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Master's Program in System Science Thesis

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Railway: Solution Selection and Risk Analysis

Prepared by Fang Qiu

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System Science Thesis



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Abstract

The Beijing-Shanghai high-speed railway is a very big and important project in China. Whether it can succeed or not will have a direct impact on the construction of future high-speed railway network system in China and even affect China's economic development. With regard to this well-known project, there are many disputes and different opinions. In this thesis, an analysis of some main possible solutions and a deep research on the recommended solution were provided through using system engineering theory and Monte Carlo simulation.

First the thesis introduces the background and current status of the Beijing-Shanghai railway and indicates the need for improving its traffic capacity. Subsequently, the advantages and disadvantages of four popular possible methods of upgrading the existing railway system and building a new railway system are presented one by one: electrification, tilt train technology, high-speed wheel-on-track (HSWOT) technology and Maglev technology. Analysis of the data generated as part of this thesis research has resulted in the conclusion that HSWOT technology should be applied to the Beijing-Shanghai corridor.

Preliminary cost estimation for the new Beijing-Shanghai high-speed railway is introduced based on HSWOT technology. Ridership forecast, fare estimation, fund raising, and some other financial aspects are discussed in detail. A Monte Carlo model and a Stella model were built to simulate the project's revenue and calculate its financial indexes. Economic analysis included uncertainty analysis, social, environmental, and economic benefit analysis. Various kinds of risks in this project are pointed out, including policy risk, project management risk, technical risk, capital risk and completion time risk.

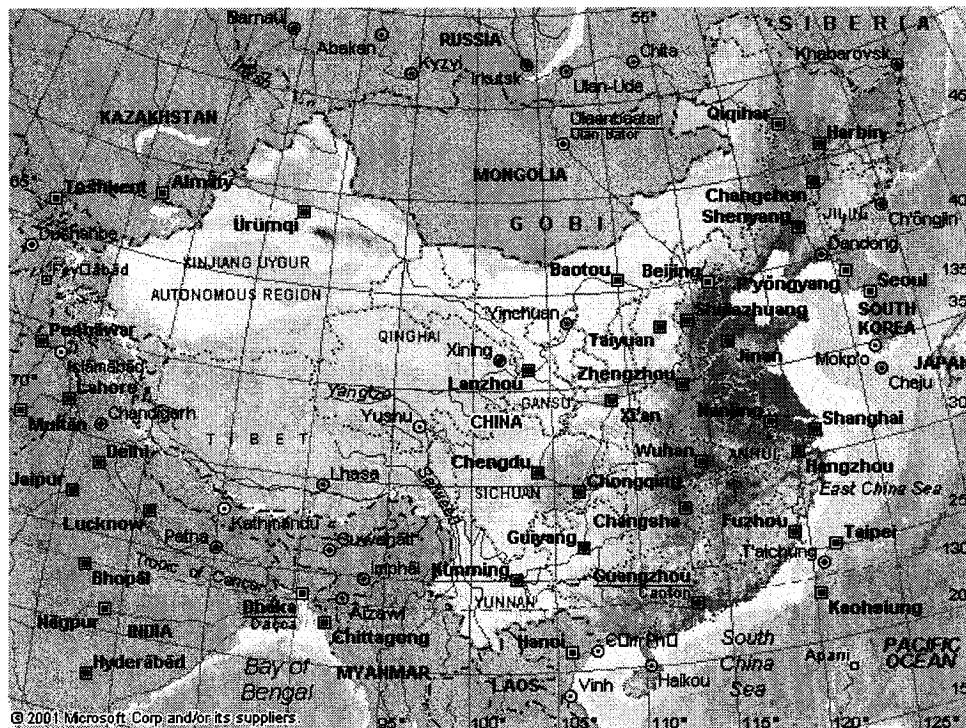
The thesis concludes that HSWOT technology is the best choice for the new Beijing-Shanghai railway, and it is also financially feasible. In addition, some suggestions are provided in relation to the effective implementation of the Beijing-Shanghai high-speed railway.

1.0 Introduction

1.1 Problem definition

The fast-paced development of China's economy drives quick growth of China's GDP on the one hand, but on the other hand it causes not only shortness of resource material such as oil, coal, electricity and mineral etc. but also serious insufficiency of railway traffic capacity. The economic zone between Beijing and Shanghai includes three economic centers: the capital region, the Bohai Circle and the Yangtze River delta. A lot of large and medium cities are distributed along the Beijing-Shanghai railway. This Beijing-Shanghai economic zone is an area of the fastest growing economy, the most advanced manufacturing industry and the highest standards of living in China.

Figure 1-1: map of China (Expedia, 2000)



In this area, since the pace of economic growth is much higher than the average level of the whole country, the requirement of transport is also much higher than the

average level of the whole country. The seriously insufficient traffic capacity of the Beijing-Shanghai railway has appeared gradually and become an important bottleneck that preventing China from further economy development.

How to basically resolve the insufficient traffic capacity of the Beijing-Shanghai railway in order to accelerate national economic development and meet the needs of people's standards of living is becoming an important issue in China. Since enormous investment, national economic development and people's standards of living are involved in this kind of project, the Chinese government, Chinese people are all concerned about it. (Zhong, 2004) Under this situation, various solutions, assumptions, comments and debates have appeared. There are many viewpoints about these issues. Different people consider and view these issues from different angles. Having been argued for more than 10 years, these discussions focus on four modes to improve traffic capacity: electrification, tilt trains, new HSR and magnetic levitation (Maglev) systems.

1.2 Study objective

The Chinese government has started doing research and investigations since 1990's, and there is no final resolution on these issues so far. It also indicates that this project is very complicated and inconsistent. I would like to make an input into this big and intense debate about the Beijing-Shanghai high-speed railway project through the analysis process underlying this thesis. Specifically through use of solution selection and mathematic model simulation, this thesis will address key issues associated with technology selection and the financial situation associated with this project.

The goal of this research is to use system engineering theory, economic analysis and mathematical modeling to analyze the Beijing-Shanghai high-speed railway project. I hope that my thesis could provide decision-makers of this project with objective, valuable and instructive suggestions and references. In this research, my study objectives are

- To utilize system-engineering theory to systematically analyze the feasibility of Beijing-Shanghai high-speed railway.
- To explore relative advantages and disadvantages of the different types of high speed railway in the Beijing-Shanghai corridor
- To analyze the profitability of this project by using quantitative and qualitative methods
- To demonstrate the financial results through the use of two specific computer modeling processes: Monte Carlo simulation and Stella system modeling process
- To indicate some potential risks in Beijing-Shanghai high-speed railway.

1.3 Methodology

Since this research is about high-speed railways, an engineering project, Hall's system engineering theory was applied to the study process. This research was organized by following the seven steps of Hall's system engineering model at the programming plan stage: problem definition, value system, options, option analysis, optimization, decision making and plan for next step.

In order to better understand the project, a review of relevant literature is necessary. The literature reviewed as part of this study includes traffic condition and current research status of the project and high-speed railway technology. The thesis outlines data about national and regional passenger traffic, passenger kilometers, passenger traffic density, and cargo turnover to demonstrate the traffic situation of the Beijing-Shanghai railway. The state of art high-speed railway technologies including electrified trains, tilt trains, high-speed wheel-on-track trains and maglev trains are introduced, as well as their advantages and disadvantages.

In the financial analysis, a mathematical model was built to help analyze the cost/benefit. Since costs are statistical in nature, using a statistical method to handle the associated uncertainties is most appropriate. The Monte Carlo simulation method was

chosen because of its statistical nature and its powerful and flexible way of performing quantitative uncertainty analysis.

Monte Carlo modeling includes a series of techniques to mathematically describe the impact of risk and uncertainty on a problem. (Vose, 1996) It allows all uncertain components of a mathematical model of the problem being assigned in advance. Then, through random sampling of each probability distribution within the model, hundreds or thousands of iterations are produced. “Each uncertain parameter within the model is represented by a probability distribution. The shape and size of these distributions defines the range of values that the parameters may take and their relative probabilities.” (Molak, 1997) Because the probability distribution of all uncertainties is sampled in a way that reproduce the distribution’s shape, the distribution of the values calculated for the model outcome can reflect the probability distribution of all potential outcomes that could occur under these uncertainties.

In addition, the Stella computer modeling process was used to demonstrate the dynamics of the Beijing-Shanghai financial realities. Stella is a powerful tool for constructing mathematical models of systems. It provides an object-oriented programming environment, and is easy to use. Stella has been used in a wide variety of fields.

