing interchange–loading procedure

d) Improve Subsidy Scheme

After integrated operation of CR express, it is expected to improve subsidy scheme as well by overall management the subsidy scheme instead of separated management. The amount of subsidies may refer to sea freight; however, the subsidies should be reduced gradually and canceled after a certain years in order to be regulated by market mechanism.

6.5. Preliminary Summary

This chapter started from problem statement of Alataw Pass cases by assignment of exact cargo value of each FEU and traffic volume. Then relative data were generated in terms of nodes, distance, transport cost, transport durations and etc. On top of that, the calculation methods of transport cost and duration were explained in detail. By placing the organized data in MATLAB combining genetic algorithm, Zhengzhou was specified to be the integration center for CR express via Alataw Pass. In other words, the economic route was achieved by integrated operation of CR express to Zhengzhou, and then dispatch further to Europe. Moreover, the sensitivity analysis was conducted and found the outcome is not sensitive to the chances of transport cost by road and railway. On top of that, the integrated capability of Zhengzhou was analyzed in terms of CR express. Lastly, the supporting policies and measures of CR express under integrated operation mode were discussed.

Chapter 7 – Conclusions and Recommendations

The final chapter is going to summarize the findings of this paper. Moreover, some limitations and recommendations for future research will be mentioned related to the field of studies as well.

7.1. Conclusions

This research studied about the problems of CR express under the background of increasing trade volume, growing number and frequencies of CR express trains, established a multi-objective optimization model of transport time and duration to figure out economic routes of CR express.

The research started from introduction of CR express background and mentioned the current problem of low utilization rate, high operation cost, route duplications, government subsidies and etc. The author figured out the root cause of these problems is the isolated operation mode of CR express. Comparing the isolated and integrated operation modes, it verified the necessity to implement integrated operation mode since the competitiveness for CR express will be improved due to the reduction of route duplication and the promotion of negotiation power at the same time. Referring to the traditional economic route selection model, the research improved it by involving multiple objectives which expect to reduce transport cost and duration since they are believed to be the valuable influencing factors. Based on that, the model was realized by Genetic Algorithm.

Therefore, based on the theoretical analysis and the results of the modelling, it solves the research question that Zhengzhou is supposed to be the integration center of CR express from China to Europe through Alataw Pass. It can be seen that compared to isolated operation mode, the transport cost for each FEU is decreased by 13.64% and overall transport duration declined about 7.14%. In doing so, the economic routes with minimum transport cost and duration could be realized.

The research facilitates a better understanding of CR express operation mode, and provides appropriate guidance for economic route selection problems.

7.2. Limitations and Further Research

This research has its limitations that should be mentioned which leads to recommendations for further research.

Firstly, the low utilization rate of CR express from Europe to China is much more serious due to volatile amount of return cargo. Therefore, there is a possibility to study about integrated operation mode of CR express for route from Europe back to China. In doing so, it is expected to reduce operation cost and improve timeliness significantly.

Secondly, it is necessary to study about the integration center further, and provide more theoretical support for necessity to implement integrated operation mode of CR express.

Thirdly, for simplifications of modeling and considering limitations of relevant data, the author makes assumptions based on full container loaded and unifies the actual cargo quantity for each train. Future studies in this field may include the cargo quantity into the model and the less than container loaded conditions.

Last but not least, the multi-objective optimization model implemented in the research is based on transport cost and transport duration. However, it is possible to improve the model by setting up more objectives, such as CO_2 emissions objective functions. On top of that, the transport cost in the model can be segmented more to make the outcome to be more practical.

Bibliography

21st Century Economics, 2019. Same Frieght Rate of Shipping and Railway. [Online] Available at: https://m.sohu.com/n/413093234/ / [Accessed 29 7 2019].

An, F., 2014. Network Planning and Design of Inland Container Liner Shipping Routes. [Online]
Available at: http://www.doc88.com/p-1446663519350.html
[Accessed 16 8 2019].

Bank, E. C., 2013. Economic and Monetary Developments. The external environment of the euro area.Statistics Bulletin, 1, pp. 11-12.

Bernard, 2015. China's economy has entered a period of new normal. China Daily, 2 2.

Cambridge University Press, n.d. Meaning of Integration in English. [Online]
Available at: https://dictionary.cambridge.org/dictionary/english/integration
[Accessed 19 7 2019].

Changjiang Waterway Bureau, 2012. Draft Limit of Yangtze River Channel. [Online]
Available at: http://www.cjhdj.com.cn/CjhdjManage/water/allwaterList.jsp
[Accessed 15 8 2019].

