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Yuxinou international railway optimization in terms of the return trip cargos and the total cost

by

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Abstract

One Belt One Road Initiative has benefited many countries since it was proposed and it can be roughly divided into two major sections. The first one section is seaway transportation, and the other one is railway transportation.

Shipping from China to the rest of the world has long been an innovation, but the railway from China to the depths of Europe is the first time. In addition, the opening of the China-Europe Railway has greatly shortened the transportation time.

In all the Central European railways, the first opened and the largest amount of transportation is one of the international railways called Yuxinou international railway from Chongqing to Duisburg.

This railway line has great significance for the economic development of Chongqing. However, due to the few return trips and other factors impacts, the cost for this international railway stays at a high level. This has led to a decline in its competitiveness.

We would like to reduce the total cost and identify suitable return cargos to enhance this international railway's competitiveness. For this reason, we compare the total cost to transport cargos in different modes of transportation to select return trip's cargos, and we see it as the minimum cost issue. Then, we create the total cost modal and get the optimal solution of the varies.

In the end, we find that electric equipment, transportation equipment, plastics and plastic articles, optical, technical, medical apparatus and food drink are suitable to be the return trip cargos. And we also find that the optimized crane number in the exchange railway stops is 3, the optimized driver should be prepared in each country is 6, and the optimized speed can be generally considered to be 90 km/h.

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List of Abbreviations

CRE	China Railway Express
HLP	Hub-location problem
MCNF	Minimum cost network flow models
NSGA-II	Non-dominated Sorting Genetic Algorithm II
OBOR	One belt One Road
SSTL	The EU – China Smart and Secure Trade Lanes
TTP	Trans-Pacific Partnership Agreement
TTIP	Transatlantic Trade and Investment Partnership

WCO SAFE International trade is an essential driver for economic prosperity framework of standards

Chapter 1 Introduction

1.1 Introduction

China’s One Belt, One Road is one of the biggest stories in Asian business ((McKinsey, 2018). In the old time, the Silk Road was a land route across Europe and Asia which used to connect traders and travelers from regions like the China, Persia, and the Roman Empire. And these days, the new silk road changed into a modern road which transport cargos in gas pipelines, oil pipelines, railroad from China to Europe (Insider, 2018).

The One Belt One Road policy made lots of rail-way transportation from China to Europe. This policy gives a lot of opportunities for both China and Europe in terms of their economic growth, increased trade, faster transit of goods, and enhanced international cooperation (Herald, 2018). Since the first trip started in 2011, China Railway Express has enjoyed rapid development, gradual expansion of its cargo categories and a substantial increase in the quality of its launch. The total import and export trade amount to about 17 billion U.S. dollars. And the full-service platform of China Railway Express has been set up and run that the service scope has been gradually expanded and its service capability has been steadily improved (Yuxinou, 2018).

In 2011, Chongqing has formed a “3+6+300”[1] notebook computer cluster. In order to meet the requirements of constructing Asia’s largest laptop production in Chongqing. Chongqing Municipal Government has put Chongqing-Xinjiang-Europe International Railway into service through further optimization and improvement of the original Eurasian Land Bridge, with the great support of National Ministries and Commissions such as the General Administration of Customs and the Ministry of Railways. Chongqing-Xinjiang-Europe International Railway can shorten present shipping times by up to 20 days. The distance covered is at least 1,000 kilometers less than Northern Railway from Manzhouli (a city in China) passes Russia, Belarus, Poland and ends in Germany. Compared with the second Eurasian Continental Bridge linking Lianyungang in East China’s Jiangsu province passes Alashankou (a city in China) in Xinjiang with Rotterdam in the Netherlands, Yuxinou route will be used to link Europe to South China’s manufacturing hub and Southwest China’s industrial belt (Yuxinou, 2018). In this reason, Chinese government would like to use this international railway as a platform to develop area economics.

[1] “3+6+300” means that since 2009, Hewlett-Packard, Acer, and ASUS "laptop export manufacturing bases" have settled in Chongqing, and then six Taiwanese OEMs and more than 300 parts and components companies such as Foxconn have settled in Chongqing.

Figure 1. Yuxinou route

Hence, after Yuxinou international railway opening, lots of scholars start to find out the how this route will affect the regions' economics and whether this route will change the global trading flows and what is the impact on neighboring countries. All these researches are based on one potential premise which is that the Yuxinou international railway need to run well. However, almost no one study on this field. That is the original intention of our research on optimizing this international railway.

The reason why we would like to optimize this international railway is that for now, Yuxinou international railway faces multiple challenges that we would like to solve them. In terms of the price, the sea way transport has a very attractive competitive advantage compare with this railway route. In the meanwhile, in terms of the cargo trading volume, the lack of returning trip cargo make this railway not as efficiency as people expected.

Moreover, there are also some challenges from other lines under the policy of OBOR (one belt one road) such as the international railway from Chengdu to Poland, and the international railway from Zhengzhou to Germany. All these international railway line have similar start point and similar destination. In this case, these lines just like the alternatives competes with the original product.

In these reasons, we would like to make the route from Chongqing to Duisburg more competitive and run well. By using a multilabel objects model, at the end of this thesis, we would like to get a conclusion on what kind of cargo is suitable as returning trip cargo and how to reduce the total cost and time.

1.2 Research Objectives

The main idea behind writing this thesis is that the cargo trade between China and Europe has enlarged in recent years, then Chinese government created one after another railway from China to Europe. The first one, also the most famous one, is Yuxinou, however, the Yuxinou route is now facing some problems that need to be solved urgently and also needs to be optimized to be more efficient. For this reason, we intend to optimize this railway based on the supply chain management knowledge and focus on three main objects which are time, cost and cargo.

In this thesis, we based on the cargo transportation between Chongqing and Duisburg. After reading some papers and materials, we found some issues on this route and we put these issues as our research questions.

1.The lack of returning cargo material problem cannot be solved in most cases and the simplification of return materials is a serious problem. Currently, from Yuxinou company's website, we know that the total number of trips from Chongqing to Duisburg has reached the number of 1,651 trips from its start, including 1081 forward trips and 570 return trips that we can see the number of return trips less than forward trips. In terms of the type of goods, forward trips cargos are mostly electrical consumer products mostly like computers made in China, while the returning cargos are mostly cars which manufactured in Germany (Yuxinou, 2018).

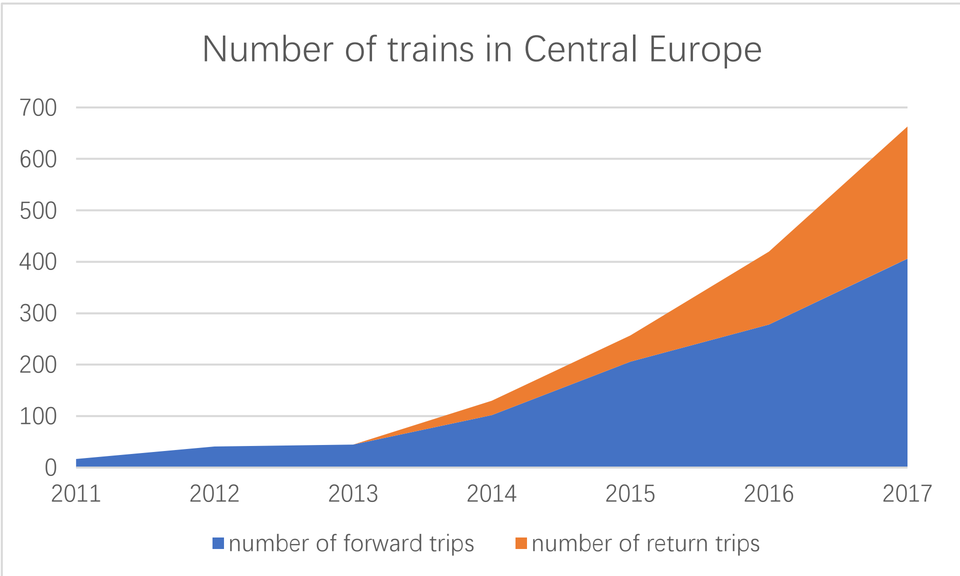


Figure 2. The number of trains of Central Europe from 2011-2017

Source: http://economists-pick-research.hktdc.com/business-news/article/研究文章/重庆-渝新欧-的钢铁丝绸之路/rp/sc/1/1X000000/1X0ADYAW.htm

2.The total transit time can be shorter. This international railway goes through 6 countries. In this case, by going through this route, it includes many processes, for example railway exchange, driver change, etc. Because of these complex processes, the transportation time came into longer than was expected.

3. The high freight rate should be reduced. For now, the transportation price for each 40 ft container for one-way trip is about 4500 dollars to 5500 dollars. However, the transportation price for each container from Shanghai to Rotterdam by sea is much

lower. In this case, to make this railway more attractive we need to optimize the cost structure.

For this reason, we would like to optimize this route in two ways:
1. Choose the suitable return cargo
2. Reduce the total cost of this railway which includes the transportation cost and the holding cost

1.3 Thesis Structure

This study is structured into seven chapters. In these seven chapters, cover different elements of the research questions and the conclusion

Chapter 1 Introduction

In Chapter 1, we give a short introduction for why we would like to choose optimized Yuxinou international railway as our study. Then we introduce about research objects and the structure.

Chapter 2 Literature review

In this part, we describe the history of silk road and one belt one road, then we describe others scholars' research on this road and what did they do on solving transportation problems. Moreover, we point out the insufficient research by other scholars.

Chapter 3 Research Design and methodology

In this part, we would like to introduce the methodologies that we use and we think our problem as a minimum cost problem to solve our research questions.

Chapter 4 The background of Yuxinou railway

In this part, we introduce the importance of this railway to Chongqing and the necessity of the creation of this railway.

Chapter 5 Choose the return trip cargo

In this part, firstly, we choose some items which suitable trading from Germany to China, then we filter some items out which are suitable for transporting by train.

Chapter 6 Reduce total cost

In this part, we create the total time modal and the total cost modal. Then, we optimize the varies in the total cost formula.

Chapter 7 Conclusion

In this part, we briefly summarized the full text and list 7 kinds of cargos which are suitable as the return trip cargos. In addition, we optimized the crane number, the driver number in the stops and get the optimized speed of the train. More than that, we give some advices for the current situation.

Chapter 2. Literature review

Firstly, to let our research be more purposeful, we would like to know the work that other scholars' have done on our study topic and the related topics. Moreover, we also try to find out the insufficiency of their researches, then we can consummate that kind of things in our research.

Then, we look over what kind of methodology did other scholars use when they studying their subjects. After that, we will compare these methodologies to see their application scope and in what conditions they can be used. At last, in Chapter 3, we would like to choose our own methodology.

In this case, this Chapter, for 2.1, we would like to introduce the background of One Belt One Road and the related policy which aims to reduce trading processes to give a deep understanding of the whole policy framework. Then, in 2.2, we will introduce what other scholars' research areas on the topic of "One Belt One Road" and what their studies' contributions and insufficient on the study of "One Belt One Road".

After doing that, in 2.3, we would like to learn how other scholars have studied the transportation problems. Moreover, we will point out the limitations and particularity of their research methods on the transportation problems, then we learn from them.

2.1 The background of One Belt One Road

The "One Belt One Road Initiative" (OBOR) is one of the key geopolitical and strategic developments shaping the world today. Touted as the 21st century Maritime Silk Road, OBOR aims to connect the eastern part of China's coastal cities with Europe via the Indian Ocean and South China Sea (Krishnan R, 2012).

In the late 2013, Chinese premier Xi Jinping announced a pair of new development and trade initiatives for China and the surrounding regions: the "Silk Road Economic Belt" and the "Twenty-First-Century Maritime Silk Road," together known as One Belt, One Road (OBOR) (Erebus Wong, 2017).

Among One Belt One Road policy, the one road is an ancient road connected with neighbor countries. At the time of the Tang Dynasty (618—907), China's expanding trade with the west motivated the Islamic world to exert control over the trading routes of central and west Asia (Erebus Wong, 2017).

However, this ancient road has been ruined in hundreds of years ago. But in recent years, China has actively expanded its rail freight transport links with Europe, as well as with individual countries along the routes of the Belt and Road Initiative (BRI) and let this road revival. As of early 2018, the China-Europe Railway Express (CR Express) has operated 61 routes in 43 mainland cities with connections to 41 cities in 13 European countries (HKTDC, 2018).

All of these departure stations are mostly from the middle of or from the west of China. In these railway lines, one of the railways named Yuxinou which is the one we would like to study. This railway line connects two traffic hub city which are Chongqing and Duisburg. Chongqing is a city directly link with Yangtze Economic Belt, while Duisburg also is an important transfer station in Europe, and this railway line linked two cities together. Two cities are thousands of miles apart and the transportation cross 6 countries. Because of the large distance span, it is a difficult thing to transport containers in this long-distance route in terms of the document processes. Then, to make the transportation document processes easier, Chinese government cooperated with the other countries' government and negotiate a pilot project which is called SSTL to reduce the transport document process. The EU – China Smart and Secure Trade Lanes (SSTL) is a pilot project between the EU and Asia which allows testing end-to-end supply chain security instruments and mechanisms in line with WCO SAFE Framework of Standards (FoS) (Shujie Z, 2009).

This pilot project was launched in 2006 and the aim for this project is to test specific safety and security related recommendations of the WCO SAFE framework of standards as regards security measures applied to containers, facilitating 'Customs-to-Customs' data exchange, risk management cooperation, mutual recognition of customs controls and trade partnership programmers (Taxation and Customs Union, 2018).

Moreover, in the future, Chinese government also expects this policy can improve the security of the entire supply chain and enhance cooperation between customs. But for now, in terms of the Yuxinou international railway, this policy has made the process of the checking cargoes reduced. Therefore, the transportation time decreased which attracts more cargo owners to select this railway to transport.

Based on this project, OBOR started to operate smoothly and the neighboring countries cooperated in a good way.

After the one belt one road official operation, lot of scholars stared to find out the reason why China announced this policy and what are the impacts of this policy in different areas.

Ferdinand (2016) analyzed the reason why Jinping Xi announced this policy and Ferdinand gave a conclusion in two parts. He said that for domestic part, this policy can promote the idea of the 'China dream' and encouraged the young people to enthusiasm about the country's future, while for foreign part, Chinese government aimed to promote development of western China by strengthen links with Europe

(Ferdinand, 2016). Ravi Bhoothalingam (2016) also agreed with this opinion, he said that the main reason for launching this policy aimed at linking all of Asia with Europe and Africa (Bhoothalingam, 2016). William H. Overholt (2015) also put forward one point of the strategy of One Belt One Road that China want to use this policy to create an international environment of prosperity and stability friendly to China (Overholt, 2015).

After knowing the reason why China announced this policy, some scholars prefer to get a deep research on the influences and the impacts of this policy. Swaine (2015) tried to find out what are the impacts of this policy to China and what are the influences to other countries under this policy, then he got a conclusion that the success or failure of the One Belt, One Road concept will depend in no small measure on the resources that Beijing is willing and able to devote to it (D., 2015).Tian Jinchen (2016) analyzed the reasons why the one belt and one road connected China and the world and what efforts does China do to create the world's largest economic platform based on this policy (Jinchen, 2016).

The One belt One road will have a heavy domestic focus, in the meanwhile, the government also wants to use this initiative as a platform to address the country's chronic excess capacity (Cai, 2017). Chinese policymakers want to integrate them into regional economies such as Xinjiang, Chengdu and other areas in the west of China. In the past years, China has developed an impressive reputation as the 'world's factory'. But Chinese government not satisfied with this and still want to upgrade the industry while exporting Chinese standard with this initiative.

In the same time, there are some scholars try to compare this initiative with other countries' policies. Jia R, Bin D (2016) compared OBOR with TTP and TTIP and got three main conclusions.