Stella uses simple, icon-based building blocks. Models can be easily built by connecting icons together in different ways into a model framework. The software automatically creates the equations based on input. These equations can show the mathematical details of the model. After constructing a model, simulations can be run by changing the input variables and following the response of a model on a graph or in a table of output variables or results. Since the Stella model allows for the modification of various parameters in a simulated modeling exercise, it allows the study to carry out a number of “if-then” calculations, resulting in stronger conclusions based on the modeled output.

2.0 Background

2.1 Current research status the Beijing-Shanghai railway

As early as 1993, the Chinese Ministry of Railways had begun to discuss the feasibility of the construction of the Beijing-Shanghai high-speed railway and it proposed the project in 1997 (Hu, 2002), and later the project was listed in China's Tenth Five-Year Plan (2001-05). (Xinhuanet, 2001) Because of the enormous investment and the heated debate about what kind of technology it should use, the decision to implement the project has not been made.

There are four main proposals about this project. Updating the current line to electrification railway or reconstructing it to suit tilt trains are two of them. Since many key routes are now approaching their maximum capacity (see utilization data, Table 2-2 and 2-3), and building another railway could be a way of resolving this. Because of the low speed, it is likely that a conventional railway system cannot attract enough passengers from highway and air systems to make it profitable. Building a new high-speed railway system with the wheel-on-track technology (HSWOT) or the Maglev technology are the other two proposals.

Among those proposals, the argument about whether to adopt the Maglev technology or the wheel-on-track technology is the most contentious. Multinational companies from German, France and Japan are competing for bidding on the railway and energetically promoting their technology, known as Transrapid, Train à Grande Vitesse (TGV) and Shinkansen respectively. According to the published data on people's daily newspaper, the 1,300-kilometres (800 miles) Beijing-Shanghai high-speed railway will cost 400 billion Yuan (US\$48 billion) or 300 million per km (US\$36 million per miles) by adopting the Maglev technology and 130 billion Yuan (US\$16 billion) or 100 million

Yuan per km (US\$19 million per miles) by adopting the wheel-on-track technology. (Railway Industry, 2001) The new 1300-km-long Beijing-Shanghai high-speed railway will be used as a dedicated passenger railway. “The projected maglev running time was three hours at a top speed of 450 km/h (280 mph). For conventional rail, the time need was about four hours at a top speed of 350 km/h (220 mph).” (Murakami, 2003) That means, when the high-speed railway has been completed, people can travel from the Chinese capital of Beijing to the major coastal commercial center Shanghai within four hours by new HSR trains or three hours by Maglev. This is competitive to the airtime of approximately two hours, not including travel to and from the airport. This means that both of the high-speed rail solutions represent viable alternatives to travel by air and allow for much expanded travel volumes between the two cities.

The majority of the current research on the Beijing-Shanghai high-speed railway is still focused on technology selection. That is, which technology should be applied to the Beijing-Shanghai HSR: electrification, tilt trains, new HSR, or Maglev? This thesis will build on this technology-focused research and model the financial cost/benefits of the project using statistical and system-modeling processes.

2.2 Beijing-Shanghai corridor overview

The current Beijing-Shanghai railway extends 1,463 kilometers (907 miles), which starts at Beijing and ends at Shanghai passing through the four provinces of Hebei, Shandong, Anhui and Jiangsu. The Beijing-Tianjing part, Shanghai-Nanjing part and Tianjing-Pudong part of this line were built in 1881, 1905 and 1908 respectively (China Encyclopedia, 2004) This more than one hundred-year old line has been reconstructed many times and now becomes one of the best equipped railways in China with double tracks, diesel engine traction, and automatic block signal. (Science Museum of China, 2004) The highest running speed of passenger train is at 160km/h and the biggest traction quality of cargo transport is at 4500 tons (4500t). (Chen, 2004)

2.2.1 Current situation of the Beijing-Shanghai railway

The Beijing-Shanghai railway connects two economic areas, the capital area and the Yangtze Delta. It goes through four provinces and three cities directly under the central government's jurisdiction. This economic zone plays a very important role in the whole country's economy, with 26% population of the whole country producing 45% of the whole country's industrial and agriculture products. (Han, 2003) In 2002, the Beijing-Shanghai railway, which occupies only 2% of the whole country's business railway, provided 10.2% of passenger kilometers and 7.6% of freight turnover. (Li, 2004) It is the busiest artery in China, even in the world.

Figure 2-1: Beijing-Shanghai high-speed route (Railway Industry, 2001)



2.2.1.1 Passenger traffic

Transport capacity of the Beijing-Shanghai railway is insufficient and short by about 50% of the required capacity. (Li, 2004) The Beijing-Shanghai railway dispatched 92.6 million passengers and 55.38 million tons of cargo in 2002, compared with 92.3 million passengers and 35.9 million tons of cargo in 1990. The number shows that the volume of dispatched passengers was basically even, but the volume of dispatched cargo increased by 3.7% annually. (Statistics China, 2002) Since 1990s, the volume of dispatched passengers of the four provinces and three cities along the Beijing-Shanghai segment via all transport modes has increased by 8.2% annually. (Statistics China, 2002) However, the volume of dispatched passenger via the Beijing-Shanghai railway has stopped increasing from 1990 to 2002. The main causes are that the railway company has focused on longer distance passenger travel, expanding the number of trains dedicated to this type of service. This has reduced the number of trains available for shorter trips and caused passengers to turn to bus and other means of travel as road infrastructure also increased in quality and availability.

Table2-1: passenger kilometer and cargo turnover of the Beijing-Shanghai Railway (Statistics China, 1990, 2002)

		Passengers kilometer (million people-kilometers)			Cargo turnover (million ton-kilometer)		
		1990	2002	Annual rate of increase	1990	2002	Annual rate of increase
Beijing	Tianjin	1824.84	1980.88	0.69%	9543.75	11904.6	1.86%
Tianjin	Dezhou	3073.78	3796.28	1.77%	7119.09	9099.67	2.07%
Dezhou	Jinan	1388.27	1920.27	2.74%	6387.93	9103.07	3.00%
Jinan	Xuzhou	3643.60	5278.37	3.14%	15477.84	17846.94	1.19%
Xuzhou	Banbu	2177.34	3168.00	3.17%	11470.07	12754.83	0.89%
Banbu	Nanjing	2473.18	4122.09	4.35%	11896.17	14403.98	1.61%
Nanjing	Changzhou	2210.35	3363.61	3.56%	6595.85	8549.11	2.19%
Changzhou	Shanghai	2806.16	4085.90	3.18%	5618.31	5611.66	-0.01%
Total		19597.52	27715.4	2.93%	74109.01	89273.86	1.56%

From above passenger kilometers and cargo turnover of the Beijing-Shanghai railway segment (table 2-1), we can see that passenger kilometers had continually increased since 1990 and it reached 27.7 billion in 2002 and increased by 2.93% annually; all cargo turnover kept increasing except for the segment between Shanghai and Changzhou, and it reached 89.3 billion tons-kilometer (cargo turnover) in 2002 and increased by 1.56% annually. The Beijing-Shanghai railway is the main artery of China's railway network, which links 25 railway arteries and branches, and is also responsible for a large volume of cross line traffic. Because of the nearly unchanged dispatched passenger volume via the Beijing-Shanghai railway, we can concluded that the continuous increase in passenger kilometer is the result of a continuous increase in the length of passenger trip (from 212km in 1990 to 300km in 2002) and the volume of cross line passengers. (Refer to Table 2-1 for ridership and cargo volume data)

Table 2-2: passenger and cargo train set number and transit capacity from 1990 (China Statistics transportation year book, 1990, 1995, 2000, 2002)

Segment	Year	Passenger car	Cargo car	Post car	Total	Utilization percentage*
Beijing-Tianjing	1990	34	75		109	77.50%
	1995	36	70		106	77.39%
	2000	47	63		110	77.35%
	2002	50	66	1	117	82.91%
Tiangjin-Dezhou	1990	35	44		79	72.62%
	1995	37	44		81	75.35%
	2000	44	41	1	86	73.28%
	2002	52	37	2	91	81.32%
Dezhou-Jinan	1990	29	66		95	76.94%
	1995	30	70		100	80.57%
	2000	36	62	1	99	74.17%
	2002	41	60	4	105	80.62%
Jinan-Xuzhou	1990	32	72		104	84.43%
	1995	33	72		105	85.79%

	2000	42	67	1	110	83.80%
	2002	49	65	4	118	92.64%
Xuzhou- Bangbu	1990	37	77		114	94.07%
	1995	37	77		114	94.07%
	2000	42	71	3	116	86.78%
	2002	49	69	4	122	94.62%
Bangbu- Nangjing	1990	30	81		111	86.81%
	1995	37	68		105	88.96%
	2000	49	64	3	116	91.65%
	2002	54	59	4	117	95.62%
Nangjing- Shanghai	1990	43	59		102	92.03%
	1995	44	63	3	110	97.36%
	2000	54	52	4	110	92.14%
	2002	59	54	4	117	99.09%

(Ministry of railway, 1984)

* Please see Appendix 2: "Carrying-Capacity Utilization" Calculation Formula for explanation of the calculation of utilization percentages.