Chang, X., 2016. Simulation Research on the "X New Eueropean" Intenational Railway Performance-based on Xi'an Port Transit. [Online]
Available at: https://www.ixueshu.com/document/e5dabc29866c372105d245eaa5878b66.html#pdfpreview / [Accessed 15 8 2019].

Chen, R. (2016).Analysis of SWOT of Hanxinou in the Process of Intergrating China-European Trains[J]. Comprehensive Transportation, 36(1), pp.91-96.

Chen,R. (2015).Thoughts on Creating China-Europe Block Train with Concept of "One Economic Belt, One Silk Road"[J]. Railway Transport and Economy, 37(11), pp.71-74.

China Railway, 2018. Notice of Price Adjustment for Railway Container Transport. [Online]
Available at: http://www.sohu.com/a/233845895_343156 /[Accessed 15 8 2019].

China Railway, 2019. Introduction to China Railway Express. [Online]
Available at: http://www.china-railway.com.cn/english/InternationalCooperation/CRexpress/201904/t20190409_93060.html / [Accessed 5 8 2019].

CICC, 2015. The strategic outline of major-country diplomacy with Chinese

characteristics is emerging. [Online]
Available at: http://www.cicc.org.cn/html/2015/4_0226/1641.html
[Accessed 12 7 2019].

Cross Border, 2019. What are the China Railway Express Routes. [Online]
Available at: http://www.kuajingyan.com/article/4458 / [Accessed 29 7 2019].

Cui, S., 2007. Studies of Time Cost. [Online]
Available at: http://www.docin.com/p-1219533756.html / [Accessed: 23 7 2019].

Cui, S., 2016. The Choice of Logistics Mode of Transport on the Impact of Transport Costs. Logistics Engineering and Management, 26 5, pp. 74-78.

Daily Headlines, 2019. The largest marshalling station in Asia: North Zhengzhou Railway Station. [Online]
Available at: https://kknews.cc/zh-sg/news/vranm6q.html [Accessed 19 8 2019].

Deng, R., Wang, B., Xiong, D. & Dai, L. (2015). A Path Planning for Power Transmission Line Inspection with Unmanned Aerial Vehicle Based on Genetic-pattern Seraching Algorithm. Computer Measurement & Control,23(4), pp.1299-1301.

Deng, X., 2008. Research and Improvement on Genetic Algorithm for Solving TSP. [Online]
Available at: http://www.doc88.com/p-3117186936202.html
[Accessed 9 8 2019].

Dole, 2016. Welcome to Dole. [Online]
Available at: http://www.doleoceancargo.com/#homepage[Accessed 11 8 2019].

Dong, Q., 2011. Logistics Integration Theory & Implementation Mechanism. [Online]
Available at: https://baike.baidu.com/item/%E7%89%A9%E6%B5%81%E9%9B%86%E6%88%90%E7%90%86%E8%AE%BA%E5%8F%8A%E5%AE%9E%E7%8E%B0%E6%9C%BA%E5%88%B6
[Accessed 24 7 2019].

Dong, Q., 2016. Research on China-Europe Trains Integrated Operations Based on International Transit Hub Port Strategy Theory. Science and Technology Management Research, pp. 230-237.

Economic Information Daily, 2018. Construction of Intenational Logistics Channel for Yangtze River. [Online]
Available at: http://tradeinservices.mofcom.gov.cn/article/news/gnxw/201801/51888.html
[Accessed 15 8 2019].

Eurostat, 2019. EU-China trade in goods: €185 billion deficit in 2018. [Online] Available at: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/EDN-20190409-1 [Accessed 25 7 2019].

Fan, L., 2011. The Carbon Agenda of Green Logistics. China Business and Market, 26 8, pp. 46-51.

Farlex Financial Dictionary, 2012. Transportation Costs. [Online] Available at: https://financial-dictionary.thefreedictionary.com/Transport+Cost [Accessed 11 8 2019].

Fu, X., Zhang, X., Zou, M. & Fan, D., 2016. Analysis on Economics of China-Europe Block Trains based on the Value Model. Railway Transport and Economy, 1 11, pp. 1-11.

Fu, X., Zhang, Y. & Wan, H., 2017. Study on Economy Optimization of China-Europe Block Train Corridor in Central West of China. Railway Transport and Economy, 5 4, pp. 26-30.

Gong, J., 2017. Zhengzhou Intenational Inland Port. [Online] Available at: http://cpc.people.com.cn/19th/n1/2017/1023/c414305-29602207.html [Accessed 19 8 2019].