1. In terms of goals, the TPP and TTIP is intended to introduce a new generation of trade and investment rules – the rules of building in the Asia-Pacific region and even the future global trade and investment model. "One Belt and One Road" focuses on building community of common interests, responsibility and fate.
2. In principle, the TPP is legally binding as a free trade zone, and the "Belt and Road" initiative is an initiative. Adopting this principle is voluntary.
3. From the content point of view, TPP and TTIP give priority to the new problems of economic and trade implementation, mainly the development of multinational companies. "One Belt and One Road" focuses on "five unobstructed" areas (Roads linked, trade flows, currency circulation, policy to communicate, the heart is same) and "six silk roads" (the ground silk road, the maritime silk road, the air silk road, the energy silk road, and the information silk road) (Jia R, 2016)

2.2 Other scholars' research on transportation problem

However, in all of the OBOR studies, none of the scholars mention about how to optimize the transportation modes or how to optimize one specific railway. In this reason, we try to optimize one of the railways which called Yuxinou railway from Chongqing to Duisburg.

From ancient times to the present, lots of researchers created different models to analysis different modes transportation problems. The main modes of transportation are air transportation, seaway transportation, pipeline transportation, intermodal transportation, truck transportation and railway transportation. And for the inland transportation modes, they have similar characteristics and similar research methods. In this reason, we would like to see what other scholars done in these areas.

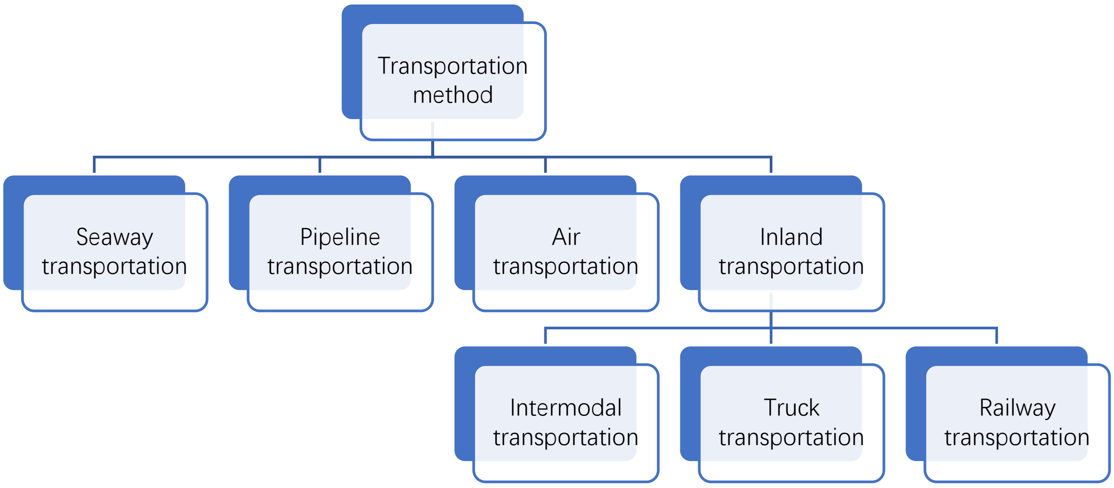


Figure 3. The structure of transportation method

2.2.1 Intermodal transportation and truck problem

The intermodal network transportation problem and the truck problem has many similarities. For example, in terms of the location selection, the intermodal transportation problem would like to optimize hub location. Similar to intermodal transportation, for the truck transportation problem, it prefers to optimize warehouse location. And in terms of the path selection, both of the two transportation would like to use the minimum cost problem. In this reason, we put these two modes of transportation together to discuss.

For intermodal network transportation problem, Kagan (2012) use two different types of intermodal network models to analysis intermodal transportation, one is the hub-location problem (HLP) and the other modal is minimum cost network flow models (MCNF). The focus of the two models is different, hub-location problem focus on optimizing the location of the hub, while minimum cost network flow models more focused on path selection and optimizing total cost (Krishnan R, 2012).

For hub-location problem, as Farahani (2013) said Hub location problem (HLP) is a relatively new extension of classical facility location problems also is one of the novels and thriving research areas in location theory (Farahani, 2013).There are two versions for hub location problem one is single allocation versions and the other is multiple allocation versions. In single allocation versions, each demand point must be allocated to communicate with one hub, while in multiple, each demand point may be allocated to communicate with more than one hub (Bing.com, 2018).

While for the minimal-cost network flow problem (MCNF), it is an optimization and decision problem to find the cheapest possible way of sending a certain amount of flow through a flow network (Ahuja, 1993).

The basic aim of the minimal-cost network flow problem modal is to find the “best route” from factory to “warehouse”. The definition of the problem is to minimize the total cost of the flow over all edges.

This modal needs to define on a network N= (V, A). V is a set of vertices(nodes), while each node has a connect with value b_i. They use different b_i number to separate the situation. For $b_i<0$, node i is a demand node, when $b_i=0$ node i is a transshipment node and when $b_i>0$ node i is a supply node. And A is a set of arcs that arc (i, j) is from node i to node j. Then, define the capacity and cost for each arc by using u_{ij} (upper bond capacity), l_{ij} (low bond capacity) and c_{ij} (cost per unit). After that, we let X_{ij} be the units of flow on arc (i, j) and get the target equation which is $\sum c_{ij}\, x_{ij}$. And the key problem for MCNF is to let $\sum c_{ij}\, x_{ij}$ smallest (Slideplayer.com, 2018).

In the transportation issue, a single criterion that minimizes the total cost is considered. But in some practical situations, two or more goals are related. Therefore, this problem can be solved by using multi-objective linear programming techniques. (Aneja, 1979).

By optimize two things, we can use the multi-criteria (or multi-objective programming). The multi-objective programming can be defined as “A vector of decision variables which satisfies constraints and optimizes a vector function whose elements represent the objective functions. Hence the term “optimizes” mean finding the solution which gives the value of all the objective functions acceptable to decision maker.” (Sharma, 2013)

The multi-objective problem can be formulated as:

$$\text{Optimize:} \quad f(\mathrm{X}) = (f_1(\mathrm{X}), f_2(\mathrm{X}), \ldots f_k(\mathrm{X}))$$
$$\text{Subject to} \quad g_j(X) \le b_j, j = 1,2, \ldots \; or \; g_j(X) \ge b_j, j = 1,2, \ldots$$
$$\mathrm{X} \ge 0$$
$$\mathrm{X} = (x_1, x_2, \ldots x_n)^T$$

That $f(\mathrm{X})$ is the objective function to optimize, while the formula $(f_1(\mathrm{X}), f_2(\mathrm{X}), \ldots f_k(\mathrm{X}))$ are k number of distinct objective functions subject to m constraints. X is a vector consisting of decision making $x_1, x_2, \ldots x_n$.

The multi-objective problem is a branch of mathematical programming which finding the optimization of more than one objective function over a given area. Also known as multi-objective optimization. Multi-objective problem has been applied in many different fields such as Economics, Finance, Optimal control, Optimal design, Process optimization and etc.

The idea about multi-objective optimization was proposed by Vilfredo Pareto in 1896. From the perspective of political economy, he considered the optimization of many goals that are essentially incomparable into a single goal, thus involving the concept of multi-objective programming and multi-objectives. In 1951, T.C. Koopmans introduced the multi-objective optimization problems from production and distribution activities and introduced the concept of effective solutions. In 1976, Wallenius (Wallenius, 1976) used an interactive programming method to solve a problem involving multiple objectives the decision maker is requested to provide answers to yes and no questions regarding certain tradeoffs that he likes or dislikes. Moreover, he tested the method can also use for solving integer linear programming problems. Then in 1999, Zitzler (Zitzler & Thiele, 1999) introduced a new evolutionary approach to get the solution which is the strength Pareto EA (SPEA), that combines several features of previous multi-objective EAs in a unique manner. K.Deb (Deb, et al., 2002) proposed an idea about a fast and elitist multi-objective genetic algorithm which called NSGA-II (Non-dominated Sorting Genetic Algorithm II), NSGA-II based on a number of test problems including five objectives and seven constrains. In this reason, NSGA-II is more suitable for a complicated multi-objective problem.

There is a branch of the multi-objective transportation problem called linear multi-objective transportation problem. The linear multi-objective transportation problem is a special type of vector minimum problem in which constraints are all equality type and the objectives are conflicting in nature. In this reason, lot of scholars try to use different methods to solve it. Because all the methods before 1992 generated a set of nondominated solutions or construct a single compromise solution. Biswal and Alam started to use a fuzzy linear programming to solve the linear multi-objective transportation problem (Bit, 1992).

At present, the ideal methods for solving the effective solutions of multi-objective linear programming problems are ideal point method, linear weighted sum method, maximum and minimum method, target programming method, and fuzzy mathematical solution (Baidu, 2018).

2.2.2 Railway transportation problem

Among railway optimization problems, the directions of the researchers are mainly line planning, train timetabling, and crew planning (Cacchiani, 2008).

For the line planning optimization, the multi-line train research planning problem is similar to the vehicle routing problem. Gao (2016) focus on optimize the transportation plan, he investigated a frequency service network design problem in a railway freight transportation system with a fixed charge and transportation costs (Gao, 2016). In his paper, he listed the mathematical formulation of the railway freight transportation problem with the object formula and constrains which is the same way with dealing with the vehicle routing problem.

For the train timetable problem, Cacchiani (2008) solved this problem by using a column generation approach. He deals with problem as an integer linear programming, but there are a large number of constrains which is difficult handled in a same time. In this reason, he chose to give each of constrains a weight.

And for the crew planning problem, it is the problem for passenger railway transportation which is not our scope of research. In this reason, we will not discuss it.

After discuss all topics related our study, we will create our models and research direction in Chapter 3.

Chapter 3 Research design and methodology

Based on Chapter 2, we already know what kinds of models did other scholars created to deal with different kinds of problems. Then in this chapter, we would like to create a model for researching our study.

Learn from other scholars' experience, firstly, we identify what kind of railway transportation problem we are facing. Then, we determine the outputs we would like to get. After that, we can simply create the model for our study.

3.1 Research design

In this thesis, we will use quantitative method to answer two things which are choosing the return trip cargos and reducing the total cost on the way. The process of answering these two questions is closely related to supply chain network design knowledge.

Mallidis, Dekker and Vlachos (2012) said that for supply chain network design incorporates strategic decisions on the number, location, capacity and operation of distribution centers/production facilities (Mallidis, 2012).

Also, we based on Chapter 2 where we already understood other scholars' thinking ideas, and create our own ones.

In this study, we should find what the difference between transporting different kinds of goods, what kind of things are related to total time spending on this route and what kind of things will influence the total cost.

3.2 Methodology

In this thesis, we use the score method in Chapter 5 when we choosing the return cargoes. While, for Chapter 6, we change the reduce total cost as another problem which is the minimum cost problem.

3.2.1 Comprehensive scoring method

The comprehensive scoring method is a method that widely used in the medical field.

The comprehensive scoring method quantifies the items classified according to quality by scoring, and can be used for comprehensive evaluation of qualitative sorting problems. The core content is to assign different scores to different levels of evaluation, and to conduct comprehensive evaluation based on this.

For the scoring method, mainly it needs four steps to get the answer. Step one: identify the surveys to be included in the scoring process. Step two: identify the information from each survey to be included in the scoring process. Step three: score each of the three sets of surveys (most recent, second most recent, and third most recent). Step four: calculate the overall score. This is the total of the scores for each of the three survey periods, weighted so that recent surveys count more than older surveys (in.gov, 2018).

To enlarge the volume of the returning cargo, we try to find which kind of cargo is more suitable as the return trips transportation cargo. To compare different kinds of cargo, we just need to know there holding cost rate. However, in the process of giving each of cargo a specific holding cost rate, we cannot find the data for one of the indicators that linked with the holding cost rate. In this reason, we use the comprehensive scoring method to rank all cargos based on their category, and then we give all of them a score.

After that, we can simply give each of cargo in a specific holding cost rate.

3.2.2 Minimum cost problem

For optimizing the total cost problem in Chapter 6, we would like to think it as a minimum cost problem which we would like to use the operations research knowledge to solve it. In this reason, we list all the factors that will influence the total cost on the way and put the total cost as a formula. Then, we use the corresponding mathematical methods to solve the problem step by step.

Chapter 4. The background of the Yuxinou international railway

One of the important reasons why we would like to study this railway is that this railway has a great importance. Not only it is the first international railway created under one belt one road, but also it pushed Chongqing's economic growth a lot (Yuxinou, 2018).

Yuxinou international railway is one of the "productions" under One belt One Road. For Chongqing, this railway constructed a trading bridge between China and Europe. Moreover, this railway also gave more transportation options for cargo owners.

In this Chapter, we would like to describe the history of this railway route, and analyze why it is a necessary thing for Chongqing to create this route. Then, we would like to give a short description on the importance of this railway route for Chongqing.

4.1 The history of Yuxinou

Since 2011, under the efforts of the Chongqing municipal government and relevant state departments, China, Kazakhstan, Russia, Belarus, Poland, and Germany have signed an agreement to implement Yuxinou international railway (sina, 2017).

Then, on April 12, 2012, Yuxinou (Chongqing) Logistics Co., Ltd. was established, and was jointly established by China Railway, Russia Railway, Harbin Railway, Germany Railway and Chongqing Transportation Group. It is mainly engaged in the two-way "station-to-station" railway freight transportation business along Chongqing and Europe. The business scope is mainly for the international shipping freight forwarding business of import and export goods and transit goods, including: booking, distribution, warehousing, packaging, handling, handling, circulation inspection, settlement and transportation, and related logistics information processing. Due to the particularity of the Chinese system, Yuxinou (Chongqing) Logistics Co., Ltd in most of time as an operator to organize the source of supply, and arrange train schedule. While for the facilities, drivers and other railway fixed assets, the company does not own them (Yuxinou, 2018).

Yan Xin, general manager of the company, said that the birth of Yuxinou is closely related to the industrial structure of Chongqing at that time. It is a microcosm of Chongqing's reform and opening up, promoting industrial development and creating an inland open highland (Yuxinou, 2018).

4.1.1 The necessity to create this route

Chongqing is an economic center in the upper reaches of the Yangtze River, an important modern manufacturing base of the country, an international comprehensive transportation hub in the southwest, an international aviation hub, and a shipping center in the middle and upper reaches of the Yangtze River (wikipedia, 2018).

Currently, Chongqing notebook production industry has been far ahead in the world. However, before August 2009, there was no laptop produced in Chongqing. All these achievements go through a long process.

All stories started from 2010. On December 1, 2010, Acer, the world's second largest personal computer brand, signed an agreement with the Chongqing government that Acer will coordinate its supply chain partners to deploy a global manufacturing base in Chongqing. At the same time, Asus invests a total of US$150 million in Chongqing after 2010. By 2015, it forms an annual production capacity of 30 million smart terminals (including but not limited to laptops, tablets, etc.) in Chongqing. The high-tech zone will build ASUS China's second operational headquarters building and other supporting facilities to build the ASUS global computer base. (Anon., 2010)

Moreover, also in the same year, Taiwan's Huake Group, the world's largest manufacturer of circuit boards (PCBs), signed a contract with the municipal government on December 5th to build its western headquarters and second production base in Yong chuan district. With a global production value of US$3.5 billion, Huake Group is the world's largest manufacturer of notebook computer circuit boards. Therefore, the entry of Huake has important significance for the notebook supporting industry (Anon., 2010).

Then time has come to 2013, in that year, the laptop industry already sharped in Chongqing. In 2013, about one in four laptop computers in the world was made in Chongqing, 55 million of them, and Chongqing's laptop industry had revenue of 157 billion yuan ($26 billion) in this year. This city exported 48.68 million laptops worth $19.8 billion.

However, the large-scale production has far exceeded the domestic demand. In this reason, Chongqing was looking for an export road. However, based on the fact of its inland location, the way of export is very limited.

Before Yuxinou international railway start, if there are cargos want to transport from Chongqing to Europe, the cargo owners only can use intermodal transportation or by air. Among all these transportation cargos, 60% to 70% by intermodal transportation and the rest by air. It takes more than 30 days to go by sea, so the delivery time is long. After the items arriving in Europe, the market price of the products has dropped sharply in sometime. In the same time, if it takes by air, although the transportation time reduced the transportation cost will be high.