Based on the number of passenger and cargo trains starting from 1990, we can see that the utilization of carrying capacity for the whole line had reached 80%, and carrying capacity utilization for some parts of the line nearly got 100% and was almost close to saturation. The demands for passenger and freight transport of the Beijing-Shanghai railway are always high and the traffic capacity is always in short supply. In terms of passenger transport, there are 5 pairs of trains between Beijing and Shanghai, 1 pair of train between Beijing and Nanjing, and Changzhou, and Suzhou, and Hangzhou respectively and 5 pairs of trains between Nanjing and Shanghai. (China transportation yearbook, 2002) The number of passenger trains cannot meet the passenger transport requirement. Because of the insufficiency of the transport capacity, the annual passenger volume carried by each train continuously increases, and it becomes very hard to improve the train marshalling. This has led to reduction in passenger comfort. For example, because of the insufficiency of carrying capacity, many temporary passenger trains that are added in rush season have to be arranged to depart after 12:00 o'clock at night and

arrive before 5:00 o'clock in the morning. The problem of seasonal transport insufficiency has also seriously troubled the railway department. During the annual 120 days with high density of passenger flow such as spring festival, summer holiday, May 1st Labor Day and Oct 1st National day, transport capacity is in a state of emergency at all sides. People have difficulties in buying tickets and riding trains, and the trains are much congested. For political and social reasons, the ministry of railway during this period has to focus on passenger transport, so freight transport is affected accordingly.

2.2.1.2 Freight traffic

With continuously rapid growth of the national economy, the demand for freight transport by railway is increasing. (See Table 2-1) The volume of the request for cargo cars keeps high, but railway can only meet 60% of the demands. (China Transportation Statistics Yearbook, 2002) In terms of freight transport, the Beijing-Shanghai railway is not capable of meeting the request for car loadings from the north that is the main resource area of freight within recent years, and the rate of meeting the request for car loadings is always low. For example, the load ratio for freight cars requested from eight northern Bureaus such as Harbin, Shengyan and Beijing etc. to Shanghai was 55.7% in 1998 and decreased to 36% in 2002. (China transport yearbook, 2002)

Table 2-3 national car-loading request and car-loading request to Shanghai (China transport yearbook, 2002)

	The whole country			Eight northern bureaus to Shanghai		
	Car loading request	Actual car loadings	Car loading percentage	Car loading request	Actual car loadings	Car loading percentage
1998	94371	72429	76.75%	7092	3948	55.67%
1999	103291	74038	71.68%	7079	4225	59.68%
2000	155522	77645	49.93%	13689	4447	32.49%
2001	160615	83693	52.11%	14359	4819	33.56%
2002	161112	87457	54.28%	14824	5334	35.98%

The Chinese Ministry of railways is in a dilemma whether to ensure the transportation of coal and other important goods or take benefit into account to carry some goods with high traffic charge rate and high profit. Under the situation of heavy load, Chinese Ministry of Railways has decided to guarantee transportation of some important goods such as coal, food supplies, oil and fertilizer etc., with income being affected accordingly.

2.2.1.3 Conflict between passenger and freight transports

As talked above, the utilization rate of the Beijing-Shanghai railway transport capacity is close to 100%. Since passenger and freight trains share the same railway, the conflict between passenger transport and freight transport is apparent.

During the annual spring festival (January-February), freight transport is affected severely. Every year in order to deal with the extraordinary increase of the passenger flow during the spring and summer seasons, the Chinese Ministry of Railways has to take some abnormal actions such as reducing freight transport to ensure passenger transport capacity during the spring season. This results in many freight trains being scheduled to stop running so that temporary passenger trains can be added. When one temporary passenger train is added, about 2 or 3 freight trains have to be canceled. This not only causes operating income loss for the railway department but also brings a series of chain reactions to production enterprises.

These kinds of actions often have a negative impact on the normal operation of some business enterprises since they reduce the delivery of necessary business supplies during these periods. For example, because freight transport needs to be reduced during the 40 days of spring festival, in order to guarantee having enough coal in winter, some enterprises have to reserve coal in advance. Enterprises have to pay extra 200 RMB to reserve one more ton of coal, which means that they need to pay 2 million RMB if they reserve additional 10 thousand tons of coal in advance. (Liu, 2004) This practice is widespread along the Beijing-Shanghai corridor.

2.2.2 Future traffic demand of the Beijing-Shanghai railway

Ground transport is the foundation of operation and development for modern social economy. There is a close relationship between the demands for passenger traffic and the national economic development. The capacity and expanding level of traffic transport industry has a direct impact on economic development. The experience from Korea and Singapore has demonstrated that if an economy can keep growing, when per capita GDP increases from US \$1000 to US \$4000, the economy will be in a rapid growth period and the demand for passenger traffic will grow significantly. (Lin, 2004) Following this pattern, when China's economy keeps growing continuously, rapidly and healthily, the demands for passenger traffic will keep pace with the economic development and increase rapidly. Beijing-Shanghai corridor is the most flourishing economic area in China, and its pace of economic development is higher than the average of the whole country. So the passenger traffic volume of the Beijing-Shanghai corridor is predicted to increase rapidly in the future, following or potentially exceeding the increasing speed of the whole country.

Unbalanced economic development among different regions and the increasing population of labor people, especially the surplus labor, has and will continue to result in the migration of labor from low-income to high-income areas, from country to cities, from undeveloped economic areas to developed economic areas. Since the region along the Beijing-Shanghai railway is a developed economic area, its migration rate will be higher than that in other areas.

In China, the area along the Beijing-Shanghai railway is an area with cities distributed densely. It not only has four metropolises including Beijing, Tianjin, Nanjing and Shanghai but also more than 10 medium and small cities. In the future, urbanization in this area will continue and more cities and towns will appear, each requiring connections that facilitate travel between them as cities and towns will become closer and closer. This population growth will drive the demand for passenger traffic to increase

rapidly, especially the demand for short-distance passenger traffic. In addition to the natural demands from this growth that will affect business travel and transport demands, the geographic areas covered by the Beijing-Shanghai railway corridor include some of the prime recreational areas of the country. Besides Beijing and Shanghai, which represent two of China's political, cultural and economic centers, there are the Tai mountains, the Qufu Confucian temple, Suzhou gardens, Hangzhou West Lake and other tourist destinations. With growth of people's income and escalation of consumption behavior, more and more tourists will come to these places, which will drive tourist traffic to grow rapidly.

The demand for all passenger traffic for the four provinces and three cities along the Beijing-Shanghai railway was at the level of 3.5 billion people in 2001. (Statistics China, 2002) The railway department projects that average growth rate of passenger volume will be 5% per year from 2002 to 2020. (Ministry of Railway, 2002) Based on these figures, we can calculate that the demands for passenger volume will be 8.8 billion in 2020. The railway carried 260 million passengers in 2001 and it accounted for 7.5% of total volume of passenger traffic, and the Tianjin-Shanghai railway carried 92.14 million passengers. (Statistics China, 2002) Projecting the market share into the future, the railway will be responsible for carrying 660 million passengers and the Beijing-Shanghai railway will be responsible for 230 million passengers in 2020. Suppose trip distance per passenger is 300km the same as in 2002, the average one-way passenger traffic density of the Beijing-Shanghai railway will be 47 million passengers/km and will need 135 pairs of passenger trains. (See appendix 2 for calculation)

The demand for freight turnover of the Tianjin-Shanghai line was 98.37 billion ton-kilometers in 2001. (Statistics China, 2001) "The growth rate of railway freight turnover was 5.0% annually for the last 24-year years since China's reform and opening."(Ministry of Railway, 2002) In 2002, the freight traffic density is 6100tons/km (See table 2-1), even if we make a calculation based on a most conservative growth rate of 2.5%, the freight traffic density will be grow by 60% in 2020 and need 79 pairs of freight trains. (Yang, 2000)

Based on the above estimation, in order to meet the requirements of passenger and freight traffic, the railway will need to run 135 pairs of passenger trains and 79 pairs of freight trains on the Beijing-Shanghai railway in 2020. In 2002, the segment with the largest traffic density was from BangBu to Nanjing, which was 18.5 million persons/km for passenger traffic density and 81.8 million tons/km for freight traffic density, requiring 122 pairs of trains to be used. According to the above estimation, the capacity of the existing Beijing-Shanghai railway will be insufficient in 2020. Specifically, it will be short of 92 pairs of trains, an additional 75% shortage. Therefore, some powerful steps and actions must be taken to increase the transportation capacity of the Beijing-Shanghai railway. In general, it is becoming imperative to rapidly increase and extend the traffic capacity of the railway in the Beijing-Shanghai corridor immediately.