Gong, M., 2008. Research on Evolutionary Multi-objective Optimization Algorithm. Journal of Software, 22 7, pp. 271-289.

Guo, X., 2017. Route Optimization of China-EU Container Multimodal Transport Considering Various Factors. [Online] Available at: http://cdmd.cnki.com.cn/Article/CDMD-10459-1017146411.htm [Accessed: 23 7 2019].

Huang,L. (2016). Brief Discussion on Accelerating Development of Sino-Euro Railway Passenger Transportation[J]. Logistics Technology, 35(4), pp.33-36.

Hu, X., 2012. Review and Outlook of Operational Research. [Online] Available at: http://www.ncmis.cas.cn/kxcb/jclyzs/201206/W020120702402714779404.pdf [Accessed 23 7 2018].

IGLN, 2010. The Great Development of Railway Containers. [Online] Available at: http://www.newtrans.biz/zixunzhongxin/hangyezixun/3401.html [Accessed 19 8 2019].

Int.Business Daily, 2019. Increasing Frequency of China Railway Express. [Online] Available at: http://www.xinhuanet.com/energy/2019-02/21/c_1124143279.htm

[Accessed 24 7 2019].

Jiang, J. (2004). On Object and Construction Mode of Modern Enterprise's Logistics Integrated Management[J]. Theoretical Discussion, 125(7), pp.6-9.

Jorph, 2015. Fierce Price Competition of China Railway Express. [Online] Available at: http://www.landbridgenet.com/yaowen/2015-09-09/22940.html [Accessed 29 7 2019].

Khan, A. Q., 2016. The Impact of Co2 Emissions on Economic Growth: Evidence from Selected Higher Co2 Emissions Economies. Environmental Science and Pollution Research International, pp. 6376-6389.

KTZ Express, 2019. About KTZ Express. [Online] Available at: http://www.ktze.kz/en / [Accessed 29 7 2019].

Laijun Zhao, Y. Z. Q. H. H. L. J. S., 2017. Evaluation of consolidation center cargo capacity and loctions for. Transportation Research Part E, 7 9, pp. 58-81.

Li, C., 2019. Alataw Pass in Xinjiang sees growing auto imports. [Online] Available at: http://english.ts.cn/system/2019/06/10/035729031.shtml [Accessed: 21 7 2019].

Ling, T., 2017. Study on Timeing Energy Saving of Single Train Based on Paretomulti-objective Genetic Algorithm. [Online] Available at: https://www.ixueshu.com/document/67f41ab7aa25b3a39e908a3c0d3d464d.html#pdfpreview / [Accessed 23 7 2019].

Liu, H., 2018. The Influence of China Railway Express to The Port Structure in China. [Online] Available at: http://www.amiue.com/p/3672 / [Accessed 17 7 2019].

Li,Y., Liu,L., Li,X. & Li,D.(2016).Optimal Solution of Urban Cold-chain Transport Vehicle Distribution under CO2 Emission Constraint[J].Chinese Market, 877(10), pp.36-39.

Li,Y. (2015). The Problems and Solutions after Operation of China Railway Express[J]. New Silk Road, 117(11), pp.35-37.

Liu,Z. & Xu,T. (1999). Integrated Logistics Management[J]. Forum on Economy and Trade, 150(3), pp.9-11.

Li,Y., Zhao, J., Wu,G.& Chen,J.(2012).Solving the Mode Selection Problem with Fixed Transportation Cost in Intermodal Transportation[J]. Journal of Southwest Jiaotong University, 47(5), pp.881-887.

Meetei, K. T., 2014. A Survey:Swarm Intelligence vs.Genetic Algorithm. [Online]

Available at: https://pdfs.semanticscholar.org/ee7f/4a1bb8525944951527645b0a62b929313404.pdf / [Accessed 9 8 2019].

Mears-Young,B. & Jackson, M. C. (1997). Integrated Logistics-Call in the Revolutionaries! Omega, 25(6), pp.605-618.

Ministry of Commerce of PRC, 2015. Benefits and Worries about China Railway Express in Sichuan Region. [Online] Available at: http://www.mofcom.gov.cn/article/resume/dybg/201508/20150801078342.shtml [Accessed 29 7 2019].

Ministry of Commerce of the PRC, 2019. Total Number of CR Express Exceeded 14000 after 8 Years. [Online] Available at: http://www.mofcom.gov.cn/article/i/jyjl/m/201904/20190402858739.shtml [Accessed: 24 7 2019].