Figure 4. The original intermodal transportation from Chongqing to Europe

The rapidly manufactory growth in Chongqing enlarge their volume of export so quickly. In 2010, the original export transportation modes cannot meet the existing productivity. In this reason, in 2010, the mayor Chongqing Huang Qifan led a team to Beijing to formally request the Chongqing municipal government to go to the general administration of customs and the ministry of railways in China to request to open a railway from Chongqing to the European. The general administration of customs and the leaders of the ministry of railways expressed their active support.

On August 30, 2010, Deutsche Bahn took the lead and held the Eurasian Railway Conference in Berlin, Germany. At the meeting, Chongqing established the first contact with institutions such as TEL (a joint venture between Germany Railway and Russian Railway). Since then, Chongqing has successively established contacts with railway companies in Russia, Kazakhstan and other countries and government departments along the line and formed a multilateral consultation mechanism for the "five-party joint meeting of the five countries (Anon., n.d.).

Finally, in October 2010, the Chongqing government and the ministry of railways conducted a trial run of the Yuxinou five-term class with the 2,800 tons of goods in 40 cars peeled out from the west of Chongqing railway station. The opening of this railway has effectively solved the export problem. Moreover, the return trip import cargoes also have driven the economic growth of Chongqing.

4.1.2 The importance of this railway route

This international railway has a great significance for Chongqing, it brought a lot to Chongqing in recent years, especially for Chongqing’s economic growth this railway has played an important role.

After the Yuxinou international railway opening from 2012, the GDP of Chongqing increased every year. And if we compare with China GDP, we will find that after 2012, the growth rate of Chongqing is higher than the growth rate of China.

Chongqing			China		
Year	GDP (Billion yuan)	Growth rate (%)	Year	GDP (Billion yuan)	Growth rate (%)

2005	3468	0	2005	187,318.90	0
2006	3907	12.66	2006	219,438.50	17.15
2007	4676	19.68	2007	270,232.30	23.15
2008	5794	23.91	2008	319,515.50	18.24
2009	6530	12.70	2009	349,081.40	9.25
2010	7926	21.38	2010	413,030.30	18.32
2011	10011	26.31	2011	489,300.60	18.47
2012	11410	13.97	2012	540,367.40	10.44
2013	12783	12.03	2013	595,244.40	10.16
2014	14263	11.58	2014	643,974.00	8.19
2015	15700	10.08	2015	689,051.00	7.00

Table 1. GDP of Chongqing and China

Source: http://www.haojingui.com/gdp/3217.html
https://zh.wikipedia.org/wiki/中华人民共和国国内生产总值

Chongqing has two pillar industries which are electronics manufacturing industry and automotive manufacturing industry. Both two of these industries need relatively mature supply chains and industry clusters (hktdc, 2015).

For electronics manufacturing industry, laptop production industry is the most important part in it. Before Yuxinou international railway opening, the laptop production industry had already got a rapid development, but limited by its export transportation modes.

Chongqing's laptop production industry is still developing and exploring. After the international railway official opened, the enterprises had increased their investments to Chongqing.In 2014, all Acer Inc's laptops were produced in Chongqing (Jingjing, 2015) which make the import and export of electronic information industry achieved steady growth. The total value of imports and exports reached 271.3 billion yuan, an increase of 22.2%, accounting for 46.3% of the total value of Chongqing's foreign trade import and export during the same period reached 30.8% (lunwenstudy, 2017).Then, in 2017, Chongqing municipality produced 60.95 million laptops and annual output of LCD monitors reached 91.28 million (Xinhua, 2018).

4.2 Conclusion

After checking the data of the laptop industry of Chongqing and comparing the GDP and the growth rate of Chongqing, we know that Yuxinou international railway has a very important meaning to Chongqing.

Therefore, to optimize this line of international railway will make Chongqing's economy grow steadily. Hence, we will say more details that what we do to optimize this international railway in Chapter 5 and Chapter 6.

Charter 5. Choosing the return cargo

After knowing the importance of Yuxinou international railway has a special meaning to Chongqing, in this Chapter, we would like to identify the best suited return cargo for this international railway.

Since the operation of this railway line, the lack return trip has become a problem that increases transportation cost. For now, the return cargos are mostly vehicles, and we would like to find out which kind of cargo also suitable for railway transport through this line. Hence, we check out the main export commodities of Germany and compare these commodities with the main import commodities of China. If the commodities including in both lists of main export of Germany and main import commodities of China, then we roughly believe that this kind of good has benefits for both countries which means that it is a good choice to be transferred.

After that, we check the export rules in Germany and the import rules in China to make sure the cargo that we preliminarily chose can be transported. In this part, we determined the cargo that suitable to be traded from Germany to China, but still not determined whether this kind of cargo suitable for railway transportation model. Hence, we assume the cargos volume and value, then get a rate which use the cargo's volume divides value.

At last, we compare three transportation models (air, intermodal, railway) to see each kind of transportation models' suitable rate range. Then we get a result for which kind of cargo is suitable to transport from Germany to China by using Yuxinou international railway.

5.1 Main export commodities and export rules in Germany

Firstly, we would like to check main export commodities of Germany to see what the supply of Germany is. According to the Economic Complexity Index (ECI), Germany is the 3rd largest export economy in the world and the 3rd most complex economy in 2016. (OEC, 2016) And it is the Europe's most powerful economy in 2017 that it shipped US$1.445 trillion worth of goods around the globe in this year (Workman, 2018). The top ten export commodities are vehicles, machinery, electrical machinery, pharmaceutical, optical, plastics, aircraft, articles of iron or steel, mineral fuels including oil, iron or steel.

Category	Export value	Proportion of the total export
Vehicles	$257.2 billion	17.8%
Machinery including computers	$245.4 billion	17%

Electrical equipment	$148.8 billion	10.3%
Pharmaceuticals	$84.1 billion	5.8%
Optical, technical, medical apparatus	$72.8 billion	5%
Plastics, plastic articles	$63.6 billion	4.4%
Aircraft, spacecraft	$41.8 billion	2.9%
Articles of iron or steel	$30.5 billion	2.1%
Mineral fuels including oil	$26.8 billion	1.9%
Iron, steel	$26.4 billion	1.8%

Table 2. The main export commodities in Germany (2017)
Source: http://www.worldstopexports.com/germanys-top-10-exports/

And we also would like to check the export restrictions in Germany to see whether there are some kind of cargos cannot be transported to China. For the export items restrictions, the cargos that prohibit to export are only cultural artefacts, specimens of flora and fauna which are threatened with extinction and war material, arms, munitions (santandertrade, 2018). In the meanwhile, there are also some trade restriction areas that UN sanctions which are Burma / Myanmar, Republic of Guinea, Iran, Democratic People's Republic of Korea (North Korea), Ivory Coast, Zimbabwe, Sudan, Syria, Libya. More than that, there is a list about arms embargoes/ export restrictions countries, and China is in this list (Prohibitions and Restrictions , 2012).

According to this, there are no specific regulations to regulate the main export items if we would like to transport these cargos to China.

5.2 Main import commodities and import rules in China

Next, we would like to check the main import commodities of China to see what the demand of China is and the import commodities regulations of China. In 2017, the People's Republic of China imported US$1.841 trillion worth of goods from around the globe (Workman, 2018).

Category	**Import value**	**Proportion of the total import**
Electrical equipment	$455.5 billion	24.7%
Mineral fuels including oil	$247.6 billion	13.4%
Machinery including computers	$169.8 billion	9.2%
Ores, slag, ash	$125.4 billion	6.8%
Optical, technical, medical apparatus	$97.4 billion	5.3%
Vehicles	$79.2 billion	4.3%

Plastics, plastic articles	$68.9 billion	3.7%
Organic chemicals	$55.8 billion	3%
Oil seeds	$44.5 billion	2.4%
Copper	$41.2 billion	2.2%

Table 3. The main import commodities in China
Source: http://www.worldstopexports.com/chinas-top-10-imports/

From the main import commodities, it is clear to see that electrical equipment, vehicles, plastics, plastic articles, optical, technical, medical apparatus are both in the list of main import commodities in China and the main export commodities in Germany. In this reason, we roughly believe that these kinds of cargos' trading are good for both countries.

To address the reality, we also check the customs website to see the main export items from Germany to China in 2017.

Rank	HS code	Product category
1	84-85	Electrical equipment
2	86-89	Transportation equipment
3	90-92	Optics, watches, medical equipment
4	28-38	Chemical products
5	72-83	Base metal products
6	39-40	Plastic rubber
7	01-05	Animal
8	68-70	Glass and ceramic
9	16-24	Food and drinks

Table 4. Germany exports major commodities to China in 2017
Source: http://www.askci.com/news/finance/20170930/100635108915_2.shtml

After comparing with the type of cargo that we roughly chose, it is obvious that the type of items which we selected are in the table.

Then we check the import rules in China, to make sure the cargo that we roughly chose can be transferred to China. In China, there is a regulation dedicated to regulate import goods called consolidated catalogues of goods prohibited from import into the mainland regulates the catalogue of prohibited from import (mainland, 2001). Most of items that are prohibited to import are dangerous items or flammable and explosive materials, but there is still something such as electrical equipment also in the list.

Serial No.	Tariff codes	Description of goods
52	90221200	Computed tomography apparatus
53	90221300	Other apparatus based on use of X-rays, for dental uses
54	90221400	Other apparatus based on use of X-rays, for medical, surgical or veterinary uses
55	90221910	Low dosage X-ray security inspecting equipment
56	90221990	Other apparatus based on use of X-rays
57	90222100	Apparatus based on the use of alpha, beta or gamma radiations for medical uses
58	90222900	Apparatus based on the use of alpha, beta or gamma radiations for other uses

Table 5: Part of the catalogue of goods prohibited from import (No.2) used electromechanical products prohibited from import
Source:
https://www.tid.gov.hk/english/aboutus/tradecircular/cic/asia/2005/files/ci2005563a.pdf

In this case, we just believe that some machinery and also computers which is one of the main export goods cannot be imported to China while the others can be transported to China smoothly.

Then, we would like to choose five type of cargo which are 1. electrical equipment, 2. transportation equipment, 3. plastics and plastic articles, 4. optical, technical, medical apparatus, 5. food and drinks. Moreover, we select some items of each type of cargos to make it easier for calculating and comparing later. For the items list, we put it in the appendix.

5.3 Choosing the suitable return trip cargo

After choosing the five types of cargo, we would like to compare the cargo transportation cost and holding cost if we transport these kinds of cargo in different transportation modes.

5.3.1 Comparing three transportation modes' transportation cost

In general, there are three modes to transport cargo from Chongqing to Duisburg. There are railway, intermodal transportation and air transportation. Among them railway transportation and air transportation are only use one kind of transport mode and directly from Chongqing to Duisburg. But for intermodal transportation mode it uses at least two kinds of transport modes, for this reason, there will be more options that we can choose. After checking some logistic companies' website, we find that there are mainly four efficient options.

Routes	**Intermodal Transportation Path**
1	Duisburg-railway-Rotterdam port-sea-Shanghai port- Inland waterway-Chongqing
2	Duisburg-railway-Rotterdam port-sea-Shanghai-railway- Chongqing
3	Duisburg-railway-Rotterdam port-sea-Yantian port (Shenzhen)-railway-Chongqing
4	Duisburg-railway-Rotterdam port-sea-Yantian port (Shenzhen)-road-Chongqing

Table 6. Intermodal transportation from Duisburg to Chongqing

We mark the four intermodal transportation line as route 1, route 2, route 3 and route 4. Then, we compare all these four route's transportation costs.

Route 1	**Mode**	**Transit time(day)**	**Cost (USD)**
Duisburg-Rotterdam port	railway	3 (estimate)	
Transfer cost			259
Rotterdam port- Shanghai port	sea	30	
Document Charge			67.2
Port Congestion			4.4
THC			180.9
Container Loading charge			224.2
Seal Charge			6.73
Equipment Management Fee			1.49
Port construction			14.3
Customs			14.9
b/l			15

Transfer cost			1100
Other handling charges			354.4
Shanghai port - Chongqing	inland waterway	15	359
port construction			7.18
document transfer			4.4
			2613.1 USD
Sum		48	2259 EUR

Table 7. Route 1 duration and transportation cost
Source: https://www.sciencedirect.com/science/article/pii/S2092521217300445

Route 2	**Mode**	**Transit time(day)**	**Cost (USD)**
Duisburg-Rotterdam port	railway	3 (estimate)	
Transfer cost			259
Rotterdam port- Shanghai port	sea	30	
Document Charge			67.2
Port Congestion			4.4
THC			180.9
Container Loading charge			224.2
Seal Charge			6.73
Equipment Management Fee			1.49
Port construction			14.3
Customs			14.9
b/l			15
Transfer cost			1100
Other handling charges			354.4
Shanghai port - Chongqing	railway	4.5	
Handling Charge			43.7
Other handling charges			14
Document Charge			14.9
Transfer cost			1106
			3421.12 USD
Sum		37.5	2957.53 EUR

Table 8. Route 2 duration and transportation cost
Source: https://www.sciencedirect.com/science/article/pii/S2092521217300445

Route 3	**Mode**	**Transit time (day)**	**Cost (USD)**

Duisburg-Rotterdam port	railway	3 (estimate)	
Transfer cost			259
Rotterdam port- Yantian port	sea	22	
Document Charge			74.7
Original Receipt Charge			283.9
Seal Charge			3.7
Port security charge			4.48
Port construction			22.4
Customs			14.9
Telex release surcharge			50
Transfer cost			1325
Other handling charges			332.5
Yantian port - Chongqing	railway	2.5	
Handling Charge			43.7
Other handling charges			89.6
Document Charge			14.9
Transfer cost			1,121.10
			3639.9 USD
Sum		27.5	3147 EUR

Table 9. Route 3 duration and transportation cost

Source: https://www.sciencedirect.com/science/article/pii/S2092521217300445

Route 4	**Mode**	**Transit time (day)**	**Cost (USD)**
Duisburg-Rotterdam port	railway	3 (estimate)	
Transfer cost			259
Rotterdam port- Yantian port	sea	22	
Document Charge			74.7
Original Receipt Charge			283.9
Seal Charge			3.7
Port security charge			4.48
Port construction			22.4
Customs			14.9
Telex release surcharge			50
Transfer cost			1325
Other handling charges			332.5
Yantian port - Chongqing	road	1.5	
Road Toll			108.5
transfer cost			1,392

			3871.1 USD
Sum		26.5	3347 EUR

Table 10. Route 4 duration and transportation cost

Source: https://www.sciencedirect.com/science/article/pii/S2092521217300445

	Yuxinou railway	Route 1	Route 2	Route 3	Route 4	Air transportation
Transport time	13 days	48 days	37.5 days	27.5 days	26.5 days	3 day
Driving frequency	9 to 11 trips per week	Irregular	Irregular	Irregular	Irregular	9 trips per week
Freight	4920 EUR	2259 EUR	2957.53 EUR	3147 EUR	3347 EUR	134,866 EUR

Table 11. Transportation type comparing based on 40ft container

From table 11, we can see that railway transportation has its own benefits that the transfer cost for railway transportation is not as high as the air transportation, in the meanwhile, the transportation time is not long as the intermodal transportation. For searching which kind of cargo is more suitable to transport from Germany to China by railway, we do not just compare the transportation cost, we also compare the holding cost and the total cost for each kind of transportation types, then choose the suitable returning trip items.