2.3 Requirements for improving transport capacity

It is time to implement powerful steps to increase traffic capacity in this corridor. Because of the severe insufficiency of traffic capacity, passenger delays, cargo jam, and ride and freight difficulties have been severe social issues and become the main bottleneck that prevents the economy from developing within this area. Due to insufficiency of traffic capacity, many passengers cannot be transported on time and a lot of goods are often restricted to limited loading or even no loading. Due to insufficiency of traffic capacity, it is quite often that goods have been held up in some ports for a long time, and even some coalmines determine their production based on the amount of coal that can be transported.

For the next 20 years, China will still be at the stage of rapid industrialization with fast increasing gross domestic product and accelerated urbanization. If transportation cannot be improved enough to keep up with economic development, and also without providing enough basic support in time and guaranteeing flexibility and convenience,

Chinese industrialization will be restricted and the quality of people's living will be affected. This is especially true for the Beijing-Shanghai corridor. So it is necessary for the Beijing-Shanghai railway to expand traffic capacity, improve adaptability and extensity in all directions to support the future economic development.

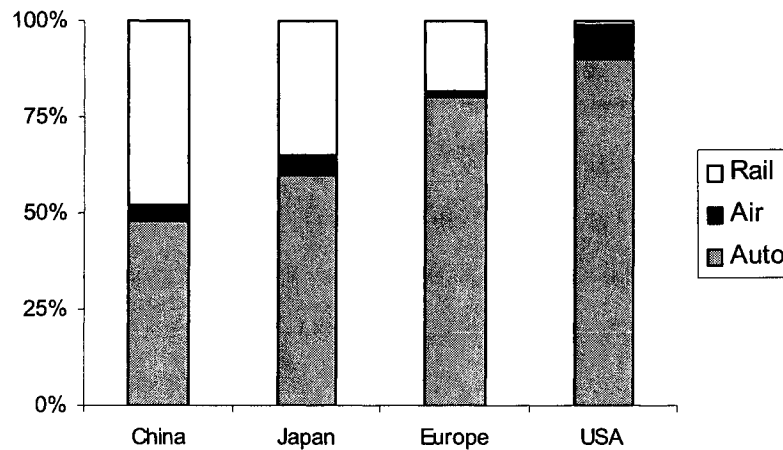
In developed countries, it is normal that busy railway arteries are multilane such as 2 or 3 pairs of parallel lines. But this current Beijing-Shanghai railway still has only one pair of parallel lines running passenger and freight trains together. This infrastructure limitation represents a current threat to operations and an opportunity for investment in additional capacity. This is precisely the situation that the High Speed Railway controversy is attempting to address. Increases limitations, due to increased mobility on the part of the Chinese population and increased enterprise activity represent sources of growing pressure to reach a decision on a choice of technology.

3.0 Rail transport and Corridors

3.1 The role of railway on the corridor

Integrated transportation corridor consists of various transportation modes and it is the lifeline of national economy development. Integrated transportation corridor is not only the requirement of social economy development in the corridor area but also a certain result of traffic transportation development. Technical and economic characteristics of each transport mode determine its own advantageous market where each transport mode cannot be replaced by other transport modes. Figure 2-4 shows the relative transportation mode usage for domestic intercity travel in China, Japan, Europe and US. As a country with dense population and scarcity of land, China needs to depend on railway to move passengers effectively like Japan.

Figure 3-1 Modal distribution of Domestic passenger travel (Safford, 1990)



The economic situation of four provinces and three cities along the Beijing-Shanghai railway is strong, and their growth rates are higher than the average of the whole country. The degree of adopting the market principle in this area along the

Beijing-Shanghai railway is also high due to historical, geographic, and cultural conditions, resulting in open and competitive transport markets forming gradually. With overall development and continuous improvement of a transportation infrastructure, including rapid development of roads and the expansion of airport facilities, all of the various transportation modes will share the work more reasonably, and the transportation structure will get better and better.

Auto travel is convenient and flexible, and it has significant advantages in short distance transport with scattered places and small volume. Air travel, as the fastest transport vehicles, has distinctive advantages in the long distance transport. But it is more suitable for some high-income and business passengers because of relative high cost. Railway, due to good safety, convenience, high capacity and low cost, has steady advantages in medium-long distance transportation and particularly in long distance transportation for low-income passengers. These transportation modes give mutual support and promotion to optimize the whole system configuration. From the viewpoint of an integrated transportation network system, railway should be mainly responsible for medium-long distance and large volume of freight and passenger transport in the main corridor. The Beijing-Shanghai corridor is precisely this - a corridor with large traffic volume and long distance.

Traffic transportation industry is also a sector that occupies and consumes many resources. On the one hand traffic transport brings convenience to society and helps people overcome space distance. On the other hand it requires a lot of land resources and consumes many energy resources, causing some negative issues such as lowered environment quality. In view of saving energy resources, rail transport is one of the most energy efficient means of mechanized ground transport known. Under the right circumstances, a train needs 50-70% less energy to transport a given tonnage of freight (or given number of passengers), than by road. Furthermore, together with the sleepers the rails distribute the weight of the train evenly, allowing significantly greater loads per axle/wheel than in road transport. (Parker, 2004) And an airplane even consumes more fuel than a bus. For example, fuel consumed by a Boeing-747-200 is 7.9 times as high as

a public bus per passenger mile. (Murty, 2000) From the viewpoint of environment protection, electric trains do not have to carry their own fuels, and they are cleaner. (Parker, 2004) From the viewpoint of land consumption, rail transport also makes a highly efficient use of space: a double tracked rail line can carry more passengers or freight in a given amount of time, than a four-lane road. (Parker, 2004) From the viewpoint of security and reliability, rail transport is also one of the safest modes of transport. (Parker, 2004) The population in China is so huge that resource and environment capacities per person are very small. For this reason, the development of traffic transport is considerably restricted by resource. For the same reason, train is the most effective transportation mode in the medium-long distance transportation, with significant advantages to the high-speed type of railway transit.

Table 3-2: Comparison among HSR, Plane and Car

	Rail Transport	Air Transport (Boeing-747-200)	Road Transport (Public bus)
Energy source	Electricity	Airplane Gas	Gas oil
Energy consumption Rate	0.5-0.7	7.9	1
Noise	Low	Medium	High
Safety	High	High	Low
Distance	Medium-long	Long	Short
Volume	Large	Small	Small
Speed	Medium	Fast	Slow
Cost	Low	High	Low

Based on the data comparison outlined in Table 3-2, from the viewpoint of integrated transportation system railway should be used on principal corridors and a railway system framework should be developed according to geographic characteristics and large traffic flow in the nation, without the necessity for developing a high-density railway network that covers the whole country. The Beijing-Shanghai corridor is the most important and busiest corridor in China, so it will be most reasonable to improve the Beijing-Shanghai corridor's traffic capacity through improving railway traffic capacity.

3.2 High speed importance in railway development

The trend for passenger traffic is becoming diversified in China. On the one hand, different levels of traffic demands exist and these levels are becoming clearer and clearer. On the other hand, each level of traffic demands pursues high-quality transport services. It can be foreseen that this tendency will keep going further with economic development and the increase of people's standards of living.

The diversification trend of passenger traffic demand is going to spur passenger transport services to develop with diversification, multilevel and multifunction. As for the requirements of transport supplies, it means to provide diversified transport products, multilevel and high-quality transport services. In a competitive market, in order to maintain or enlarge market share, various transportation modes have to perform a comprehensive competition on two key issues, price of transport products and quality of transport services according to different levels of traffic demand. Moreover, the meaning of transport service quality will be extended to the whole process of passenger travel that associates with vehicle's safety, reliability, comfort ability, traveling speed, convenience of transition, punctuality and so on.