Micheal Quayle & Bryan Jones. Logistics: An Integrated Approach[M]. New Castle Upon Tyne: Athenaeum Press Ltd, 1999.

M.Tom, V & Mohan,S. (2003). Transit Route Network Design Using Frequency Coded Genetic Algorithm. Journal of Transportation Engineering[J]. TRANSP ENG-ASCE. 129. 10.1061/(ASCE)0733-947X(2003)129:2(186).

National Railway Administration of PRC, 2017. Three Passes of China Railway Express. [Online] Available at: http://www.nra.gov.cn/xwzx/xwdt/xwlb/201705/t20170511_38212.shtml [Accessed 25 7 2019].

NDRC of PRC, 2016. Q&A regarding the China Railway Express. [Online] Available at: http://www.scio.gov.cn/xwfbh/gbwxwfbh/xwfbh/fzggw/Document/1481070/1481070.htm / [Accessed 21 7 2019].

NDRC, 2011. Adjustment of Transport Cost by Railway. [Online] Available at: http://www.ndrc.gov.cn/zcfb/zcfbtz/201109/t20110927_435788.html [Accessed 16 8 2019].

NDRC, 2018. Total Number of China Railway Express Exceeded 10000. [Online] Available at: http://www.gov.cn/shuju/2018-08/28/content_5317228.htm [Accessed: 24 7 2019].

Prins,C. (2004). A Simple and Effective Evolutionary Algorithm for the Vehicle Routing Problem. Computers & Operations Research, 31(12), pp.1985-2002.

*Pohlheim, H., 2005. Evolutionary Algorithm 3 Selction. [Online]
Available at: http://www.geatbx.com/ver_3_7/algindex-01.html#TopOfPage
[Accessed 8 8 2019].*

*Pohlheim, H., 2006. GEATbx: Genetic and Evolutionary Algorithm Toolbox for use with MATLAB. [Online]
Available at: http://www.geatbx.com/docu/algindex-04.html#TopOfPage
[Accessed 10 8 2019].*

*Riley, G., 2019. China - Economic Growth and Development. [Online]
Available at: https://www.tutor2u.net/economics/reference/china-economic-growth-and-development / [Accessed 10 7 2019].*

*Shang, H., 2015. Container Highway-rail Multimodal Transportation Cost Model Construction and Application. [Online]
Available at: http://cdmd.cnki.com.cn/Article/CDMD-10710-1015802950.htm
[Accessed 22 7 2019].*

Shiripour, S., Mahdavi, I. & Mahadavi-Amiri, N., 2014. Planning a Capacitated Road Network with Flexible Travel Times: A Genetic Algorithm. Journal of Mathematical Modelling and Algorithms in Operations Research, 23 8, p. 425–451.

Shiqi Li, Maoxiang Lang, Xueqiao Yu, Mingyue Zhang, Minghe Jiang, Sangbing Tsai, Cheng-Kuang Wang and Fang Bian (2019) "A Sustainable Transport Competitiveness Analysis of the China Railway Express in the Context of the Belt and Road Initiative," Sustainability, 11(10). doi: 10.3390/su11102896

*Sinkiang Daily, 2018. Alataw Pass customs provide legal supports for customs declarations. [Online]
Available at: http://wap.xjdaily.com/xjrb/20180815/113228.html
[Accessed 29 7 2019].*

*Sun, L., 2018. Study on the Economic Route Selection of China-Europe Express Train. [Online]
Available at: http://10.72.35.6:8080/was40/main.jsp?channelid=2771
[Accessed: 25 7 2019].*

*The Chinese Governemnt, 2019. 250 Folds in 40 Years! Rapid Development of Europe and China Trade. [Online]
Available at: http://www.gov.cn/xinwen/2019-04/10/content_5381322.htm
[Accessed 15 7 2019].*

Treasury of PRC, 2019. Treasury of Republic of China Requires the Government Subsidies to Be Reduced Gradually. [Online]

Available at: http://www.sofreight.com/news_34872.html [Accessed 26 7 2019].

Tian,Z., Zhao,R. & Zhao,Y. (2016). Design for Best Tourism Route Based on Genetic Algorithm and Ant Colony Algorithm[J]. Mathematics in Practice and Theory, 46(24), pp.43-50.

Tutorialspoint, 2019. Genetic Algorithms - Population. [Online] Available at: https://www.tutorialspoint.com/genetic_algorithms/genetic_algorithms_population [Accessed 9 8 2019].

Umbarkar, A. & Sheth, P., 2015. CROSSOVER OPERATORS IN GENETIC ALGORITHMS: A REVIEW. ICTACT JOURNAL ON SOFT COMPUTING, 5 10, pp. 1083-1092.