5.3.2 Comparing three transportation modes' holding cost

Holding costs are the additional cost associated with storing inventory (Investopedia, 2018). Actually, there are a number of different costs that comprise holding costs including depreciation, insurance, personal, etc. (cost, 2017). In this reason, there are lot of formula to calculate holding cost. While in this study, we just use a simple formula to estimate the holding cost which is

$$\text{holding cost} = \text{holding rate(yr)} * \text{value of material} * \text{duration(days)}\ /365 \qquad 5\text{-}1$$

We would like to define a value rate to make it easier to show the value for each item with the same unit. Hence, we put the cargo's value divides cargo's volume and construct this formula. Then, we can change the original formula into

$$\text{holding cost for each container} = \text{holding cost rate(yr)} * \text{value rate} * \text{container volume} *$$

$\text{duration (day)}/\ 365$
5-2

In terms of the holding cost rate, different cargos have different holding cost rate. But estimating this rate in an accuracy level is a difficult thing. In this reason, we would like to put same species of items with a same holding cost rate level. Moreover, we find that holding cost rate is related the value of the items and the speed of change in the price of items. In most cases, when an item has the characteristic that high value and price change fast then the holding cost rate is high, while with the same reason an item has the characteristic that low value and price change slow then the holding cost rate is low.

In this study, we would like to use the value rate to replace the value of every cargo, because our study's object is each container. For the price fluctuation, it is mainly based on the demand price elasticity of the product. The demand price elasticity is the percentage change in the value of the price that causes a change in demand that people sometimes called it Ed (investopedia, 2018), when 0<Ed<1 the price floating flat and when Ed>1 there will be a large price fluctuation for this kind of item.

Hence, we definite a variable to indicate the size of the price float which we call it Pf.

$$\text{Pf} \propto \text{value rate} \tag{5-3}$$

$$\text{Pf} \propto \text{Ed} \tag{5-4}$$

However, as the formula we can see, both Ed and value rate are variables. Moreover, Ed is related to number of demand change and the number of price change which is difficult to get a specific number. In this reason, to make it simple, we refer the comprehensive scoring and decide to compare every species that we choose and rank them in terms of the Ed level. Then, we give each of species a specific Ed indicator from 2 to 10 to replace. The specific details of the cargos are mentioned in the appendix.

Species	**Category**	**Rank**	**Ed indicator**
Electric motor	Electrical Equipment	4	4
Speaker	Electrical Equipment	5	4
Vehicle	Transportation Equipment	3	7
Electric vehicle	Transportation Equipment	6	3
Toys	Plastics and plastic articles	2	8
Scanning Electron Microscope	Optical, technical, medical apparatus	7	2
X-ray machine	Optical, technical, medical apparatus	8	2
Wine	Food and drink	1	10

Table 12. Sort table of the selected cargos (Author's summary)

After that, we can say

$$\text{holding cost rate} \propto \text{value rate} \qquad 5\text{-}5$$

$$\text{holding cost rate} \propto \text{Ed indicator} \qquad 5\text{-}6$$

To make it easier, we just assume

$$\text{holding cost rate} = k_1 * (\text{value rate} * \text{Ed indicator})^{k_2} \qquad 5\text{-}7$$

Based on Anna Azzi (2012) research, 25 percent is the mean value of the holding cost rate per year (Azzi, 2012), in the meanwhile, we also find some paper said that the range for the holding cost rate mostly is 15%-50%, then we simply assume the holding cost rate obey normal distribution with $\lambda = 0.25,\ \sigma = 0.2$. After that, we calculate that there will be 0.683 probability the holding cost rate is in the range of 0.155 to 0.345 per year.

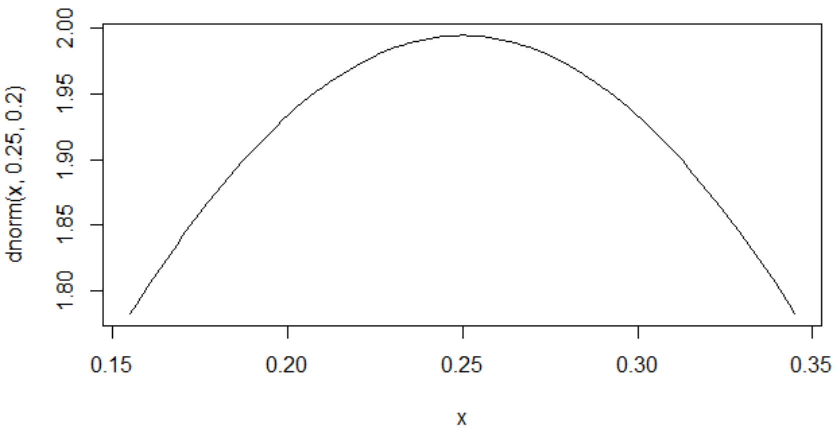


Figure 5. Normal distribution for the holding cost rate

We would like to assume that the items we chose their holding cost rate also in this range. And we sort all items' $\text{value rate} * \text{Ed indicator}$ from smallest to largest to make a list which we put it in the appendix and fitting the holding cost rate equal difference series.

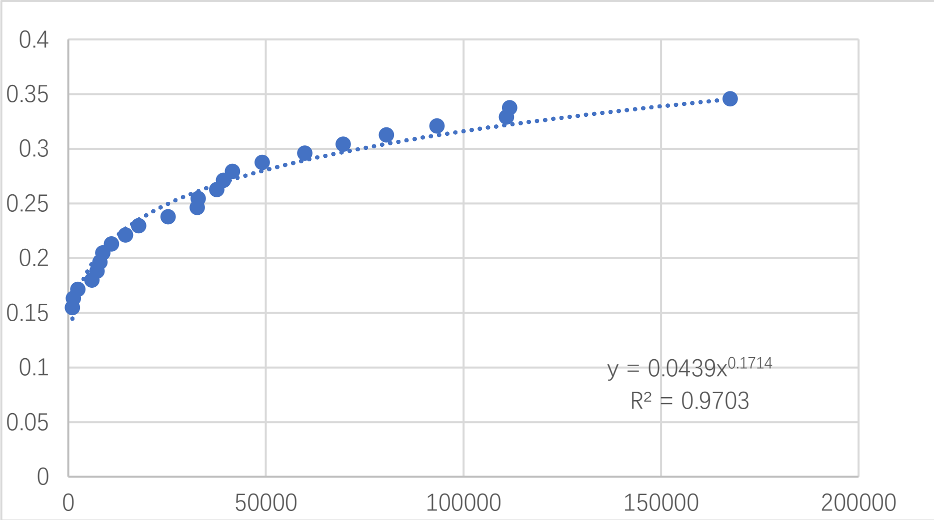


Figure 6. Power fitting for the holding cost rate (Author's summary and cargos' details in the appendix)

After using power fitting, we get a formula

$$\text{holding cost rate} = 0.0439 * (\text{value rate} * \text{Ed indicator})^{0.1714} \quad \text{5-8}$$

5.3.3 Compare the total cost and choose the suitable items

After getting the holding cost for each kind of items that we chose, we put the holding cost and the transportation cost for different transport modes together, then we get the total cost for each kind items transporting by different transportation modes (the details for each kind of transportation modes are in the appendix).

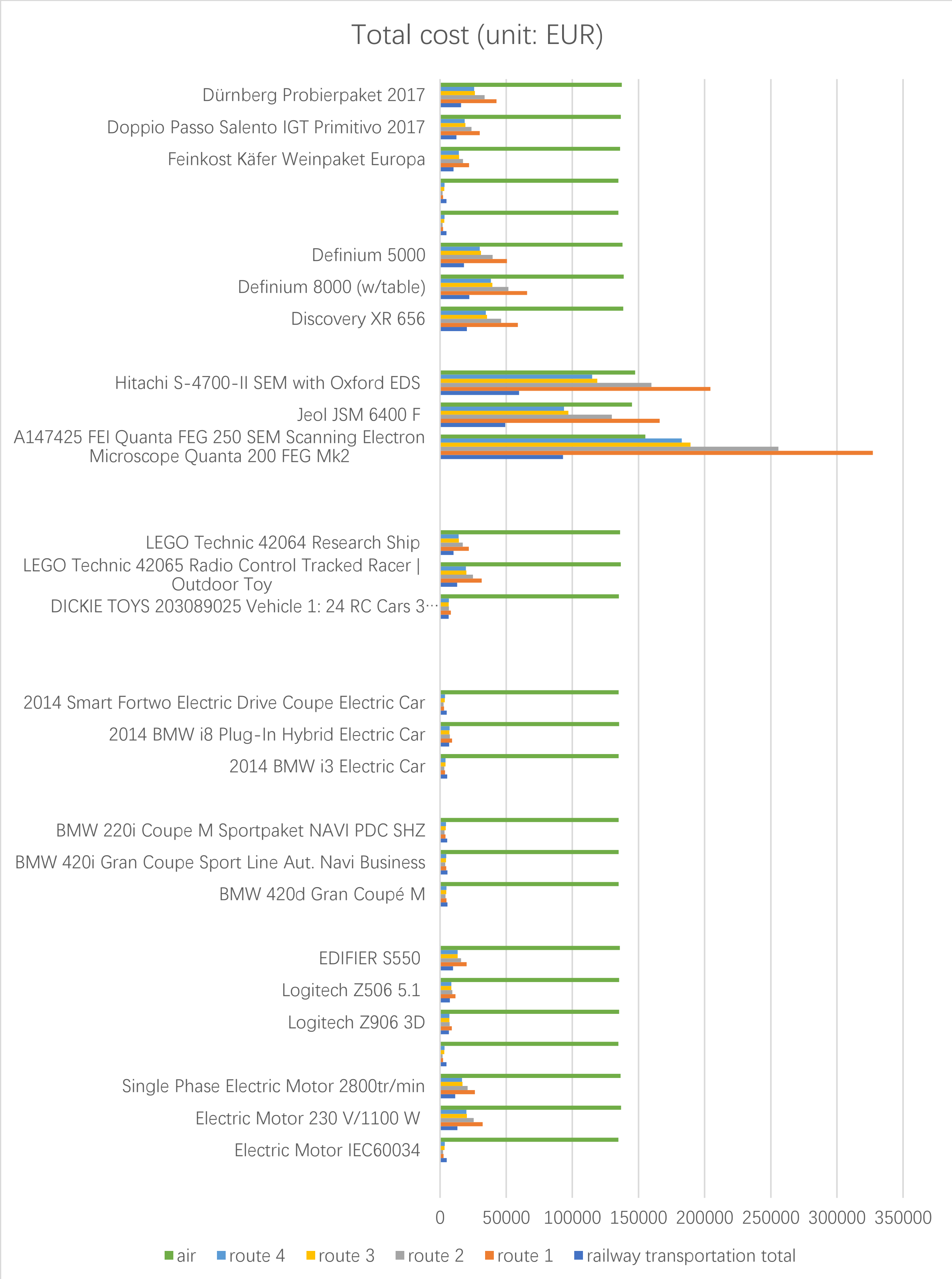


Figure 7. The total cost of the selected cargos (The author summarizes himself)

Hence, after we compare all kinds of items that we chose, among all these 24 kinds of specific items we choose, 18 of them transported by railway have lower prices.

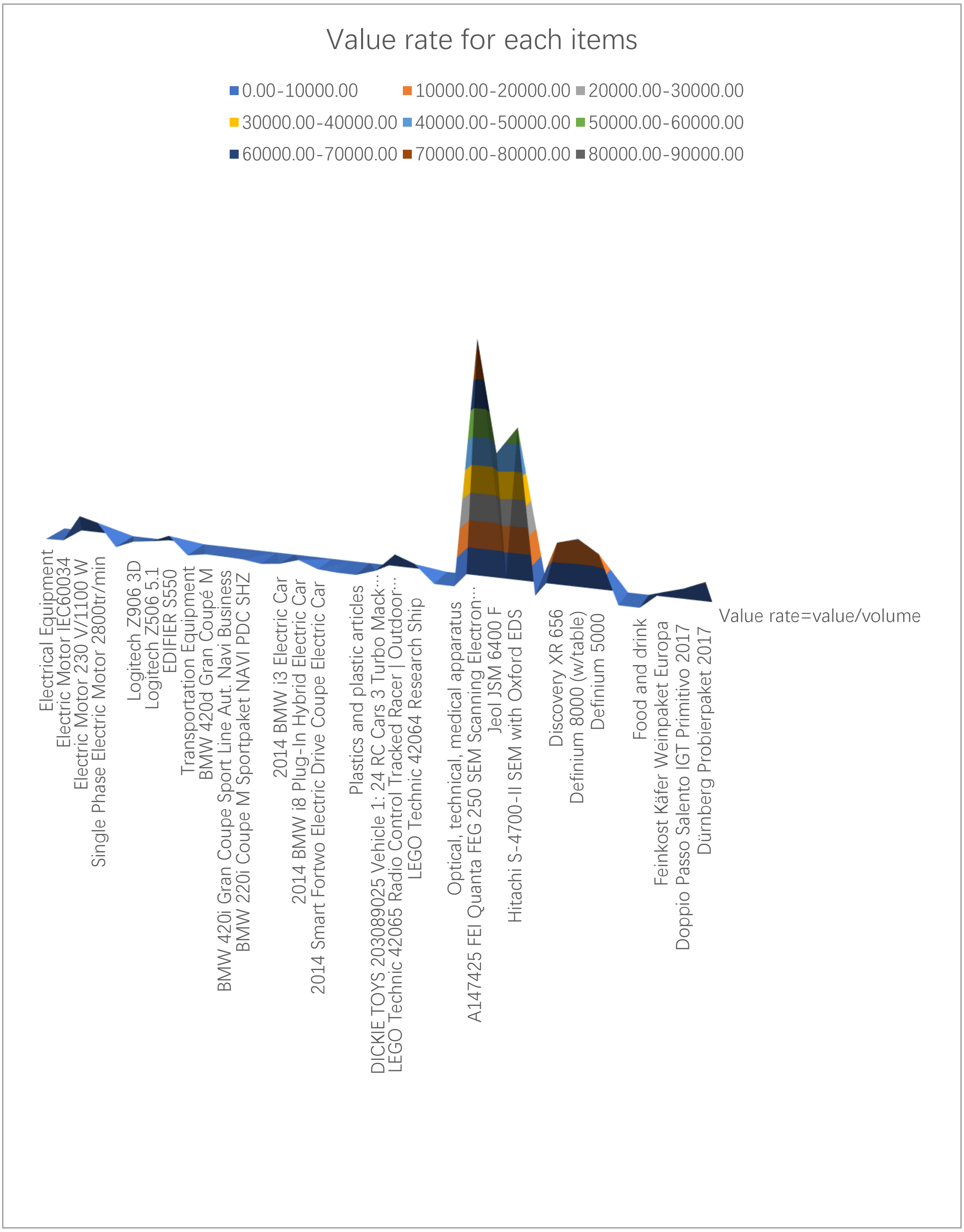


Figure 8. Value rate and holding cost rate for 24 items (The author summarizes himself)

Moreover, all these 18 items have a common feature that their value rate are in the range of 2225 to 83750 is suitable for railway transportation.

Species	Category	Value rate	holding cost rate
	Electrical Equipment		
Electric motor	Electric Motor 230 V/1100 W	9821.43	0.27
	Single Phase Electric Motor 2800tr/min	8152.33	0.26
Speaker	Logitech Z906 3D	2727.17	0.22
	Logitech Z506 5.1	3623.12	0.23
	EDIFIER S550	6313.27	0.25
	Transportation Equipment		
Electric vehicle	2014 BMW i8 Plug-In Hybrid Electric Car	2919.13	0.21
	Plastics and plastic articles		
Toys	DICKIE TOYS 203089025 Vehicle 1: 24 RC Cars 3 Turbo Mack Truck – 46 cm/18	2225.05	0.23
	LEGO Technic 42065 Radio Control Tracked Racer | Outdoor Toy	8695.51	0.30
	LEGO Technic 42064 Research Ship	6133.87	0.28
	Optical, technical, medical apparatus		
Scanning Electron Microsco	A147425 FEI Quanta FEG 250 SEM Scanning Electron Microscope Quanta 200 FEG Mk2	83750.00	0.35
	Jeol JSM 6400 F	46666.67	0.31
	Hitachi S-4700-II SEM with Oxford EDS	55833.33	0.32
X-ray machine	Discovery XR 656	18785.03	0.27
	Definium 8000 (w/table)	20779.91	0.27
	Definium 5000	16441.06	0.26
	Food and drink		
Wine	Feinkost Käfer Weinpaket Europa	5986.67	0.29
	Doppio Passo Salento IGT Primitivo 2017	8053.33	0.30
	Dürnberg Probierpaket 2017	11088.89	0.32
	Hitachi S-4700-II SEM with Oxford EDS	55833.33	0.32

Table 13. Value rate and holding cost rate for 18 items (The author summarizes himself)

Based on all these things, we can conclude that there are more options for choosing the return trip cargos. For this international railway, electric equipment, transportation equipment, plastics and plastic articles, optical, technical, medical apparatus and food drink are all good choices. Moreover, we also find that the original choice which is to transport cars are not a very wise choice in terms of the total cost.