Passenger traffic's tendency to higher speed has made traveling speed to be a competitive focus for various transportation modes. Speed is not only a main index of measuring the technological level of transport development, but also a main parameter of assessing the quality of transport service. With development of social economy and improvement of people's standards of living, the rhythm of people's work and living will expedite and people's time value will increase gradually, so the requirements of traveling speed are becoming higher and higher, which drives the demand for high-speed passenger traffic to grow rapidly.

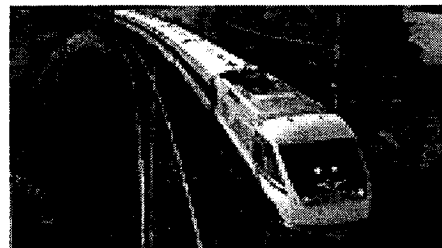
The development of high-speed passenger traffic of the Beijing-Shanghai corridor is still in development and the competition focusing on speed from various transportation modes has become more and more fierce. Auto travel develops very fast on the Beijing-Shanghai corridor. The traffic capacity of air travel has also improved with the extension of the Capital airport and the foundation of the Shanghai-Pudong airport. Confronted with the competition from auto and air travel, rail transport needs to increase its speed and volume capacities continually to keep competitive. The constructions of the Beijing-Shanghai high-speed railway will not only help increase the service level for passenger traffic tremendously but also bring rail transport to a new high-speed era.

4.0 Analysis of proposed solutions

4.1 Existing types of high speed railways

In order to enlarge traffic capacity on the Beijing-Shanghai railway, an increase in the speed of the rail transport is a way. A high-speed railway represents a preferred solution, based on the data discussed in the previous section of this paper. A train is treated as a high-speed train when running speed is over 200 km/h (125 miles per hour). High-speed train can be broadly categorized into three types: Incremental high-speed train, high-speed wheel-on-track train (new HSR) and Maglev train. Since the first high-speed railway operated in revenue service in 1964 in Japan, there have been over 20 countries and districts that have built, are building or are going to build high-speed railways in the world.

- **Incremental high speed rail** includes both non-electrified and electrified systems capable of between 90 to 150 mph top speeds. It can be achieved by updating from conventional rail systems through electrification, and the use of tilt train technologies. “Typical tilt train systems include the x-2000 in Sweden, Talgo in Spain, Pendolino in Italy and Acela in the U.S. Northeast Corridor. Examples of non-tilt trains in this category are the Amtrak Turboliners in service between New York City and Albany and the British InterCity 125 in the U.K.” (Quade, 2003).



- **new High Speed Railway** represents advanced wheel-on-track passenger railway system. Its maximum practical operating speed can reach 200 mph. “It is characterized by grade-separated, dedicated track of limited curvature



on modest grades, electric power and propulsion system, lightweight streamlined trains, and fully automated train signaling and communications equipment.” (Quade, 2003) Three representatives for this New HSR include the French TGV, the Japanese Shinkansen, and the German ICE.

- **Maglev** is an advanced transportation technology for moving passengers at very high speeds. It use forces of attraction or repulsion from magnet located in the vehicle to suspend the vehicle over a specially designed guideway. “There is no physical contact between the guideway and the vehicle, thereby minimizing resistance and permitting excellent acceleration, with cruising speeds at more than 300 mph. This high performance would enable Maglev to provide air-competitive trip time at longer trip distance than other HSR options. Germany has a Maglev technology ready for commercial introduction (Transrapid) and Japan has a completing and technologically system under test.” (Quade, 2003) The first commercial application of Maglev is between China Pudong Airport and Shanghai.



4.2 Analysis of each solution

According to the existing high-speed railway technology, there are four proposals on how to expend the traffic capacity of the Beijing-Shanghai railway: electrification, tilt train technology, high-speed wheel-on-track technology (new HSR) and Maglev technology. The first two can be achieved by improving existing systems, the latter two need to build a new rail system.

4.2.1 Updating the current railway to electrification

There are two ways to realize expanding traffic capacity through railway electrification update. One is by improving tractive effort to enhance traffic capacity; the

other is by compressing headway time between two trains to increase the number of running train pairs.

Currently on the Beijing-Shanghai railway, the engines are diesel engines. The trailing tonnage of the engines is 4000 tons from Beijing to Xuzhou and 4500 tons from Xuzhou to Shanghai. The time interval between two trains is 8 minutes from Beijing to Tianjin, 10 minutes from Tianjin to Dezhou, 8 minutes from Dezhou to Bangbu, and 7 minutes from Bangbu to Shanghai segment where the transport capacity is tightest along the Beijing-Shanghai railway. (Chen, 2004) For electrification update on the Beijing-Shanghai railway, it means that electric locomotives are adopted. Through the use of electric locomotives, trailing tonnage can be improved to 5000 tons from Beijing to Xuzhou and 5300 tons from Xuzhou to Shanghai. The headway, time intervals, between two trains can be cut down to 7 minutes.

Based on the above technical data, the introduction of an electrical update will not sufficiently improve traffic capacity on the railway when the projected increase in demand is taken into consideration. From Beijing to Xuzhou, the trailing tonnage may increase by 1000 tons through improving tractive effort. However, if we consider that passenger trains and freight trains share the track, and 80 pairs of freight trains can run at most, the railway can only carry an additional 80,000 tons of cargo in one direction, equivalent to an addition of 20 trains. The current diesel driven engines need a 30-minute maintenance window every day and cannot work during that time. Electric propulsion systems need a 120-minute maintenance window in the same period because of required maintenance of the catenary (electric power distribution systems). For diesel trains now, the train interval is 8 minutes. The calculation of a “capacity of parallel train running chart” yields a maximum number of 180 pairs $\{(1440-30)/8=180 \text{ pairs}\}$ on the current track. (See appendix 2) It will be 188.5 pairs $\{(1440-120)/7=188.5 \text{ pairs}\}$ representing an increase of only 8.5 pairs after electrification update. The total capacity improvement will be only 28.5 pairs $(20+8.5=28.5 \text{ pairs})$, equivalent to 16% $(28.5/188.5=16\%)$ of the total capacity.

For the busiest segment from Bangbu to Shanghai, improving traction quality can be equal to an addition of 14 pairs of trains $\{80 * (5300-4500)/4500=14.2\}$, but the headway between two trains remains the same. On the contrary, because the maintenance window time increases from 30 minutes to 120 minutes, the capacity of parallel train running chart decreases from 201 pairs $\{(1440-30)/7=201\}$ to 188.5 pairs $\{(1440-120)/7=188.5\}$, representing a loss in capacity of 12.5 pairs. The overall calculation in capacity represents only an increase of 1.7 pairs $(14.2-12.5=1.7 \text{ pairs})$, equivalent to only 1% of added capacity.

In a word, it is not a good idea to invest a lot of money in improving the current Beijing-Shanghai railway through electrification.

4.2.2 Tilt train solution

Tilt train technology results in the coach body of a train tilting toward the inside of the curvature in a track to add track banking (superelevation) when a train passes through a curve. The effect of centrifugal force can be offset in this way partially or fully to reduce passengers' discomfort. Through allowing an increase in the speed of passing through curves by up to 20%, this tilting mechanism can increase the travel speed of a train. The more curves, the better efficiency of the tilt trains. Tilt trains do need a certain length of straight line between the traverse curves and also have some special requirements for the gap between the rails and the smoothness of the railways.

Tilt train technology is already proven in commercial application and tilt trains are very popular in Sweden, Italy and some other European countries due to their special geography, environment, population distribution and social economy. For example, there are many reasons for Sweden to adopt tilt trains: firstly the population is small; secondly there are many hills and uplands in this country; thirdly it has a long coastline and much developed marine transport, so freight traffic volume by railway is not heavy. Thus, there is no need to develop hi-speed passenger transport by building another passenger double lines on such a hard geographical place under the condition of light

fright volume and high standard railway. The most economic way is to focus attention on the train itself, through overcoming the limiting factor for speed – the current small radius of curvature in the existing tracks. This solution makes the train structure more complicated, allows for smaller passenger loads and is expensive. But since there is no need to reconstruct the route, it is still economic for Sweden.