UNECE, 2018. Euro-Asian Transport Linkages. [Online] Available at: https://www.google.com/search?q=mode+of+tranport+china+Europe&sourceid=chrome&ie=UTF-8 / [Accessed 17 7 2019].

Unknown, 2017. Transfer and Multi-model Transport. [Online] Available at: https://www.docin.com/p-753471544.html / [Accessed 4 8 2019].

Wang, D., 2017. Data Analysis of China Railway Express in 2017. [Online] Available at: https://www.ixueshu.com/document/c3dfa8116fee407fec8b4f308072b7f5.html#pdfpreview / [Accessed 24 7 2019].

Wang, G., 2004. Comprehensive knowledge of modern logistics in China. 2004 ed. Beijing: China Railway Publishing House.

Wang,Y. (2015). Status, Problems and Suggestions on Development of Sino-Europe Block Trains[J]. Theory and Policy, 37(1), pp.70-75.

Wen, J., 2010. Research on Optimized Model of Container Multi-modal Transport Cost Control. [Online] Available at: http://www.docin.com/p-132898229.html / [Accessed 16 8 2019].

Wen, J., 2016. Research on The Optimization of Container Multimodal Transportation Route and Transportation Mode. [Online] Available at: https://www.ixueshu.com/document/19e9c48a949ed9119e908a3c0d3d464d.html#pdfpreview / [Accessed 15 8 2019].

Wu,T. (2003). Analysis on Logistics Integration System[J]. Logistics Technology, 125(2), pp.30-32.

*Wikipedia, 2019. Dole Food Company. [Online]
Available at: https://en.wikipedia.org/wiki/Dole_Food_Company
[Accessed 11 8 2019].*

*Wikipedia, 2019. Genetic algorithm. [Online]
Available at: https://en.wikipedia.org/wiki/Genetic_algorithm
[Accessed 15 7 2019].*

*Wikipedia, 2019. Multi-objective optimization. [Online]
Available at: https://en.wikipedia.org/wiki/Multi-objective_optimization
[Accessed 5 8 2019].*

Xu, L., Lu,X.(2015). Problem and Solutions for China Railway Express[J].Journal of Huaihai Institute of Technology, 13(8), pp.90-92.

*Xinhua Net, 2019. Overseas Economic and Trade Cooperation Zones Spawns the BRI. [Online]
Available at: http://www.xinhuanet.com/fortune/2019-04/24/c_1210118326.htm
[Accessed 12 7 2019].*

*Xinhua News, 2018. Market-adjusted Freight Rate of Railway Container Transport Since Jan 2018. [Online]
Available at: http://www.gov.cn/xinwen/2017-12/26/content_5250587.htm
[Accessed 15 8 2019].*

*Xinhua Silk Road, 2019. Silk Road Express. [Online]
Available at: https://www.imsilkroad.com/z//160525-4/#w-3229-t
[Accessed 14 8 2019].*

Xu,Y. (2015). Strategic View under BRI of the Development of China Railway Express[J]. Forward Positon, 385(11), pp.45-48.

*Xinhua, 2018. The China Railway Express Tains Exit from Alataw Pass Exceeded 6000. [Online]
Available at: http://www.xinhuanet.com/fortune/2018-08/15/c_1123273009.htm
[Accessed: 26 7 2019].*

*Xinhua, 2019. China and Europe Economic and Trade Cooperation from Four Figures: Mutual Benefit. [Online]
Available at: http://cacs.mofcom.gov.cn/article/gnwjmdt/sb/zo/201904/158295.html
[Accessed 22 7 2019].*

*Xinhua, 2019. Joint Development "One Belt One Road": Progress, Contribution and Outlook. [Online]
Available at: https://www.imsilkroad.com/news/p/361335.html
[Accessed 25 7 2019].*

Xinlang Net, 2014. Introduction of Gauge in Different Countries. [Online] Available at: http://www.guancha.cn/GaoTieJianWen/2014_07_22_249245.shtml [Accessed 16 8 2018].

Xinsilu, 2018. Problems and Outlook of China Railway Express under BRI. [Online] Available at: http://sc.xfafinance.com/html/BR/Business_Activities/2018/274512.shtml [Accessed 24 7 2019].

Yangtze River Navigation Bureau, 2019. Electronic Map of Yangtze River. [Online] Available at: http://www.cjienc.com/gis/search.html?CLASS=&PARENT_ID=2FBC29CD46C54FC0AD16E44FB3F9BB7A&CHANNEL_ID=E7470A2557C966AFE04010AC9B0B4A91#/ [Accessed 14 8 2019].