5.4 Conclusion

In this chapter, we compared the main imported goods of China and the main exported goods of Germany to see which kinds of cargoes need to be traded to maintain the supply demand balance in both two countries. Hence, we select 24 kinds of cargos in 5 categories.

We find mainly there are 6 modes of transportation from Chongqing to Duisburg. Then, we find the transportation cost for each kind of transportation modes. After knowing the transportation costs, we defined a value rate to estimate the holding cost rate for different kinds of cargos, and we get the holding cost for each kinds of cargos in different kinds of transportation modes.

After that, based on these 24 kinds of cargos' characteristic, we compared the total cost which includes transportation cost and holding cost that they shipped with different 6 modes of transport. Then, we find that there are18 items suitable for railway transportation in terms of the total cost.

Chapter 6. A method to reduce total cost

After selected the suitable cargos for this railway road transportation, we would like to find out how to reduce the total cost to make this line more competitive. We would like to find what kind of factors connected with the total spending time and the total cost. In 6.1, we would like to give a total time formula including the fixed time part and the variable time which is the part that we can optimize. In the meanwhile, in 6.2, we also would like to summarize the total cost formula including the fixed cost part and the variable cost which can be reduced. After getting the completed formula, in 6.3, we would like to change the variable part to push the total cost change into the minimum value.

In this reducing process, we find that there more than one variable affects the total cost. For this reason, firstly, we would like to classify which variable has a greater impact and which variables only have subtle influence to the total cost. Then, we would like to get a sensitivity analysis for the variables that have less impact on the results. After that, we can know the optimal result for the less affected variables. Then, these variables change into fixed number, and we can use linear programming to get the optimal result for the larger affected variable. In the end, we can get the final result for the number of minimal total cost.

For the total time, we list by the following formulas. In general, we can separate total time into two parts which are traveling time and stops time. Traveling time is the time that the train spends on railway, and the stops time is the time spending on each stop which includes rail exchange time, customs transfer time and change rail head, driver time.

$$\text{Total time} = \text{Traveling time} + \text{Stops time} \quad \text{6-1}$$

$$\text{Traveling time} = \sum \frac{Distance}{speed} \quad \text{6-2}$$

$$\text{Stops time} = \sum rail\ exchange\ time + \sum customs\ transfer\ time + \sum change\ rail\ head, driver\ time \quad \text{6-3}$$

For now, we just give a simple framework of the total time. Later on, we will elaborate these equations.

For the cost part in this study, we focus on the real cost which is the cost of being able to run a train. Generally, the train costs can be classified into three parts which are rail network infrastructure cost (fixed cost), train operation cost, and corporate overheads cost (Performance, 2017). Because corporate overheads cost is not connected with the traveling time, operation time, or other variables in this study, in this reason, we just not consider this kind of cost.

Then we got the total cost formula which is

$$Total\ cost =\ transportation\ cost + holding\ cost \qquad 6\text{-}4$$

$$Transportation\ cost = network\ infrastructure\ cost + operation\ cost \qquad 6\text{-}5$$

$$Holding\ cost = holding\ cost\ rate * materials\ value * duration \qquad 6\text{-}6$$

However, there are also some constrains that should be considered. Firstly, which is the speed of a train. For cargo trains' in China the theoretical maximum speed is 100km/ hour (Anon., 2017).

We change this constraint into formula as

$$Speed < 100\text{km/h} \qquad 6\text{-}7$$

Also, rail exchange time and change rail head and driver time also have constrains.

$$rail\ exchange\ time > 1.5\ \text{hours} \qquad 6\text{-}8$$

$$change\ rail\ head, driver\ time > 2\ \text{hours} \qquad 6\text{-}9$$

Then, we transfer our research question into formula as

$$Min \sum \frac{Distance}{speed} + \sum rail\ exchange\ time + \sum customs\ transfer\ time + \sum change\ rail\ head, driver\ time$$

$$Min \sum network\ infrastructure\ cost + \sum operation\ cost + \sum other\ cost + holding\ cost$$

s.t

$$Speed < 100\ km/h$$

$$rail\ exchange\ time > 1.5\ hour$$

$$change\ rail\ head, driver\ time > 2\ hour$$

6.1 The factors affecting total time

The total cost is composed of four parts which are traveling time, rail exchange time, customs transfer time, and change rail head, driver time.

Firstly, we focus on traveling time, two things will influence it which are distance and speed. But considering the distance between two points that we cannot change, in this reason, only the speed of rail will influence traveling time.

6.1.1 Rail exchange time

Kazakhstan, Russia and Belarus's rails are 1520 mm wide rails, while China's rails are 1435 mm wide rails with a difference of 85 mm. In this reason, trains must be replaced by different gauges and train chassis after it entering from one country to another (news, 2013).

For rail exchanging, one needs gantry or wheeled crane. The spreader of the crane grabs the container on the wide-gauge train, then moves it, and puts it on a railcar at the other side. All these processes are finished in a rail change workshop. Given a fixed train length, the shorter the workshop the longer the rail exchange time needed.

Figure 9. Rail exchange in workshop

Figure 10. Railway exchange with crane

Based on the process of the rail exchange, we would like to say there are three things that influence the rail exchange time which are the type of equipment (gantry crane or wheeled crane), the number of cranes and the length of the rail change workshop. Then, we express it by formula as

$$\text{Rail exchange time} = \text{number of exchanges} * \frac{k_1}{\text{number of crane} * \text{the length of the rail change workshop}} \quad \text{6-10}$$

k_1-number of hours needed for one crane with the workshop can hold 40 train compartments.

Currently, Kazakhstan uses wheeled cranes and their rail-changing workshop can only accommodate up to 20 train compartments, so that the Yuxinou international train needs to be rotated twice. While Belarus has relatively advanced equipment, they use 3 huge gantry cranes to finish this process. Moreover, their workshop is also longer implying that their workshop can process 80 train compartments (news, 2013).

We know that the number of exchanges is 2, and after checking some paper materials, we estimate that the k1=6 hours in our study, then we get the following formula.

$$\text{Rail exchange time} = 2 * \frac{6}{\text{number of crane} * \text{the length of the rail change workshop}} \quad \text{6-11}$$

6.1.2 Customs transfer time

Customs clearance involves preparing and submitting documents needed to facilitate export or import to the country, and to deliver goods and documents from customs after customs inspection, assessment, payment of taxes and joint customs clearance (universalcargo, 2013).

For Yuxinou international railway, First, documents required for import declaration：
1. Certificate of origin
2. Certificate of hygiene
3. Certificate of analysis
4.The original packaging label
5.The original packaging label Chinese translation
6. Producers filling date proof

Second, import and export food label application requires information, which are
1. Export enterprise health permit
2. Product manufacturer or distributor business license
3. Proof of official sales of the product in the producing country (region) or
4. Trademark authorized use book or authorized processing book
5. Description materials for the contents marked on the label
6. 5 sets of food label samples, difficult to provide proofs, can provide valid photos, or scan print proofs

The time to deal with these documents and the time for preparing these documents is mostly depended by governments' efficiency. For this reason, it is difficult to change in a short time. In this reason, we would like to say it is a fixed time in our formula.

6.1.3 Change rail head, driver time

For Yuxinou international railway, the operation of the trains in China parts is done by relays of railway stations along the route which means that every time a train arrives in a railway bureau (group) jurisdiction, the driver will be replaced (ifeng, 2015). While in other parts, it will change the driver when the train arrive one country.
Hence, we express it as a formula

$$Total\ change\ rail\ head, driver\ time = \sum China\ parts\ time + \sum other\ parts\ time \quad \text{6-12}$$

For this reason, there are two ways to reduce total change rail head, driver time. The first way is to reduce total change rail head and driver time is to reduce number of stops that should change divers. The second way is to reduce the changing time in each stop.

For the first one, as we know, it is difficult to reduce the number of stops that should change drivers, because this railway connected 6 countries. The only stop that we can reduce is in the China part, that it can be reduced from two to one.

In terms of the changing time in each stop, we based on a Chinese paper (http://m.dooland.com/index.php?s=/article/id/547577/from/faxian.html) the original time is 5.575 hours in each stop. And the minimal time for this process, we assume that it at least cost 2 hours.

However, as we know, sometimes the delay situations will appear on trains. In this reason, if we want to reduce the changing rail head and driver time, we should make sure that the driver should prepare for the train before it arrived. This also means that the longer the delay of the train, the longer the driver should wait. Hence, for the train management, this means that they should hire more drivers or let the original drivers overtime work and both of two ways will cost money.

We get a formula as

$$Each\ \ stop\ change\ rail\ head, driver\ time = k_2 * \frac{24}{the\ number\ of\ drivers\ used} \qquad 6\text{-}13$$

and we estimate k_2=1/2.

6.1.4 Total time model

After analyzing all parts of time, we would like to give a complete formula to display the total time.

$$\text{Total time} = \sum \frac{Distance}{speed} + \frac{k}{\text{number of crane}*\text{the length of the rail change workshop}} + \sum customs\ transfer\ time\ + \sum China\ parts\ time\ change\ rail\ head, driver\ time + \sum other\ parts\ time\ \ change\ rail\ head, driver\ time \qquad 6\text{-}14$$

6.2 The factors affecting total cost

From the formula, we know that there are four things can influence the total cost which are network infrastructure cost, operation cost, and holding cost.

All modes of transport provide services using vehicles, vessels, or aircraft that rely on a substantial infrastructure network comprising routes, terminals, and controls for the movement of those vehicles. However, railways are unique in that the same entity often provides both railway services and network infrastructure (Performance, 2017). In this reason, network infrastructure cost is a unique cost for railway transportation.

And for the operation cost, many scholars divided it into many parts and different scholars have different distributions. For this study, we would like to use the comparative public method to divide the operation cost into 5 parts which will be more detail instructions in 6.2.2.

6.2.1 Network infrastructure cost

Network infrastructure cost is an investment from companies and government to invest on railway infrastructures or other relevant facilities that will improve the whole system efficiency.

To cover these infrastructure investments, local governments or the companies who invested these infrastructures would like to charge a fee which called railway infrastructure charges. The railway infrastructure charge is one of the components of the freight rate and applied to the customs. In this reason, we would like to figure out the real network infrastructure cost in this route.

Most costs for the railway infrastructure network include capital and maintenance costs for track, engineering structures such as bridges and tunnels, train signaling, communications systems, power supply in electrified sections, and terminal infrastructure (Performance, 2017).

$$\text{Network infrastructure cost} = \frac{investment\ cost}{the\ number\ of\ trips(per\ year)*volume(containers)} + railway\ maintenance\ cost \tag{6-15}$$

For the infrastructure investment, different category of railway has different cost. And for creating a railway with double line it will cost about 1,250,000 euro per kilometer in China, and we would like to use this data to estimate the entire railway. Moreover, we also find that mostly the largest age of railway is 95 to100 years (Baidu, 2008), and in our study we optimize while considering that the largest age of railway is 100 years.

After getting the amount of investment and the year of use, we should search how many trains does this railroad track pass per year and how many containers does one trips train carried.

It is a difficult thing to statistic on the number of trains going through on one railway for one year. In this reason, we try to find which kind of thing has relationship with the number of trains going through on one railway for one year.

According to the passenger trains in China, we find that the busyness of the railway has a connection with the passenger traffic between the two places. In terms of the cargo trains transportation, the busyness of the railway connects with the cargo trading volume between two places (Zhihu, 2015).

Hence, the main thing for us is to find the cargo trading volume in this route. However, the railway we studied, Yuxinou international railway, is not an exclusive railway. This means that each country also utilizes the route in the section of their part to transport their own cargos. In this reason, the number of trains going through on this railway line are different in different countries for one year and we should know the average number.

First, we focus on the China part. After searching the China train yearbook, we know that Datong-Qinhuangdao is one of the busiest freight routes in the world and the railway with the largest amount of coal in the world (Zhihu, 2015). From the pie chart, we know that nearly 9% of cargo trading through this route.

Figure 11. Datong to Qinhuangdao

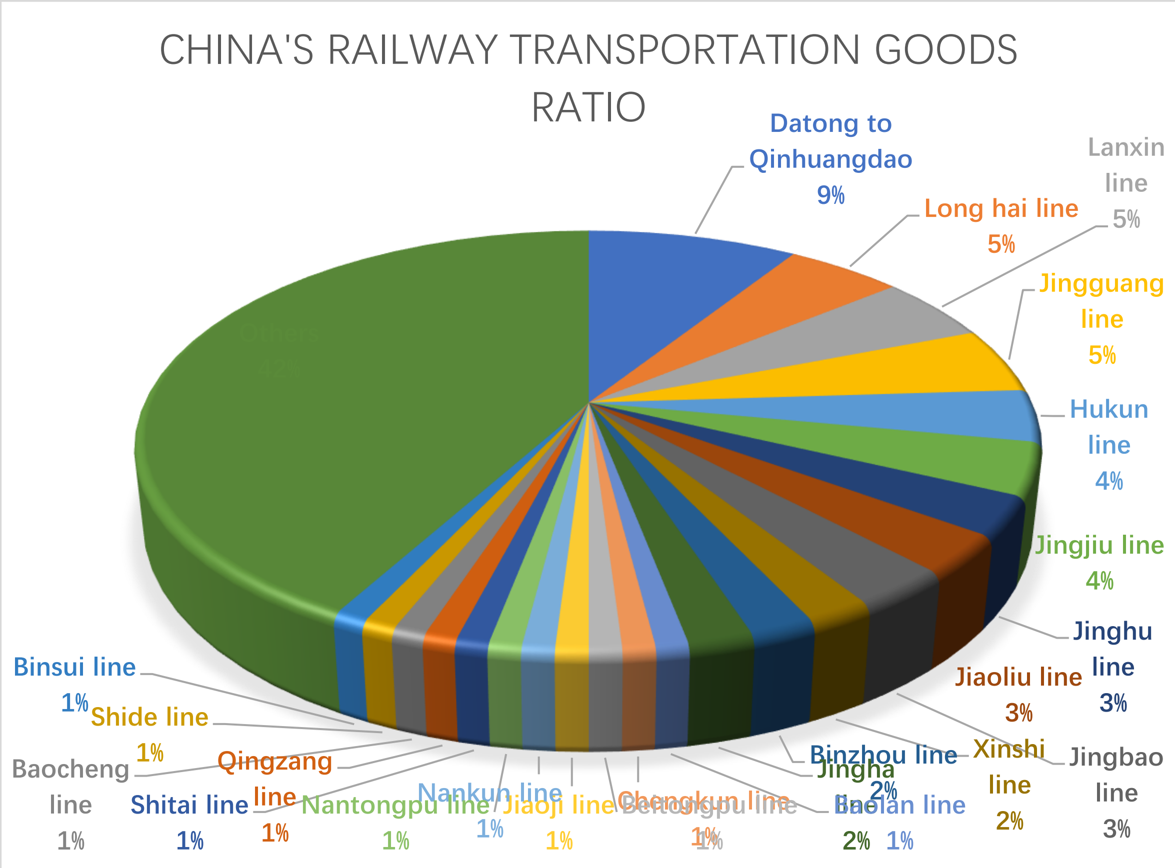
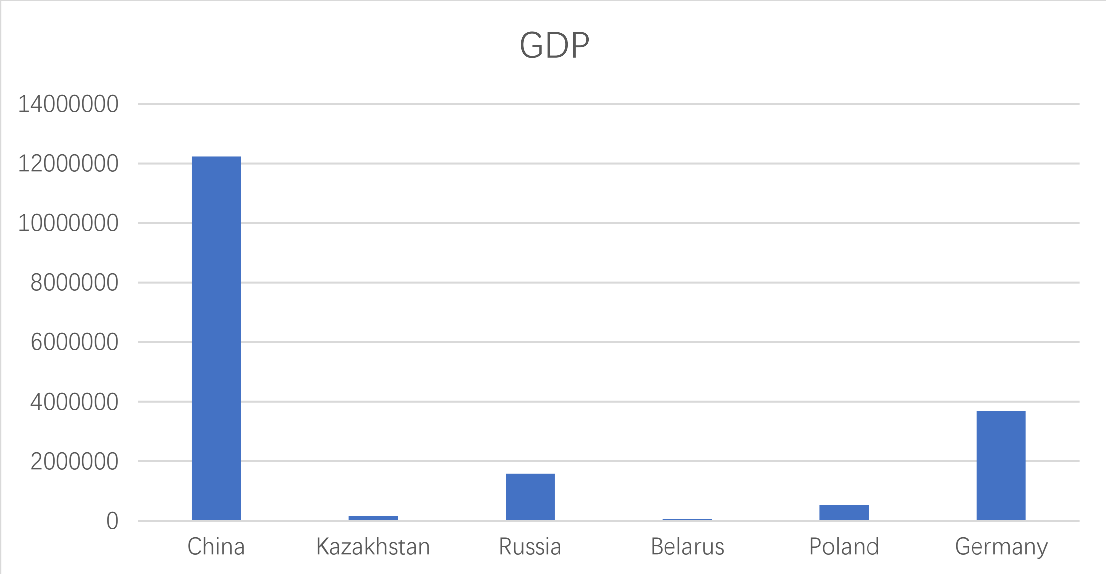


Figure 12. China's railway transportation goods ratio

Source: https://www.zhihu.com/question/31499913

In 2013, there were 170 million tons coal trading between these two places. Based on each cargo train can hold 30000 tons coal for each trip, we can know that in this route there were about 5666.7 trips train going through in every year.