On the contrary, there are lots of technical shortcomings for this solution in the Beijing-Shanghai railway case. The gap between rails of Beijing-Shanghai railway is small and there are almost no intervenient streight lines between the frequent S curves that dominate the track. All of these curves would need significant technological reconstruction to meet the requirement of running tilt trains. It will be very expensive to make such a large reconstruction on such a busy line, especially considering economic and business loss that would be caused by the disturbance to the existing transportation. The influence of this disturbance on the whole society and economy will be large. “In some of the countries, including Spain and Germany, extensive use has been made of existing rail or other transport corridors when constructing high-speed rail routes, and some rail lines have been closed for months or years in order to convert them into high speed.” (National Research Council, 1991) Even the reconstruction was successful and tilt trains were running on the Beijing-Shanghai railway, the total traffic capacity would be decreased because the speed difference between the tilt trains and the freight trains has not been taken into consideration. The bigger the train speed difference, the less effective of the service. From this brief overview, the data suggest that a tilt-train solution is also not the most effective.

4.2.3 Maglev solution

The above two solutions, electrification and tilt-train technology, are both focused on upgrading current systems and cannot meet the traffic demand as demonstrated before. There is another way to significantly improve traffic capacity of the Beijing-Shanghai corridor. This relies on the building of another new high-speed railway. Two railways, the old one for freight and a new one for passengers, will significant improve the traffic

capacity of the Beijing-Shanghai corridor. Maglev technology and new HSR technology are the two choices for building the new high-speed railway. Both technologies have many advantages including safety, large capacity, using clean energy, less land consumption, and low environmental impact.

Maglev transportation systems are based on the theory of electromagnetism. Maglev trains float on a magnetic field, running with zero friction and receiving electricity without touch. They are fast, quiet, safe, and environmentally friendly. They have distinct advantages in term of speed, having exceeded 450kmph and still having the ability to go faster. They are less noisy, producing noise at a level of about 60 decibels at the speed of 280 kph, a noise level lower than the 80 decibels that normal inner city traffic produces. (NCNA, 2002) Maglev systems are safe: the cars have wrap-around carriages or wrap-around guideways to prevent derailment, and the propulsion system driven by the magnetic system makes collisions nearly impossible. They are also environmentally friendly because they use clean energy, electric power, and are energy efficient. High-speed trains consume less energy than automobiles and airplanes. And “if Maglev were to operate at TGV speeds, it would have an energy consumption in megajoules per passenger kilometer about half that of the TGV.” (Danby, 2001)

Compared with airplanes and automobiles, Maglev systems have high capacity, but they are not high enough to meet the heavy passenger traffic requirement of the Beijing-Shanghai railway. Based on the data of the first commercial line of the Shanghai-Pudon Transrapid, the train capacity of 440 passengers and headway of 10 minutes, given 4-hour maintenance time, Maglev systems have traffic capacity of 20 million annually. With this capacity, the Beijing-Shanghai railway will soon be saturated and cannot meet the future demand. If more vehicles are loaded, theoretically, more vehicles mean lower running speed of the trains or more power needed for the trains to keep the speed. There is no information whether the load of current designed Maglev electrical system can be increased to keep the current running speed. If it cannot, research cost on a new design of the electrical system will cause the investment to increase dramatically.

Furthermore, Maglev is not compatible with the current conventional railway transport network in China due to the technology used. If it were to be used in the Beijing-Shanghai railway, the resulting system would require many passengers to make cross-line transfers on their trips. The technical and economic characteristics of today's Transrapid system determine that Maglev is suitable for point-to-point transportation methods in its early stage. This implies that Maglev systems are highly suitable for a relatively independent line with heavy load and few cross-links to other railways. It also implies that it is most appropriate for lines with traffic volume between two points accounting for a high ratio of passenger volume for the total line. In order to generate profits from a Beijing-Shanghai high-speed railway, the system needs support from various kinds of passenger flow, including direct passenger flow from Beijing to Shanghai, short and long distance passenger flow on the various shorter sections of the system, and cross-line passenger flow. Currently, cross-line passenger volume accounts for 40% of the whole passenger volume on the Beijing-Shanghai railway. The economic profit of a Beijing-Shanghai high-speed railway will not be sustained without this cross-line passenger flow.

Human resources will also be a problem to adopt Maglev technology on the Beijing-Shanghai railway. For a 1,300 km line, a large number of technicians, managers, and experts will be needed for construction, operation, and maintenance. But Maglev technology is a relative new technology and few people in China understand it. The technology itself has problems too. There are also two types of Maglev technology: Japan's electrodynamic suspension system (superconducting magnets) and Germany's electromagnetic suspension system. These systems are not compatible with each other. Both types of technology are still in their developing stage and no conclusion has been made on which technology is more advanced. If the technology chosen by the Beijing-Shanghai railway proved worse than the competing technology in the future, it will cause a dilemma in that the technology developed for the short term will potentially not be appropriate for the long term.

Currently, worldwide Maglev has only commercially run on a 30 km long line for a short time until now. There will be many technical and economic problems that need to be explored if Maglev is to be used on a successful commercial basis on the 1,300 km long Beijing-Shanghai railway. At present, it is premature to suggest the adoption of a Maglev solution for the Beijing-Shanghai railway.

4.2.4 New HSR solution

New HSR trains are similar to conventional electrified passenger trains. They achieved higher speeds through dedicated track with limited curvature, lightweight vehicle, and more powerful propulsion. New HSR systems have been widely used commercially in a variety of settings around the world. They have been verified as mature, advanced, safe and reliable systems. Compared with Maglev, new HSR is slow, noisy and not so energy efficiency. But new HSR systems have many advantages that Maglev systems do not have, including high traffic capacity, and especially compatibility to the current railway system used in China.

The running speed of new HSR, while slower than Maglev, is still “fast”. Currently, both Japan Shinkansen and French TGV can run regularly at speeds of up to 300 kmph in commercial service. Under special test conditions a TGV trainset even reached 515.3 km/h (320 mph) in 1990. (Farlex, 2004) On the aspect of derailment, Maglev systems have a higher reputation than new HSR. An ICE derailed in German in 1998 killing 102 passengers and injuring hundreds. But the safety records of new HSR are still excellent, with zero deaths recorded for 40 years in Japan Shinkansen (Asahi, 2004) and no fatality for 20 years of service in French TGV. (Rail Europe, 2000) New HSR systems also use electric power and consume more energy than Maglev systems, but the investment cost for new HSR is much lower. “For any given alignment, estimates in the USDOT 15 report indicate that Maglev would have somewhat (10-20%) higher costs than high- speed rail. Subsequent estimates for the seven US demonstration projects and

several German proposals show a much greater cost difference, with Maglev expenditures about two times greater than those for high-speed rail.” (Vuchic, 2002)

One of the key benefits of new HSR is high traffic capacity. Japan Shinkansen trains operate at very high frequency (about 5 minutes headway) (Yukinori, 1997) and provide over 1,600 seats. (Gleave, 2004) “The Shinkansen system shuts down between midnight and 6:00 every day to allow maintenance to take place.” (Farlex, 2004) Base on this information, we can conclude that the traffic capacity of Shinkansen system can reach 140 million passenger a year today. French TGV systems have a similar traffic capacity to Shinkansen systems. TGV trains’ Automatic Train Protection system TVM 430 allows 3-minute headway for TGV trains at 320kmph. (CSEE, 2000) and TGV trains provide around 1,000 seats. (Gleave, 2004)

The most important advantage of high-speed wheel-on-track technology is its compatibility to currently used technology in China. Adopting high-speed wheel-on-track technology on the Beijing-Shanghai railway will meet not only its own passenger volume requirement, but also the cross-line passenger volume requirement that accounts for 40% of the whole passenger volume, (Yan, 2004) and solve the problem of insufficient traffic capacity effectively. This 40% cross-line passenger volume is very important to ensure the profitability of the new railway. Furthermore, the compatibility of wheel-on-track with current railway network will be beneficial to build the whole national high-speed railway network in a relatively short time and accelerate its development.