Yan, N., 2012. Calculation of Railway Freight Rate. In: Practice of Multimodal Transport. Beijing: China Communications Press, pp. 36-50.

Ye, Y., Zhu, D. & Wang, X., 2014. Study of Consolidation Mode of China Railway Express. Shanghai Management Science, 6 12, pp. 1-7.

You, J., 2002. New Method for Solving Multi Objective Problem Based on Genetic Algorithm. [Online] Available at: http://jhe.ches.org.cn/jhe/ch/reader/view_abstract.aspx?file_no=030712 [Accessed 24 7 2019].

Yu, B. B., 2015. The economic growth effect of industrial structure adjustment and productivity improvement in China. *Industrial Economy in China*, 12, pp. 83-84.

Yu, C., 2005. *Cost in Accounting.* Beijing: Tsinghua University Press, pp. 1-3.

Yu, Z., Yuan, Y. & Li, X., 2016. *Genetic Algorithm of Improved Initial Population for the Flexible Job Shop Scheduling Problem*. *Machinery Design & Manufacture*, 18 5, pp. 258-260.

Zhang, X., Zhang, X. & Peng, Y., 2017. *Competitive Pricing Strategy of Railway Freight Considering Capacity Constraint. Journal of Transportation System Engineering and Information Technology*, 15 9, pp. 1-6.

Zhengzhou Inland Hub, 2018. *Company Profile.* [Online] Available at: http://m.zzguojilugang.com/index.php/2018-04-18-08-56-50 [Accessed 19 8 2019].

Zhou, K. et al., 2018. *Optimization Model and Algorithm of Empty Pallets.* [Online] Available at:

https://pdfs.semanticscholar.org/471f/6ab502d010f1985551fae3b3a0d88e56cc7b.pdf/ [Accessed 11 8 2019].

Zhu, C. & Mo, H., 2017. *Encoding of genetic algorithm for a class of fitness*. *Journal of Computer Applications*, 10 7, pp. 1972-1998.

Zheng,Z. (2016). *Problems Raised by Interprovincial Participation of "One Belt and Road" and Studies of Route Optimization*[J]. Economic Review, 38(1), pp.41-44.

Appendix

Annex 1. Table 22: Transport Cost by Railway – CNY per FEU

Railway	Wuhan	Zhengzhou	Changsha	Chongqing	Chengdu	Xiamen	Yiwu	Lodz
Wuhan	0	3893.89	2984.96	5271.48	6743.76	6218.28	4556.65	42023.16
Zhengzhou		0	5375.63	7766.3	8329.65	9773.52	6739.024	39090.96
Changsha			0	6047.86	9238.58	4495.11	8637.358	46729.34
Chongqing				0	2577.27	10076.84	8744.332	41495.36
Chengdu					0	10209.05	11364.142	40974.71
Xiamen						0	6118.87	54401.93
Yiwu							0	44012.16
Lodz								0

Annex 2. Table 23: Transport Cost by Road – CNY per FEU

Road	Wuhan	Zhengzhou	Changsha	Chongqing	Chengdu	Xiamen	Yiwu	Lodz
Wuhan	0	4672	3151	7849	10234	8884	6463	-
Zhengzhou		0	7291	10423	10729	13411	9631	-
Changsha			0	8083	10729	7930	11836	-
Chongqing				0	3619	15454	14185	-
Chengdu					0	18100	16570	-
Xiamen						0	7165	-
Yiwu							0	-
Lodz								0

Annex 3. Table 24: Transport Cost by Waterway – CNY per FEU

Waterway	Wuhan	Zhengzhou	Changsha	Chongqing	Chengdu	Xiamen	Yiwu	Lodz
Wuhan	0	-	-	877.58	-	-	-	-
Zhengzhou		0	-	-	-	-	-	-
Changsha			0	-	-	-	-	-
Chongqing				0	-	-	-	-
Chengdu					0	-	-	-
Xiamen						0	-	-
Yiwu							0	-
Lodz								0

Annex 4. Table 25**:** Waiting Time at Each Node

Waiting Time (h)	Wuhan	Zhengzhou	Changsha	Chongqing	Chengdu	Xiamen	Yiwu	Lodz
Wuhan	0	42	42	42	42	42	42	3.65
Zhengzhou	16.8	0	16.8	16.8	16.8	16.8	16.8	3.65
Changsha	28	28	0	28	28	28	28	3.65
Chongqing	16.8	16.8	16.8	0	16.8	16.8	16.8	3.65
Chengdu	21	21	21	21	0	21	21	3.65
Xiamen	42	42	42	42	42	0	42	3.65
Yiwu	42	42	42	42	42	42	0	3.65