In the meanwhile, we know that Lanxin route is connected Chongqing and Xinjiang which means that Yuxinou international railway will go through this section of railway. From the pie chart, we can know that Datong-Qinhuangdao line has a proportion of 9% and Lanxin line has a proportion of 5%. Then, we simply assume that the number of trains passed each year have a linear correlation with the cargo trading volume. Hence, we get the number of trains passing each year is 3148.



Unit: M*$

Figure 13. 6 countries' GDP in 2017

Source: https://countryeconomy.com/gdp

After getting the number of trains passing each year in China parts, we need to know the how many numbers of trains passing each year in other countries parts. As we know the busyness of the cargo railway have a connection with the trading volume, to a certain extent, one countries GDP can reflect the trading volume. In this reason, we use China as a benchmark. Then we use the following formula to assume the number of trips in each country.

$$\text{Trips} = \frac{One\ country's\ GDP}{Chinese\ GDP} * China\ part\ trips \qquad 6\text{-}16$$

	GDP	Proportion compared with China	Trips/yr
China	12,237,701	1	3148.17
Kazakhstan	159,407	0.013025894	41.01
Russia	1,577,524	0.128906892	405.82
Belarus	54,442	0.004448711	14.01
Poland	524,510	0.042860174	134.93
Germany	3,677,439	0.300500805	946.03
unit: M*$			
source: https://countryeconomy.com/gdp/			

Table 14. Train trips of the countries of this international railway

But if we consider deeply, we notice that the weight for the number of trips in each country are different. The longer the train track is in its country, the greater the influence of this track. Hence, we get the formula and know each stops railway distance have a positive rate with the weight rate k_i.

$$\text{Average trips} = \sum_{i=1}^{n} k_i * trips\ in\ each\ country \qquad 6\text{-}17$$

After calculate we get the table and the average trips in this route for one year is 1245.84.

	Distance (km)	Trips (per year)	Distance*Trips(km*year)
China	3812.00	3148.17	12000811.33
Kazakhstan	3424.00	41.01	140410.32
Russia	1497.00	405.82	607513.11
Belarus	587.00	14.01	8221.10
Poland	708.00	134.93	95531.13
Germany	1198.00	946.03	1133339.89
Sum			13985826.88
Average			1245.84
unit: km			
source: https://countryeconomy.com/gdp/russia			

Table 15. The weight coefficient times trips of each countries

In this case, we can calculate the cost equal sharing in each year for each container.

Per km investment (EUR)	Distance(km)	Total investment (EUR)	Using age (year)	Number of total trips per year	Number of containers per train	Per container shared investment (EUR)
1,250,000	11,179	13,973,750,000	100	1245.8	43	2608.5

Table 16. The investment cost sharing in each container

For the railway maintain cost,

	Per kilo per year (EUR)	Total maintain cost (EUR)	Per container shared cost (EUR)
Maintain cost	150000	13750000	256.68
source: http://www.chyxx.com/industry/201511/357479.html			

Table 17. The maintain cost sharing in each container

6.2.2 Operation cost

Mostly, train operating costs include: (1) diesel fuel or electrical energy, (2) locomotive capital depreciation or leasing cost, (3) train and yard operation cost, (4) train control, (5) intermodal cost (Performance, 2017).

In this study, there is no intermodal transportation cost and the train control fees and depreciation cost are unchangeable cost in short term with a light weight. In this case, we would like to ignore them, and use this formula as

$$\text{Operation cost} = \text{fuel cost} + \text{yard operation cost} \tag{6-18}$$

For the fuel cost, it is the cost for the train fuel consumption. In our study, we select one specific diesel locomotive to calculate the fuel consumption which is DF4.

Figure 14. DF4 diesel locomotive

According to the train main engine handbook, we know that the fuel consumption has a relationship with the number of handles and the speed of the train and we put the table on appendix. The table shows a relationship between the train traveling speed and the fuel consumption. However, in reality, the train is not always driving in the same speed. When the train is going to arrive station, the train should slow down the speed and when the train is going to leave station the train should speed up to get a target speed. Both of the two process will consume more fuel.

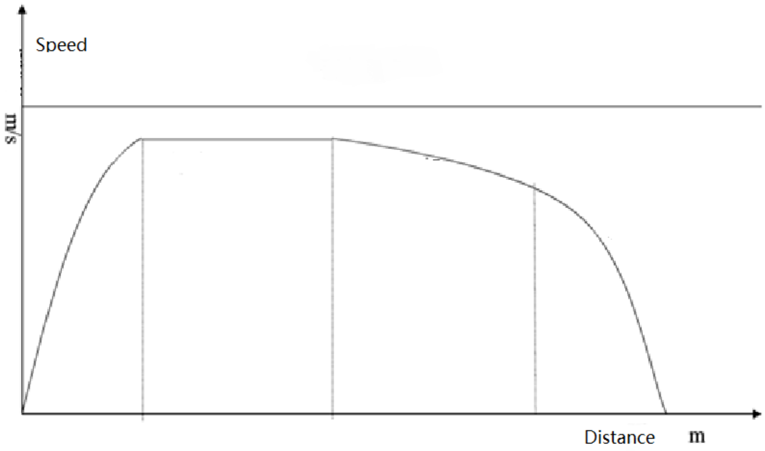


Figure 15. Train speed change chart

In this reason, we find a data to show the relationship with the average speed of train in one trip and the fuel consumption. Then, we based on the total distance of the railway from Chongqing to Duisburg is 11226 km, each trip of the train carrying 43 containers, and the fuel price is 0.56 EUR/ kg. Hence, we get the table.

Speed (km/h)	40	50	60	70
Fuel consumption (kg/min)	4.5	6.5	10	12
Total consumption (kg)	75775.5	87562.8	112260	115467.4
Per container fuel consumption (kg)	1762.22	2036.34	2610.70	2685.29
Per container fuel cost (EUR)	980.24	1132.72	1452.20	1493.70

Table 18. Fuel cost for per container changes with train speed
Source. http://www.doc88.com/p-661123629861.html

However, in our study, we would like to know what is the influence per container of the fuel cost when speed changed from 10km/h to 100km/h. For this reason, we create a scatter plot based on current speed and per container fuel cost.

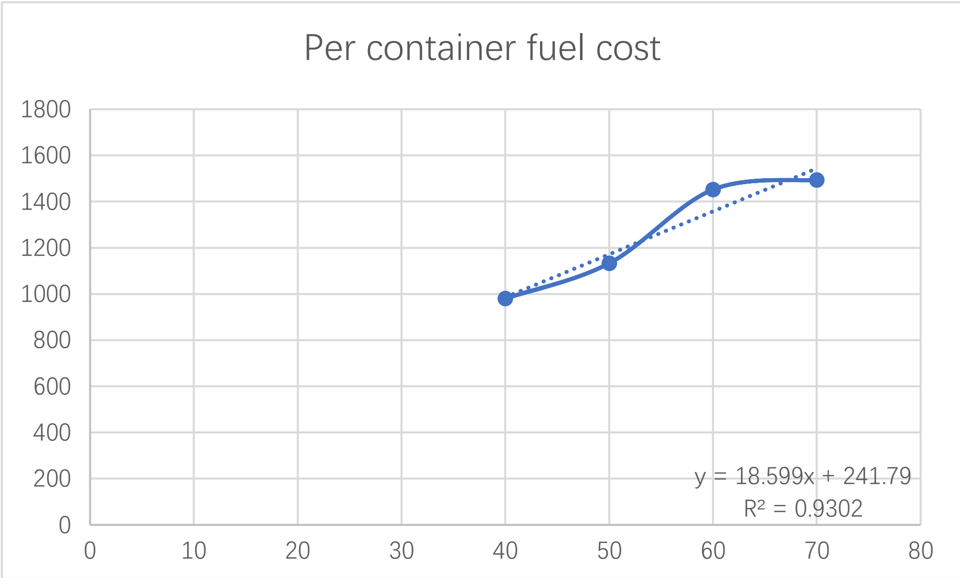


Figure 16. Per container fuel cost (Unit: EUR)

After that, we give a liner fitting for these four points and get a formula as

$$\text{Per container fuel cost} = 18.599 * \text{speed(km/hour)} + 241.79 \quad 6\text{-}19$$

with $R^2 = 0.9302$.

For the yard operation cost, we simply divided into two parts. The first part is the facility fees which connected with the rail exchange process, while the second part is the change driver cost which connected with the change driver process.

$$\text{yard operation cost} = (\text{facility fees} + \text{change driver cost}) * \text{stops} \quad 6\text{-}20$$

After checking the terminal handling charges of Rail Cargo Terminal- BILK Ltd. 2018, we find that the facility handling fees is 37 euros for each container (Terminal, 2018). But we would like to reduce the operation time. In this case, we calculate what if we add cranes and the cost of this infrastructure construction to each container. We use the same number we have mentioned in Chapter 5 that there are 1245.8 trips on this route per year and each trip of train has 43 containers. Moreover, we assume that the crane can be used 10 years and there are one quarter containers handled by each crane. Hence, we get the table and know when we add one more crane to operate there will be 0.54 euros spread on each container.

crane price (euro)	Age (yr)	trips	Container per train	total nr of containers handled /yr	cost per container (euro)
72,500	10	1245.8	43	133,923.5	0.54

Table 19. Increased cost for each additional crane for a container

Source:https://detail.1688.com/offer/563185080817.html?spm=a261b.2187593.1998088710.84.49c66171amZA47

While for the change diver cost, we assume that each driver's cost is 2000 euro per month and each driver will handle 15 trips per month. Then, we get the table and know that when we hire one more driver there will be 3.1 euros spread on each container. And for the current situation, we assume that there are 2 divers in each stop.

operation trips per month	diver wage per month (EUR)	diver wage for each one per trip	container number	per container (EUR)
15	2000 (estimate)	133.33	43	3.10

Table 20. Increased cost for each additional driver for a container

6.2.3 Holding cost

In this study, the most influential factor for the holding cost is the different kinds of holding items. Moreover, the forward trips and the return trips also holding different kind of cargos, for the forward trips they have single cargo cate while the return trips they will have more options based on our study. In this reason, we separate consider the forward trip and return trip.

For holding cost, we still use the same formula 5-2 where we have mentioned it in Chapter 5. Also, for the return trips holding cost, we would like to use the result of holding cost rate and value rate which we have gotten from Chapter 5.

For the forward trips, currently, the main category forward trips' cargo category is laptop. In this reason, we roughly think the forward trips all carry laptops. Then, we would like to calculate the holding cost for the forward trip.

	Volume (m^3)	Item number per container	Value for each container	holding cost rate
laptop	0.0030855	27978	8,393,400	0.25 /year

Table 21. Forward trip items' characteristic
Source: https://cargofromchina.com/air-freight/

For the return trips' carrying cargos, we would like to use the data that we have already gotten in Chapter 5. However, in Chapter 5, we just simply list which kinds of cargos are suitable for return trips. In this part, we got the average of the 18 kinds of cargos' holding cost rate and value rate, then we separate them by category.

Category	Value rate EUR/m^3	Holding cost rate / year
Electric motor	8986.88	0.26
Speaker	4221.19	0.23
Toys	5684.81	0.27
Scanning Electron Microscope	62083.33	0.33
X-ray machine	18668.67	0.27
Wine	8376.30	0.31
Electric vehicle	2919.12	0.21

Table 22. 7 types selected categories' value rate and holding cost rate

6.3 Optimize total cost

After analyzing all parts of the cost, we would like to give a table to display the structure of the total cost.

Cost structure	Cost (EUR)
investment cost	2608.5(from table 16)
railway maintain cost	256.68(from table 17)
fuel cost	affected by speed
facility fees	affected by crane number
change driver cost	affected by driver number
holding cost	affected by holding cost rate, value rate and total time

Table 23. The cost structure for the total cost

And then, we would give a complete formula to show the total cost.

$$\text{Total cost} = 2608.5 + 256.68 + 18.599 * \text{speed} + 241.79 + (0.54 * \text{crane number} + 3.10 * \text{driver number}) * 6 + \text{holding cost rate} * \text{value rate} * \text{container volume} * \text{total time}/365 \quad \text{6-21}$$

From the formula, we can know that the variables in this formula are 1. Crane number 2. Driver number 3. Total time 4. Holding cost rate 5. Value rate.

Then, we can know that the total cost has a complicate relationship with the total time. When the crane number and the driver number increases, the cost of $(0.54 * \text{crane number} + 3.10 * \text{driver number}) * 6$ part increase with it. However, in the meanwhile, in case of the increased cranes and drivers, the total time will decrease which will let the holding cost part decrease.

In this reason, the first step we would like is to do a sensitivity analysis to see how much impact will the crane number and driver number change have. Hence, we use the seven kinds of cargos' data to get a sensitive analysis by using R program. Then, we put the results into tables as follow.