Since new HSR technology is more mature and stable than Maglev, new HSR systems are also more attractive than Maglev systems. Japan Shinkansen opened in 1964 and the first electric French TGV launched in 1981. Years of new HSR operation have built a set of standard for construction and maintenance. For example, Both TGV and Shinkansen have experience on tunnel and bridge construction for new HSR system, but there is no such experience for Maglev systems. New HSR also has a more mature, reliable and complete management system. The punctuality of Japan Shinkansen is incredible. “In 2003, JR Tokai reported that the Shinkansen's average arrival time was

within 0.1 minute or 6 seconds of the scheduled time. This includes all natural and human accidents and errors and is calculated from all of about 160,000 trips Shinkansen made.” (Farlex, 2004)

As time goes on, Maglev can solve many problems it faces today in the future. Using it the Beijing-Shanghai railway now is premature. Generally, adopting wheel-on-track technology is the best way to build the Beijing-Shanghai high-speed railway today. Based on this assertion, the term “high-speed railway” will refer to high-speed wheel-on-track railway in the rest of this thesis.

Table 4-1: advantages of Maglev and HSWOT

	Maglev	HSWOT
Advanced technology	√	√
Safe	√	√
Large capacity	√	√
Land consumption	√	√
Environmental friendly	√	√
Energy effective	√	√

Table 4-2: Comparison between Maglev and new HSR

	Maglev	HSWOT
Speed	Fast	Slow
Noise	Quiet	Noisy
Capacity	Small	Large
Compatibility	Incompatible	Compatible
Human resources	Few	Many
Technology	Premature	Mature

5.0 Speed: the standard of the solution

Speed target value is a key index of high-speed rail. It is a main indicator of the technology level of high-speed railway system and also an important parameter of designing the high-speed railway system as a whole.

For new HSR, “although the world speed record for a wheeled train was set in 1990 by a French TGV which reached a speed of 515 km/h (320 mph),” (Quade, 2003) high-speed trains typically travel at top service speeds of between 250 km/h (150 mph) to 300 km/h (180 mph). “For high-speed railway to be competitive with air and auto travel in a specific transportation corridor, the maximum train speed can be significantly lower than the higher speeds associated with high-speed railway corridors.” (National Research Council, 1991)

Based on the recommendations of the National Research Council studies (1991), the selection of the Beijing-Shanghai railway target speed should comply with the following principles:

Firstly, it should make sure that the technologies used by the Beijing-Shanghai high-speed railway are at the top end of the technologies available in the world. At present, the speed of high-speed railway has developed to 350 km/h in the world. As the start-up engineering of China’s high-speed railway development, the Beijing-Shanghai high-speed railway will not be completed and operated until 2010. Given the lead time until this point and the potential for changes in technology, in order to shorten the gap with the world’s most advanced technologies and keep up with them, China should set a high-speed target value and choose advanced technologies for Beijing-Shanghai high-speed railway.

Secondly, infrastructure construction should meet requirement for long-term technology development. The selection of speed target value implies two things: speed

target value of infrastructure and speed target value of operation. To determine these two speed target values, different lifecycle costs as well as short-term and long-term benefits should be considered in order to obtain the best economic benefit. The selection of speed target value for fixed devices should focus on long-term development and leave space for technical development, so higher speed should be chosen for continuous technology development. However, when choosing speed target value for operation, it is suitable to appropriately lower it down and gradually increase it within a certain scope based on the situation of technical development and economic benefit.

Thirdly, the technologies should be feasible, reliable and economically efficient. Speed target value should be suitable to the current technology development, current production status and manufacturing level of domestic high-speed railway on civil engineering, power supply system and communication signaling systems in China. Human resources including technology reserve and professional reserve of high-speed railway technology also influence the success of the project. So speed target value is not always better when it is higher. It should suit China's current situation. Then through technology transfer, technology can be absorbed and digested within a short period, local technicians can master high-speed railway technology, and workers can manufacture equipment quickly. This is also helpful to obtain high economic profit.

Fourthly, the determination of speed target value should take full advantage of integrated services of high-speed railway in the transport network system. Currently there are rail, auto, air, and water transport modes between Beijing and Shanghai. Various transport modes occupy a certain amount of market share respectively based on their own technical and economic advantages. The selection of speed target value should help the high-speed railway take its advantages of high speed, safety and economy to participate in competition. As soon as a high-speed railway is built, data gathered should easily be in a position to demonstrate that it is better than auto travel in terms of speed and safety, and better than air travel in terms of saving money.

Finally, it should conform to the transport organization mode. Since the network of high-speed railways has not been established and high-speed railways need to carry cross-line passengers, it is inevitable that high and medium speed trains will share the track at the early stage of the Beijing-Shanghai high-speed railway's operation. The reasonable match of high and medium speed trains is also an important factor that we need to consider when choosing speed target value. A reasonable match of high and medium speed trains has a huge impact on the capacity of railway transport. If the speed difference becomes bigger, the traffic capacity will be reduced. Secondly, once the minimum curve radius is determined, if the speed difference between high and medium speed trains becomes bigger, the unbalanced acceleration will also become bigger. It will not only lower riding comfort of passengers, but also make it more difficult for railway maintenance. Therefore, it is necessary to do research on different speed combinations of various high and medium speed trains on the Beijing-Shanghai high-speed railway.

So in this research, the speed target value for HSR foundation used in calculation is 350km/h and the speed target value for HSE operation used in calculation is 300km/h.

6.0 Cost analysis of Beijing-Shanghai HSR

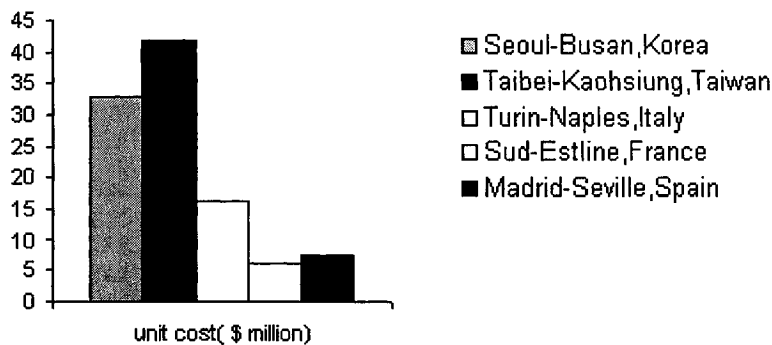
Capital costs for a new HSR system are very corridor specific. Land cost can vary greatly and construction costs, which make up a major part of total system costs, are difficult to estimate without detailed design and engineering studies. Since detailed cost estimation is beyond the scope of this study and it is also impossible for me to have large amounts of data about the Beijing-Shanghai HSR, I will make some deduction and estimation according to some data about the cost of some other high-speed railways that have been constructed in the world.

6.1 General situation of some other countries' HSR

The market for high-speed railway is different in different countries, reflecting demographic and socio-economic differences. The costs of new construction also vary significantly among countries. “Factors that influence capital costs include design and engineering; Right of way (ROW) acquisition; construction of tracks, stations, and maintenance and staff facilities; rolling stock and equipment; power distribution system; train signaling control, and communications equipment; and testing and adjustment before revenue operations. In addition, local geology and ecology, labor costs, and alignment criteria would affect capital costs.” (National Research Council, 1991)

The following graph shows the unit construction costs of HSR in some countries without rolling stock and financing costs. (Data see Appendix 5) In order to compare costs among these countries, unit costs were used because financing and project management costs are separately identified to allow a focus on the underlying engineering factors.

Figure 6-1: High-speed railway construction unit costs (\$ million per KM)



High-speed railway construction costs appear to be much lower in Spain and much higher in Taiwan. In general, higher construction costs are caused by the following reasons:

- *Number of tunnels:* Construction of track through tunnels or over viaducts is shown to be 4-6 times as much as construction over flat land. (National Research Council, 1991)
- *Number of sections using economic banking:* Frequent earthquakes, heavy rain and deep weak ground on the plains do not suit the economic banking method and few sections can use it in Taiwan. Elevated track (including site acquisition cost) usually costs about four times that of economic track.
- *Environmental costs:* To meet the strict environmental standards cost for sound barriers and ballast mats where required tend to be high.
- *Station-to-station distance:* If the distance from one station to the next station is short (30 to 40 km), then more stations will be needed. Station construction requires higher costs, which raises the total construction cost.

Because of the difference in geography, geology, climate, technology and economy, different countries and areas have different construction cost index for high-speed railways. In comparison with other high-speed railways, the construction condition and background of the Korea's Seoul-Busan high-speed railway are more similar to those of China's Beijing-Shanghai high-speed railway.