Annex 5. Table 26: Transport Cost by Railway after Adjustment

Railway Transport Cost	Wuhan	Zhengzhou	Changsha	Chongqing	Chengdu	Xiamen	Yiwu	Lodz
Wuhan	0	3627.5926	2806.0628	4872.7167	6203.4267	5728.4749	4226.6233	37380.021
Zhengzhou		0	4966.8521	7127.6415	7636.8216	8941.8528	6199.1459	34720.947
Changsha			0	5574.4424	8458.3514	4171.001	7914.941	41647.836
Chongqing				0	2439.7968	9229.6957	8023.2806	36901.388
Chengdu					0	9335.5035	10379.525	36338.55
Xiamen						0	5638.6243	48605.747
Yiwu							0	39183.76
Lodz								0

Annex 6. Table 27: Transport Cost by Road after Adjustment

Road Transport Cost	Wuhan	Zhengzhou	Changsha	Chongqing	Chengdu	Xiamen	Yiwu	Lodz
Wuhan	0	2821.6	1909	4727.8	6158.8	5348.8	3896.2	
Zhengzhou		0	4393	6272.2	6455.8	8065	5797	
Changsha			0	4868.2	6455.8	4776.4	7120	
Chongqing				0	2189.8	9290.8	8529.4	
Chengdu					0	10878.4	9960.4	
Xiamen						0	4317.4	
Yiwu							0	
Lodz								0