Crane number	Driver number	Holding cost+ yard operation cost
1	2	1698.39
1	3	1440.67
1	4	1321.11
1	5	1256.81
1	6	1220.14
2	2	1287.15
2	3	1029.42
2	4	909.86
2	5	845.56
2	6	808.89
3	2	1152.22
3	3	894.50
3	4	774.93
3	5	710.64
3	6	673.9713

Table 24. Electric motor sensitivity analysis (holding cost rate=0.26, value rate=8986.88)

Crane number	Driver number	Holding cost+ yard operation cost
1	2	729.33
1	3	633.12
1	4	594.31
1	5	578.47
1	6	574.10
2	2	560.35
2	3	464.14
2	4	425.33
2	5	409.48
2	6	405.12
3	2	506.18
3	3	409.97
3	4	371.16
3	5	355.31
3	6	350.95

Table 25. Speaker sensitivity analysis (holding cost rate=0.23, value rate=4221.19)

Crane number	Driver number	Holding cost+ yard operation cost
1	2	1129.55
1	3	966.63
1	4	894.47
1	5	858.61
1	6	840.91
2	2	860.51
2	3	697.59
2	4	625.43
2	5	589.58
2	6	571.87
3	2	772.99
3	3	610.07
3	4	537.91
3	5	502.06
3	6	484.36

Table 26. Toys sensitivity analysis (holding cost rate=0.27, value rate=5684.81)

Crane number	Driver number	Holding cost+ yard operation cost
1	2	14577.58
1	3	12173.33
1	4	10980.50
1	5	10272.24
1	6	9806.27
2	2	10946.54
2	3	8542.28
2	4	7349.45
2	5	6641.20
2	6	6175.22
3	2	9738.35
3	3	7334.09
3	4	6141.26
3	5	5433.01
3	6	4967.03

Table 27. Scanning Electron Microscope sensitivity analysis (holding cost rate=0.33, value rate=62083.33)

Crane number	Driver number	Holding cost+ yard operation cost
1	2	3617.01
1	3	3039.52
1	4	2760.07
1	5	2599.84
1	6	2499.22
2	2	2726.11
2	3	2148.62
2	4	1869.17
2	5	1708.94
2	6	1608.32
3	2	2431.30
3	3	1853.81
3	4	1574.36
3	5	1414.13
3	6	1313.51

Table 28. X-ray machine sensitivity analysis (holding cost rate=0.27, value rate=18668.67)

Crane number	Driver number	Holding cost+ yard operation cost
1	2	1882.93
1	3	1594.44
1	4	1459.50
1	5	1385.98
1	6	1343.16
2	2	1425.54
2	3	1137.06
2	4	1002.12
2	5	928.60
2	6	885.78
3	2	1275.24
3	3	986.76
3	4	851.82
3	5	778.30
3	6	735.48

Table 29. Wine sensitivity analysis (holding cost rate=0.31, value rate=8376.3)

Crane number	Driver number	Holding cost+ yard operation cost
1	2	475.41
1	3	421.52
1	4	403.87
1	5	400.72
1	6	404.82
2	2	369.91
2	3	316.01
2	4	298.37
2	5	295.22
2	6	299.32
3	2	336.90
3	3	283.01
3	4	265.36
3	5	262.21
3	6	266.31

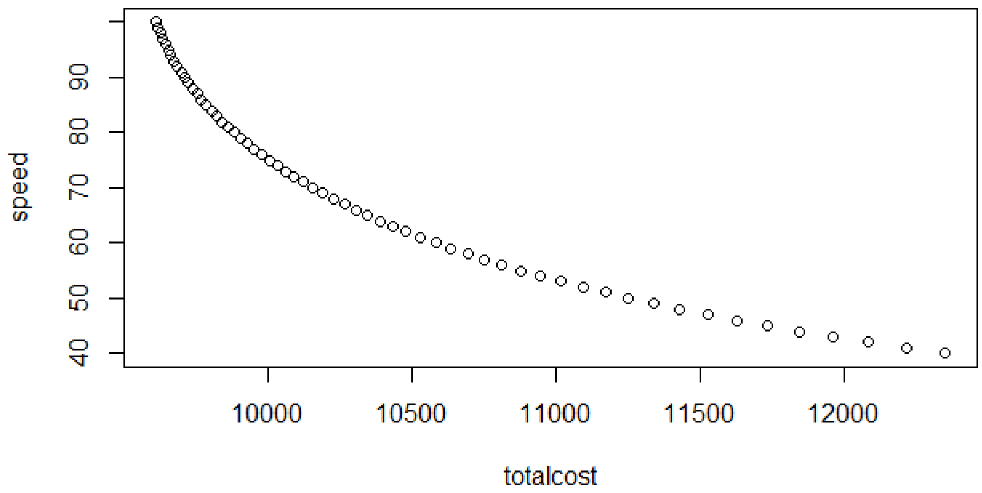
Table 30. Electric vehicle sensitivity analysis (holding cost rate=0.21, value rate=2919.12)

After getting the results, we can know what is the optimized crane number and the optimized driver number for each kinds of cargos. In this reason, we got

Category	Optimized crane number	Optimized driver number
Electric motor	3	6
Speaker	3	6
Toys	3	6
Scanning Electron Microscope	3	6
X-ray machine	3	6
Wine	3	6
Electric vehicle	3	5

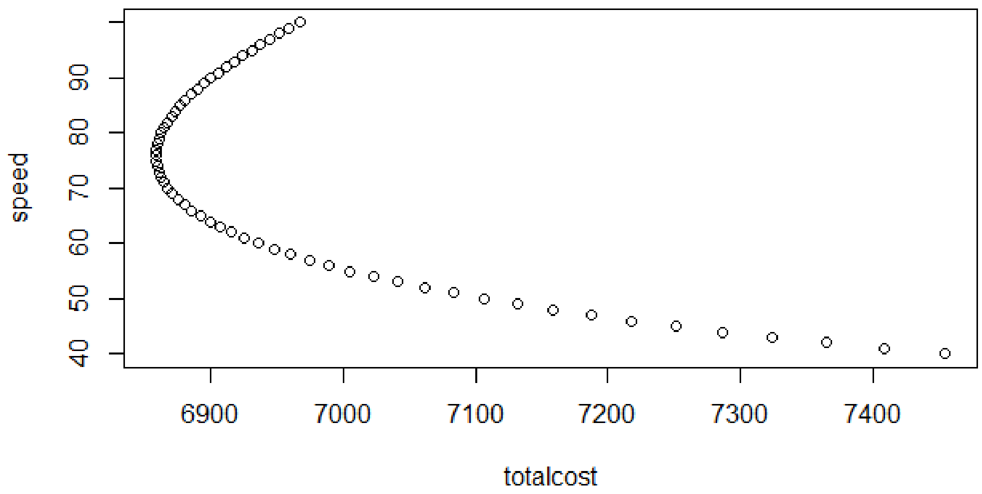
Table 31. Optimized crane number and optimized driver number for each cargo

Then, we can enter the second step of optimizing the total cost. In this step, we would like to get the optimized speed for the trains on this line. Then, we combine the optimized crane number and optimized driver number by using R program to get the result of the optimized speed and minimal total cost.



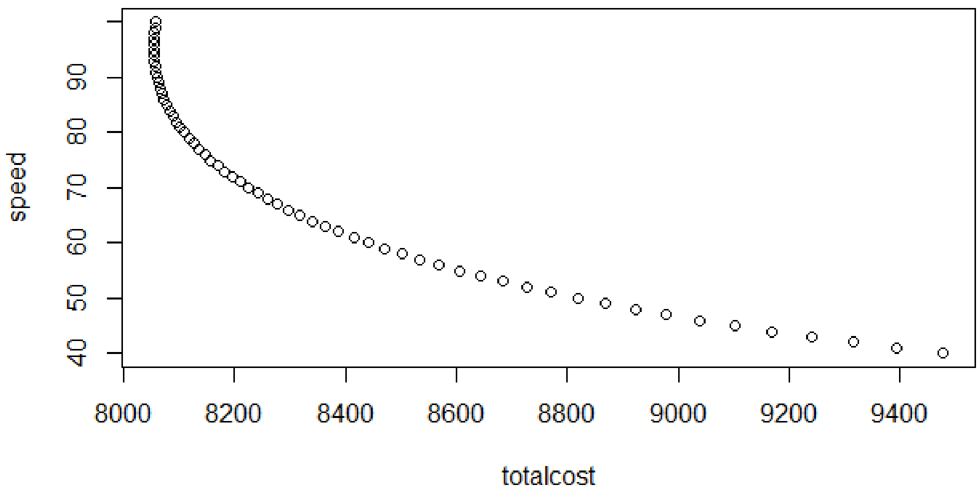
Unit: speed(km/h) total cost (EUR)

Figure 17. The relationship of train speed and total cost for electric motor



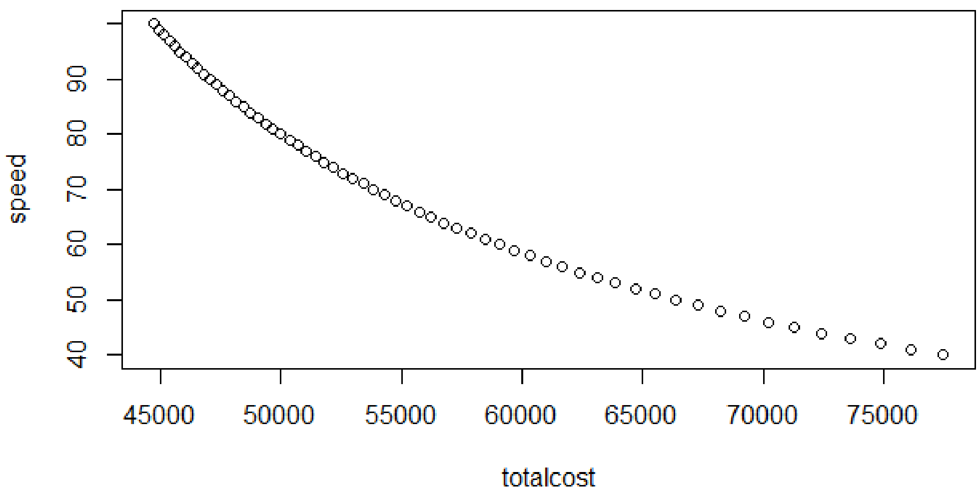
Unit: speed(km/h) total cost (EUR)

Figure 18. The relationship of train speed and total cost for speaker



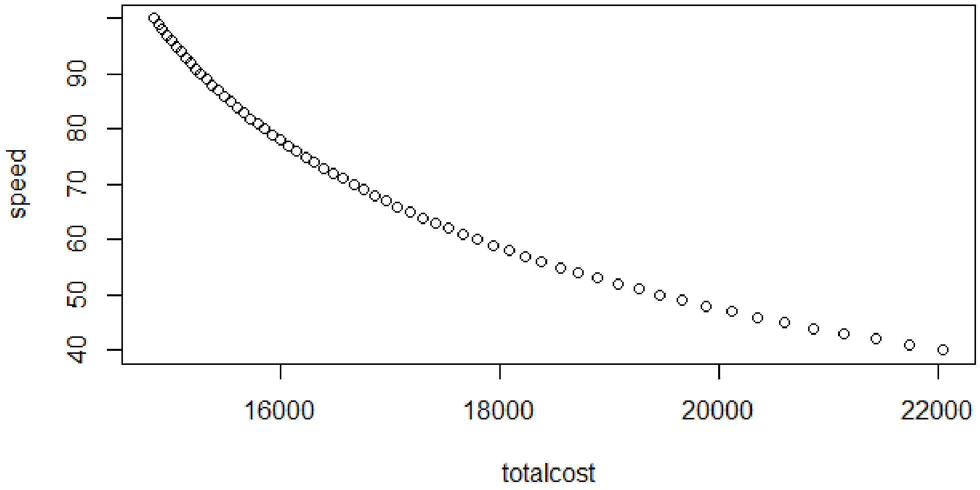
Unit: speed(km/h) total cost (EUR)

Figure 19. The relationship of train speed and total cost for toys



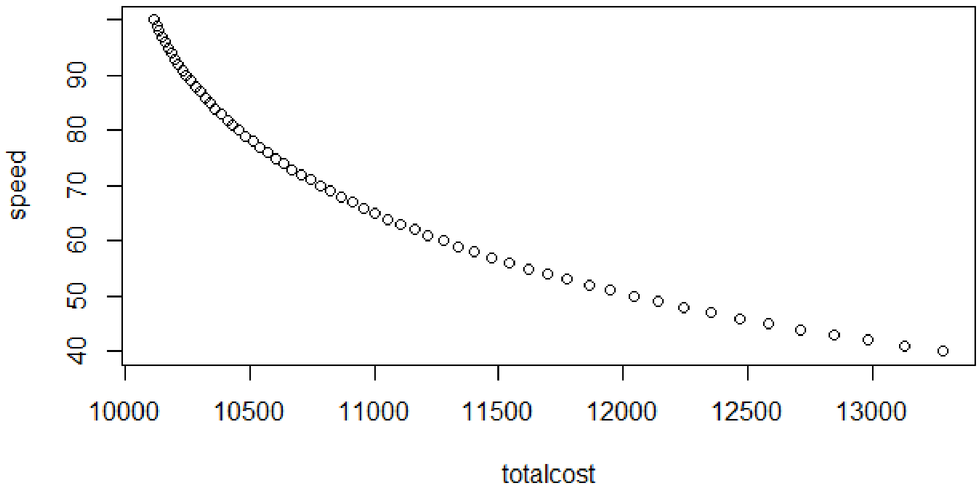
Unit: speed(km/h) total cost (EUR)

Figure 20. The relationship of train speed and total cost for scanning electron microscope



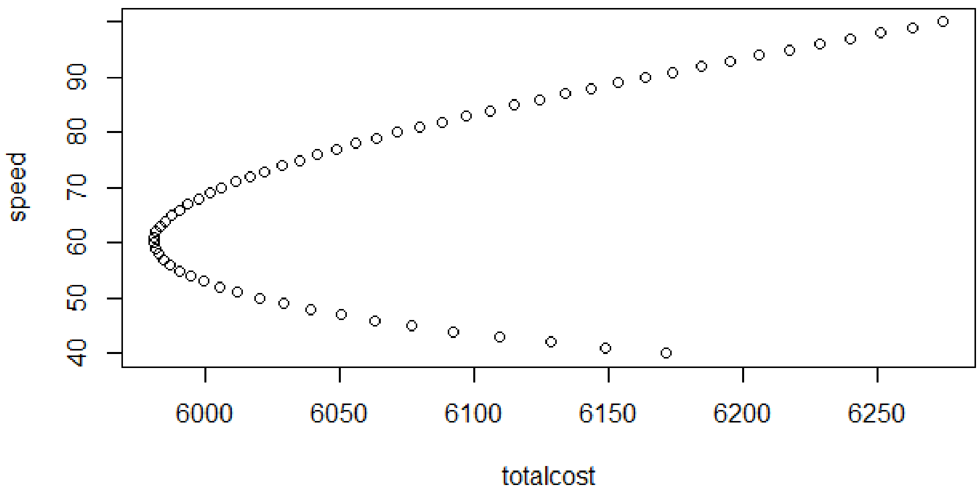
Unit: speed(km/h) total cost (EUR)

Figure 21. The relationship of train speed and total cost for X-ray machine



Unit: speed(km/h) total cost (EUR)

Figure 22. The relationship of train speed and total cost for wine



Unit: speed(km/h) total cost (EUR)

Figure 23. The relationship of train speed and total cost for electric vehicle

After getting the relationship figure of each kinds of cargos, we would like to give a table to show all the results for each kind of cargoes' optimized speed and minimal total cost.

Category	Optimized speed (km/h)	Minimal total cost (EUR)
Electric motor	100	9610.72
Speaker	76	6858.62
Toys	95	8055
Scanning Electron Microscope	100	44742.29
X-ray machine	100	14844.29
Wine	100	10114.08
Electric vehicle	60	5980.81

Table 32. Optimized speed and minimal total cost for the chosen goods

6.4 Conclusion

In this chapter, we found the general total time structure and after looking for relevant information, we give a total time model. Then, we also found the general total cost structure, and we created a total cost model.

After that, we get a results of optimized crane number, optimized driver number, and a optimized speed number for each kind of different cargos based on the returning trip cargo result of Chapter 5.

At last, we know that the container is loaded with various types of goods but the crane number and driver number are not easy to change. Therefore, based on the result from table 31 that every kinds of cargos' optimized crane number are 3 and the optimized driver number is 6 except the electric vehicle. In this reason, overall, we would like to say the optimized crane number is 3 and the optimized driver number is 6. And for the speed, it can run in an average speed as 90 km/h or it can change the speed according to the proportion of each cargo type which is more complicated for the schedule.

Charter 7 Conclusion

In the last chapter, we summarize our main findings. In addition, we would like to mention the limitations of our research.

7.1 Key conclusions

In this section, we highlight the main takeaways from this study.

In Chapter 1, we come up two research questions which are choosing the return cargos and reduce the total cost. Then, after searching relevant data and analysis these data, we got the answers to two questions in Chapters 5 and 6 respectively.

To answer the question of choosing the return cargos, in Chapter 5, after searching all the data of different kinds of cargoes that we needed, we analyzed these data and choose seven kinds of cargoes which is suitable for being the return trip cargoes in terms of the total cost. The 7 kinds of categories are electric equipment, transportation equipment, plastics and plastic articles, optical, technical, medical apparatus and food drink.

For this reason, Yuxinou company should cooperate with the cargo owner and motivate them to transport the suitable goods which we chose. In addition, in the optimized process of increasing return goods, Yuxinou company also need to maintain the volume of its going trips cargo volume.

As an unexpected harvest, in the process of finding the suitable return trip cargos, we also found that some kinds of transportation equipment are more suitable for Route 2 and Route 3 intermodal transportation.

To answer the question of reducing the total cost, in Chapter 6, we created a total cost model. After that, we optimize each varies step by step. In the end, we get the optimal value for each variable that the optimized crane number in the exchange railway stops is 3, the optimized driver should be prepared in each country is 6, and the optimized speed should be generally considered to be 90 km/h.

For this reason, Yuxinou company should promote cooperation with other countries. Moreover, Yuxinou company should persuade other countries treat problems according to long-term interests and to improve their facilities. Apart from the infrastructure investment, to reduce the time for dealing with documents and checking cargos also an efficient way to reduce total cost and it no need to expand investment.

All in all, the basic thing to optimize this entire international railway is to let all the countries reach consensus and all these countries should pay their efforts to Yuxinou international railway.

7.2 Limitations of the research and areas for further study

Although we strive to push the research method to the limit to obtain reliable and reasonable results, we still encounter some limitations in our research.

In general, there are still three aspects of the limitation.

1. The holding cost cannot be estimated very accurately.
2. The fuel cost for the train is very flexible, it is determined by many factors. For example, driver's driving habits, fuel price, terrain effect, etc.
3. The optimized speed will be deviations in reality that sometimes the train will be late or delayed or other situations.

We will try to reduce these limitations in future research.

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Appendices

Annex 1. Basic characteristic

Species	Category	Value /eur	Volume/m3	Rate=value/volume	Items number	Value for each container	Indicator
	Electrical Equipment						
Electric motor	Electric Motor IEC60034	249.95	0.96	260.36	89.00	22245.55	4.00
	Electric Motor 230 V/1100 W	99.00	0.01	9821.43	8564.00	847836.00	4.00
	Single Phase Electric Motor 2800tr/min	165.90	0.02	8152.33	4242.00	703747.80	4.00
Speaker	Logitech Z906 3D	199.00	0.07	2727.17	1183.00	235417.00	4.00
	Logitech Z506 5.1	81.85	0.02	3623.12	3821.00	312748.85	4.00
	EDIFIER S550	449.80	0.07	6313.27	1211.00	544707.80	4.00
	Transportation Equipment						
Vechiel	BMW 420d Gran Coupé M	49295.00	43.16	1142.05	2.00	98590.00	7.00
	BMW 420i Gran Coupe Sport Line Aut. Navi Business	44800.00	43.16	1037.91	2.00	89600.00	7.00
	BMW 220i Coupe M Sportpaket NAVI PDC SHZ	36980.00	43.16	856.74	2.00	73960.00	7.00
Electric vehicle	2014 BMW i3 Electric Car	34950.00	43.16	809.71	2.00	69900.00	3.00
	2014 BMW i8 Plug-In Hybrid Electric Car	126000.00	43.16	2919.13	2.00	252000.00	3.00
	2014 Smart Fortwo Electric Drive Coupe Electric Car	18910.00	43.16	438.10	2.00	37820.00	3.00
	Plastics and plastic articles						
Toys	DICKIE TOYS 203089025 Vehicle 1: 24 RC Cars 3 Turbo Mack Truck – 46 cm/18	49.98	0.02	2225.05	3843.00	192073.14	8.00
	LEGO Technic 42065 Radio Control Tracked Racer | Outdoor Toy	61.79	0.01	8695.51	12148.00	750624.92	8.00
	LEGO Technic 42064 Research Ship	85.00	0.01	6133.87	6229.00	529465.00	8.00
	Optical, technical, medical apparatus						
Scanning Electron Microscope	A147425 FEI Quanta FEG 250 SEM Scanning Electron Microscope Quanta 200 FEG Mk2	125625.00	1.50	83750.00	57.00	7160625.00	2.00
	Jeol JSM 6400 F	70000.00	1.50	46666.67	57.00	3990000.00	2.00
	Hitachi S-4700-II SEM with Oxford EDS	83750.00	1.50	55833.33	57.00	4773750.00	2.00
X-ray machine	Discovery XR 656	94637.50	5.04	18785.03	17.00	1608837.50	2.00
	Definium 8000 (w/table)	104687.50	5.04	20779.91	17.00	1779687.50	2.00
	Definium 5000	82828.75	5.04	16441.06	17.00	1408088.75	2.00
	Food and drink						
Wine	Feinkost Käfer Weinpaket Europa	26.94	0.00	5986.67	19183.00	516790.02	10.00
	Doppio Passo Salento IGT Primitivo 2017	36.24	0.00	8053.33	19183.00	695191.92	10.00
	Dürnberg Probierpaket 2017	49.90	0.00	11088.89	19183.00	957231.70	10.00

Annex 2. Holding cost

Species	Category	Holding cost rate	Railway transportation holding cos	Intermodal route 1	Intermodal route 2	Intermodal route 3	Intermodal route 4
	Electrical Equipment						
Electric motor	Electric Motor IEC60034	0.14	114.44	422.55	330.12	242.09	233.28
	Electric Motor 230 V/1100 W	0.27	8126.03	30003.82	23440.49	17189.69	16564.61
	Single Phase Electric Motor 2800tr/min	0.26	6533.09	24122.19	18845.46	13820.01	13317.46
Speaker	Logitech Z906 3D	0.22	1811.45	6688.44	5225.35	3831.92	3692.58
	Logitech Z506 5.1	0.23	2526.57	9328.86	7288.17	5344.66	5150.31
	EDIFIER S550	0.25	4839.89	17870.35	13961.21	10238.22	9865.92
	Transportation Equipment						
Vechiel	BMW 420d Gran Coupé M	0.20	719.26	2655.72	2074.78	1521.51	1466.18
	BMW 420i Gran Coupe Sport Line Aut. Navi Business	0.20	643.05	2374.33	1854.94	1360.29	1310.83
	BMW 220i Coupe M Sportpaket NAVI PDC SHZ	0.19	513.63	1896.49	1481.63	1086.53	1047.02
Electric vehicle	2014 BMW i3 Electric Car	0.17	415.78	1535.17	1199.35	879.52	847.54
	2014 BMW i8 Plug-In Hybrid Electric Car	0.21	1867.40	6895.03	5386.74	3950.28	3806.63
	2014 Smart Fortwo Electric Drive Coupe Electric Car	0.15	202.48	747.62	584.08	428.32	412.75
	Plastics and plastic articles						
Toys	DICKIE TOYS 203089025 Vehicle 1: 24 RC Cars 3 Turbo Mack Truck – 46 cm/18	0.23	1607.33	5934.76	4636.53	3400.12	3276.48
	LEGO Technic 42065 Radio Control Tracked Racer | Outdoor Toy	0.30	7934.56	29296.83	22888.15	16784.64	16174.29
	LEGO Technic 42064 Research Ship	0.28	5271.81	19465.14	15207.14	11151.90	10746.38
	Optical, technical, medical apparatus						
Scanning Electr	A147425 FEI Quanta FEG 250 SEM Scanning Electron Microscope Quanta 200 FEG Mk2	0.35	87995.83	324907.67	253834.12	186145.02	179376.11
	Jeol JSM 6400 F	0.31	44355.98	163775.94	127949.95	93829.96	90417.97
	Hitachi S-4700-II SEM with Oxford EDS	0.32	54725.38	202062.94	157861.67	115765.22	111555.58
X-ray machine	Discovery XR 656	0.27	15302.24	56500.59	44141.09	32370.13	31193.03
	Definium 8000 (w/table)	0.27	17222.63	63591.24	49680.66	36432.48	35107.66
	Definium 5000	0.26	13090.37	48333.68	37760.69	27691.17	26684.22
	Food and drink						
Wine	Feinkost Käfer Weinpaket Europa	0.29	5324.01	19657.87	15357.71	11262.32	10852.78
	Doppio Passo Salento IGT Primitivo 2017	0.30	7535.36	27822.86	21736.61	15940.18	15360.54
	Dürnberg Probierpaket 2017	0.32	10960.39	40469.12	31616.50	23185.43	22342.33

Annex 3. Total cost

Category	Railway transportation	Route 1	Route 2	Route 3	Route 4	Air transportat
Electrical Equipment						
Electric Motor IEC60034	5034.44	2681.55	3287.65	3389.09	3580.28	134892.41
Electric Motor 230 V/1100 W	13046.03	32262.82	26398.02	20336.69	19911.61	136741.24
Single Phase Electric Motor 2800tr/min	11453.09	26381.19	21802.99	16967.01	16664.46	136373.64
Logitech Z906 3D	6731.45	8947.44	8182.88	6978.92	7039.58	135284.03
Logitech Z506 5.1	7446.57	11587.86	10245.70	8491.66	8497.31	135449.05
EDIFIER S550	9759.89	20129.35	16918.74	13385.22	13212.92	135982.90
Transportation Equipment						
BMW 420d Gran Coupé M	5639.26	4914.72	5032.31	4668.51	4813.18	135031.98
BMW 420i Gran Coupe Sport Line Aut. Navi Business	5563.05	4633.33	4812.47	4507.29	4657.83	135014.40
BMW 220i Coupe M Sportpaket NAVI PDC SHZ	5433.63	4155.49	4439.16	4233.53	4394.02	134984.53
2014 BMW i3 Electric Car	5335.78	3794.17	4156.88	4026.52	4194.54	134961.95
2014 BMW i8 Plug-In Hybrid Electric Car	6787.40	9154.03	8344.27	7097.28	7153.63	135296.94
2014 Smart Fortwo Electric Drive Coupe Electric Car	5122.48	3006.62	3541.61	3575.32	3759.75	134912.73
Plastics and plastic articles						
DICKIE TOYS 203089025 Vehicle 1: 24 RC Cars 3 Turbo Mack Truck – 46 cm/18	6527.33	8193.76	7594.06	6547.12	6623.48	135236.92
LEGO Technic 42065 Radio Control Tracked Racer | Outdoor Toy	12854.56	31555.83	25845.68	19931.64	19521.29	136697.05
LEGO Technic 42064 Research Ship	10191.81	21724.14	18164.67	14298.90	14093.38	136082.57
Optical, technical, medical apparatus						
A147425 FEI Quanta FEG 250 SEM Scanning Electron Microscope Quanta 200 FEG Mk2	92915.83	327166.67	256791.65	189292.02	182723.11	155172.73
Jeol JSM 6400 F	49275.98	166034.94	130907.48	96976.96	93764.97	145102.00
Hitachi S-4700-II SEM with Oxford EDS	59645.38	204321.94	160819.20	118912.22	114902.58	147494.93
Discovery XR 656	20222.24	58759.59	47098.62	35517.13	34540.03	138397.29
Definium 8000 (w/table)	22142.63	65850.24	52638.19	39579.48	38454.66	138840.45
Definium 5000	18010.37	50592.68	40718.22	30838.17	30031.22	137886.85
Food and drink						
Feinkost Käfer Weinpaket Europa	10244.01	21916.87	18315.24	14409.32	14199.78	136094.62
Doppio Passo Salento IGT Primitivo 2017	12455.36	30081.86	24694.14	19087.18	18707.54	136604.93
Dürnberg Probierpaket 2017	15880.39	42728.12	34574.03	26332.43	25689.33	137395.32

Annex 4. Original total time in this way

Stops	Distance (km)	Speed (km/h)	Traveling time (hours)	Rail exchange time	Customs transfer time (hours)	Change rail head, driver (hours)
China						
Wulumuqi						
Alashankou(Customs transfer/ rail exchange)	3812	40	95.3			5.575
Kazakhstan						
Dostyk (rail exchange)	12	40	0.3	4	38.925	5.575
Russia						
Iletsk(customs transfer)	3412	40	85.3			5.575
Krasnoye(customs transfer)	1497	40	37.425			
Belarus						
Brest(customs transfer)	587	40	14.675		21.725	5.575
Poland						
Malaszewioze(rail exchange)	0	40	0	2		5.575
Kenuo Izzie		40	0			
Frankfurt		40	0			
Duisburg	1906	40	47.65			5.575
Sum	11226		280.65	6	60.65	33.45
source:http://www.yuxinoulogistics.com/website/h-English/en-home.html#						
source:http://m.dooland.com/index.php?s=/article/id/547577/from/faxian.html						
source:https://www.jinchutou.com/p-40069410.html						

Annex 5. Early internal combustion engine energy consumption

DF4	Number of handles	Distance										
		11226.00	11226.00	11226.00	11226.00	11226.00	11226.00	11226.00	11226.00	11226.00	11226.00	11226.00
Speed(km/h)		10.00	16.50	20.00	30.00	40.00	50.00	60.00	70.00	80.00	90.00	100.00
	8.00	3.00	3.00	3.00	3.00	3.00	3.00	2.98	2.95	2.90	2.85	2.80
	12.00	5.23	5.23	5.23	5.23	5.27	5.28	5.27	5.18	5.08	4.98	4.70
Fuel consumption(kg/min)	15.00	7.29	7.29	7.29	7.29	7.29	7.28	7.23	7.14	6.80	6.40	5.98
	16.00	8.15	8.24	8.28	8.33	8.34	8.33	8.24	7.97	7.55	7.08	6.52
		202068.00	122465.45	101034.00	67356.00	50517.00	40413.60	33453.48	28385.74	24416.55	21329.40	18859.68
total fuel consumption		352271.88	213498.11	176135.94	117423.96	88741.53	71127.94	59161.02	49843.44	42771.06	37270.32	31657.32
		491025.24	297591.05	245512.62	163675.08	122756.31	98070.34	81163.98	68703.12	57252.60	47897.60	40278.89
		548951.40	336371.78	278853.84	187025.16	140437.26	112215.10	92502.24	76689.62	63567.23	52986.72	43916.11
		4699.26	2848.03	2349.63	1566.42	1174.81	939.85	777.99	660.13	567.83	496.03	438.60
per container		8192.37	4965.07	4096.18	2730.79	2063.76	1654.14	1375.84	1159.15	994.68	866.75	736.22
		11419.19	6920.72	5709.60	3806.40	2854.80	2280.71	1887.53	1597.75	1331.46	1113.90	936.72
		12766.31	7822.60	6484.97	4349.42	3265.98	2609.65	2151.21	1783.48	1478.31	1232.25	1021.30
per container fuel cost		2613.96	1584.22	1306.98	871.32	653.49	522.79	432.76	367.20	315.85	275.92	243.97
		4557.01	2761.82	2278.50	1519.00	1147.96	920.11	765.31	644.78	553.29	482.13	409.52
		6351.93	3849.65	3175.96	2117.31	1587.98	1268.64	1049.94	888.75	740.62	619.61	521.05
		7101.26	4351.32	3607.27	2419.37	1816.70	1451.62	1196.61	992.06	822.31	685.44	568.10
Basic statement	P(t)	min speed(kr	Max F (kN)	diameter Dj(mm)	Starting force F	Starting resistanc	Gear ratio	Max speed (km/h)	L	fuel cost eur/l		
	135	20	302.1	1013	401.7	5	4.5	100	21.1	0.55625		
source: http://www.doc88.com/p-9078751868113.html												
source:https://www.baidu.com/link?url=JG85F8CmZgP0X2RpEyFlVMrW-zaJCT7MjtR0v0Ep_n3no6HtxOIug0_-GGnyxuKurp20Vxo38EB1nFx1g-Xyut1hfN3dwSlIp6bfvGqdg0_&wd=&eqid=f8d65ae500037840000000065b60b422												