Annex 7. Coding of the GA

Coding of the GA

```
%% nsgaII GA Multi-objectiveOptimization
clc;close all;clear all;warning off;%FREE
rand('seed', 100);
randn('seed', 100);
format long g;

global L trannumber nodenumber ege_number tran_cost_cell change_cost
lossp tran_dist_cell change_v change_time wait_time;
global theta V t2;
global neartable E datatable ege_mset ege_mset_index_cell lb ub;
global Q;

% Input Data
filename='Data.xlsx';
[adata201,bdata201,cdata201]=xlsread(filename,'Road Transport Cost');
[adata202,bdata202,cdata2021]=xlsread(filename,'Railway Transport
Cost');
[adata203,bdata203,cdata203]=xlsread(filename,'Waterway Transport
Cost');
[adata204,bdata204,cdata204]=xlsread(filename,'Transfer Cost');
[adata205,bdata205,cdata205]=xlsread(filename,'Cargo Damage Ratio');
[adata206,bdata206,cdata206]=xlsread(filename,'Road Distance');
[adata207,bdata207,cdata2027]=xlsread(filename,'Railway Distance');
[adata208,bdata208,cdata208]=xlsread(filename,'Waterway Distance');
[adata209,bdata209,cdata209]=xlsread(filename,'Transit Time');
[adata210,bdata210,cdata210]=xlsread(filename,'Transfer Time');
[adata211,bdata211,cdata211]=xlsread(filename,'Waiting Time');

citynamecell=cdata201(1,2:end);

tran_cost201=adata201;
tran_cost201(isnan(tran_cost201))=0;
tran_cost201=tranTriangle2mat(tran_cost201,1);

tran_cost202=adata202;
tran_cost202(isnan(tran_cost202))=0;
tran_cost202=tranTriangle2mat(tran_cost202,1);
```

```
tran_cost203=adata203;
tran_cost203(isnan(tran_cost203))=0;
tran_cost203=tranTriangle2mat(tran_cost203,1);
% Transport Cost
tran_cost_cell=cell(3,1);
tran_cost_cell{1,1}=tran_cost201;
tran_cost_cell{2,1}=tran_cost202;
tran_cost_cell{3,1}=tran_cost203;

change_cost=adata204;% Transfer Cost
lossp=adata205;% Cargo Damage Ratio

tran_dist201=adata206;
tran_dist201(isnan(tran_dist201))=0;
tran_dist201=tranTriangle2mat(tran_dist201,1);

tran_dist202=adata207;
tran_dist202(isnan(tran_dist202))=0;
tran_dist202=tranTriangle2mat(tran_dist202,1);

tran_dist203=adata208;
tran_dist203(isnan(tran_dist203))=0;
tran_dist203=tranTriangle2mat(tran_dist203,1);

% Transport Distance
tran_dist_cell=cell(3,1);
tran_dist_cell{1,1}=tran_dist201;
tran_dist_cell{2,1}=tran_dist202;
tran_dist_cell{3,1}=tran_dist203;

change_v=adata209;% Speed of Transport Mode
change_time=adata210;% Transfer Time
wait_time=adata211;% Waiting Time

% Parameter
theta=0.3/100;% Fixed Cargo Damage Rate
V=2000000;% CNY/FEU
t2=96;%
Q=41;

% Transfer Information
trannumber=3;% No.of Transport Mode
```

```
nodenumber=size(tran_cost201,1);

[neartable,E,datatable,ege_mset,ege_mset_index_cell,ege_number,lb,ub
]=nearfun(tran_cost_cell,trannumber,nodenumber)

L=nodenumber+ege_number;% Length of Code

popsize=200;%Population Size
maxiter=100;%No.of Generations

%% Objective Funtion
objnumber=2;% No.of objective function
variablenumber=L;% No.of Variable
PM=0.1;% Mutation Rate
PC=0.7;% Crossover Rate

Chrom=inivariables(popsize,objnumber,variablenumber,lb,ub);% Initial
Operator
Chrom=nondominationsort(Chrom, objnumber, variablenumber);%
nondominated Operator
value01=zeros(maxiter,2);
value02=zeros(maxiter,2);

tic;

wait_hand = waitbar(0,'GA mutil running...', 'tag', 'TMWWaitbar');
tour = 2;
for i = 1 : maxiter
    pool=round(popsize/2);
    parent_chromosome=tournaselect(Chrom,pool,tour);% Selected
Operator

offchrom=mutationcross(parent_chromosome,objnumber,variablenumber,lb
,ub,PM,PC,nodenumber);% Crossover and Mutation Operator
    mainp=size(Chrom,1);
    offspring_pop=size(offchrom,1);
    tempchrom(1:mainp,:)=Chrom;

tempchrom(mainp+1:mainp+offspring_pop,1:objnumber+variablenumber)=of
fchrom;
    tempchrom=nondominationsort(tempchrom,objnumber,variablenumber);%
Nondominated Sorting Operator
```

```
    Chrom=replacechrom(tempchrom,objnumber,variablenumber,popsize);%
Selection

    value01(i,1)=min(Chrom(:,variablenumber+1));
    value01(i,2)=mean(Chrom(:,variablenumber+1));

    value02(i,1)=min(Chrom(:,variablenumber+2));
    value02(i,2)=mean(Chrom(:,variablenumber+2));

    waitbar(i/maxiter,wait_hand);%Update process after each generation
end
delete(wait_hand);%Delete original process after publishment

runtime201=toc

%% Interation Figure
figure;
plot(value01(:,1),'r-','linewidth',1);
xlabel('Generations','fontname','Calibri');
ylabel('Transport Cost per FEU','fontname','Arial');
title('Transport Cost GA Curve','fontname','Calibri');

figure;
plot(value02(:,1),'r-','linewidth',1);
xlabel('Generations','fontname','Calibri');
ylabel('Transport Duration','fontname','Calibri');
title('Transport Duration GA Curve','fontname','Calibri');


%% Figure out non-dominated solutions
dominatedmat=determinedomination(Chrom(:,variablenumber+1:variablenu
mber+objnumber));% Figure out non-dominated solutions
h_dominate= dominatedmat==0;
[mat2,indexa1]=matuniquefun(Chrom(h_dominate,variablenumber+1:variab
lenumber+objnumber));% Figure out Pareto font
index99= find(h_dominate);
indexselect=index99(indexa1);
mat3=Chrom(indexselect,1:variablenumber);
NDvalue=Chrom(indexselect,variablenumber+1:variablenumber+objnumber)
;%
disp('non-dominated solution');
mat3
```

```
figure;
plot(NDvalue(:,1),NDvalue(:,2),'*');
xlabel('Transport Cost per FEU');
ylabel('Transport Duration');
grid on;
title('Pareto Front of Objective Funtction by NSGAII
Algorithm','fontname','Calibri');

G=size(mat3,1);
for i=1:G
    disp(['No.',num2str(i),'Outcome of Non-dominated Solution']);
    x=mat3(i,:);

[y1,y2,S2,midmat201,cost201,cost202,cost203,time201,time202,time203]
=myfunga(x);
    disp('Cost');
    y1
    disp('Duration');
    y2
    outcell={'Node Name','Node Number','Transport
Mode','Cost','Duration'};
    outcell=[outcell;

citynamecell(S2)',num2cell([S2',midmat201,cost201+cost202+cost203,ti
me201+time202+time203])]
end
```