6.2 The Beijing-Shanghai HSR and the Seoul-Busan HSR

The capital Seoul is the largest city in South Korea, locating at the northwest of a peninsula. The second largest city Busan lies in the southeast of the peninsula and it is the largest seaport in this country. The corridor from the economic and trading center - Seoul to Busan through Daejeon has dense population and is the most developed area in South Korea. The original transport ways from Seoul to Busan include double-line railway with diesel drive locomotive, bi-directional four-lane highway and air transport. With the rapid economic development, the original ones cannot meet the transport's demands any longer. It is under these situations that South Korea's government decided to introduce high-speed rail service to expand the corridor capacity. This background is similar to that of the Beijing-Shanghai high-speed railway.

The similarity between the Beijing-Shanghai HSR and the Seoul-Busan HSR is also reflected on the construction standards. The following table is the construction standards of the South Korea's HSR. The construction standards of the Korea's Seoul-Busan HSR are similar to those of China's Beijing-Shanghai HSR except for some indexes such as maximum weight of axle and maximum gradient.

Table 6-2: Korea's HSR construction standard (Kim, 1998)

Maximum design speed	350km/h
Maximum running speed	300km/h
Gauge	1435mm
Interval between lines	5m
Minimum curve diameter	7000m
Rail	60kg/m
Maximum weight of axle	
Maximum gradient	15%-25%

Similar to China, South Korea also pays much attention to technology transfer and localized manufacture of rolling stock. According to the contract, France's Alstom

company should transfer all technologies about TGV to Korea, including transferring technologies of design, manufacturing, testing and construction to Korea's enterprises and transferring technologies of system linking, engineering, operation and maintenance to Korea's high speed Rail Construction Authority. (TGV 1998)

The difference between Korea's Seoul-Busan HSR and China's Beijing-Shanghai HSR is geography. Korea is a peninsula, most corridors are mountainous and a few are in hills or on plains in this country. However along the Beijing-Shanghai HSR, most are plains and a lot of large and medium cities are located along the corridor itself. Furthermore, the Beijing-Shanghai high-speed railway links 25 railway arteries and branches and the cross-line traffic volume accounts for 40% of the whole traffic volume.

6.3 Analysis of key construction cost elements

6.3.1 Rolling stock

"The number of trainsets needed varies depending on ridership, the operating schedule, equipment availability, and system length. The TGV trainset in Korea consists of two power cars, two booster cars and 16 coaches and has a seating for 935 passengers". (TGV, 1998) According to the supply contract of the Seoul-Busan HSR, Alstom will supply 46 trainsets, 2 sample trainsets manufactured in France, 10 trainsets assembled in France with some of the parts made in Korea and 34 trainsets totally made in Korea by Daewoo, Hyundai and other local companies. The Chinese government also wants to implement localized manufacture through technology transfer. According to the table in Appendix 5, the cost for rolling stock of Korea Seoul-Busan HSR is \$1518 million, and each one costs about \$33 million.

The Beijing-Shanghai HSR is 3.2 times ($1320/416=3.2$) as long as the Seoul-Busan HSR, and the population along the Beijing-Shanghai HSR is much higher than that

of the Seoul-Busan HSR. So the required trainsets of the Beijing-Shanghai HSR should at least be 3.2 times as many as the Seoul-Busan HSR. Because of the higher population density and larger passenger volume along the Beijing Shanghai HSR, it should be multiplied by a factor of 1.1. Since the high-speed traffic volume is about 60% of the total traffic volume, the required number of high-speed trains should be 98 sets ($46*3.2*1.1*60\%=98$). The cross line traffic (medium-speed traffic) volume accounts for 40% of the whole traffic volume, and the distance of cross line traffic is shorter, equivalent to 2/3 of high-speed train travel distance. So the required number of medium speed trains is 44 sets ($46*3.2*1.1*40%*2/3=44$). China contracted to improve train speed to 200km/h on some lines with Japan, France and Canada in Sept. 2004 and has contracted to produce these medium-speed trains in 6 years. So the cost of medium-speed train will be much lower, approximately 20% of the high-speed train. So the cost of 44 set of medium-speed train is equivalent to the cost of 9 sets of high-speed trains ($44*20\%=9$). Compared with the cost of Korea's rolling stock, if reducing some cost for luxury, the cost of the Beijing-Shanghai rolling stock may be 3.5 billion. $[(98+9)*(1518/46) = 3.5]$

6.3.2 Signaling, power, communication and control systems

In general, high-speed railways require a large investment in electric-related construction, including signaling, control, communication, and power systems. These systems can control train operation at high speeds and can lower headways down to 4 minutes safely. The four electric systems of the Seoul-Busan HSR cost Korea 1.935 billion and this cost for the Beijing-Shanghai HSR would be 6.17 billion ($1.935*3.2=6.17$) if we calculate it based on 3.2 times as many as the volume. Considering the rapid development of information technology, China already has great capacity of manufacturing these products, and mass production can be used for such a long line. The total investment on these four electric systems will be from 3.1 to 4.3 billion ($6.17*50\%=3.1$, $6.17*70\%=4.3$) if it is calculated by 50% to 70% of the estimated cost based on the Korean experience.

6.3.3 Land acquisition costs

A high-speed railway system has significant land requirements. The land acquisition cost per KM of the Seoul-Busan HSR is \$3.62 million. Since Korea has higher land and labor costs than China, although there are many cities and towns along the Beijing-Shanghai HSR, the unit land cost per KM should still be cheaper than the Seoul-Busan HSR's.

According to the government report, this project will acquire about 90 thousand Mus (Chinese unit of area) of land and demolish 1.8 million square meters of existing buildings. In order to reduce land acquisition costs, the department of railway has purchased some land in advance. Jingsu government declares that the lowest cost of land used for industrial purposes is \$10 thousand per Mu in their province. Now in China the cost of resident relocation is about \$500 per square meter. So the total land acquisition cost may be \$1.8 billion ($90,000 \times 10,000 + 1,800,000 \times 500 = 1,800,000,000$).

6.3.4 Civil engineering cost

According to the cost of international HSRs, the civil engineering costs such as banking, bridges and tunnels, still dominate the expense ledger by accounting for approximately 70% of the high-speed railway total construction cost. The civil engineering cost accounts for 71.3% in Korea and 70.1% in Taiwan. Usually unit construction cost is relatively higher if the figure of the proportion of a route in tunnel or on viaduct is higher. The tunnel and viaduct percentages in Korea and Taiwan are all above 50% of the total line (See appendix 5). In China, however, it is about 34% for tunnel and 1.5% for viaduct. China's other advantage is that for rolling stock and the four systems that need import or purchase from other countries, China's construction mainly depends on its own capacity. Labor cost in China is also much cheaper, so this part of cost percentage will be lower than in Taiwan and Korea. Based on China's advantageous

position as noted, the costs in this area will be approximately 70% of the total construction cost. So the civil engineering cost may be from \$11.4 billion $[(3.1+1.8)/30%*70%=11.4]$ to \$14.2 billion $[(4.3+1.8)/30%*70%=14.2]$. Based on the above, the total investment of the Beijing-Shanghai HSR is from \$19.6 to \$21.9 billion as outlined in Table 6-3.

Table 6-3: Cost estimation of Beijing-Shanghai HSR (\$ billion)

BS HSR 1320km	Rolling stock	Construction			Total cost	Unit cost (Million)
		The four systems	Land acquisition	Civil Engineering		
1	\$3.5	\$3.1	\$1.8	\$11.4	\$19.8	\$15.0
	17.6%	15.6%	9.1%	57.6%	100.0%	
2	\$3.5	\$3.4	\$1.8	\$12.1	\$20.8	\$15.8
	16.8%	16.3%	8.6%	58.2%	100.0%	
3	\$3.5	\$3.7	\$1.8	\$12.8	\$21.8	\$16.5
	16.0%	16.9%	8.2%	58.8%	100.0%	
4	\$3.5	\$4	\$1.8	\$13.5	\$22.8	\$17.3
	15.3%	17.5%	7.9%	59.3%	100.0%	
5	\$3.5	\$4.3	\$1.8	\$14.2	\$23.8	\$18.1
	14.7%	18.0%	7.6%	59.7%	100.0%	

7.0 Financial analysis

Financial analysis is the most important part in assessing an investment project. It accesses the project's financial cost and revenue in its whole life cycle based on the financial data and construction data, and demonstrates whether the project is economically feasible. Generally, financial analysis is the ground of the feasibility of the project and also of the funding requests from banks. To validate its profitability, a model that based on 16 factors (including passenger flow density, Passenger growth rate, Express train fare, Local train fare Route length, Express train capacity, Local train capacity, Passenger load factor, Fluctuation rate, Construction cost, Trainset cost, Trainset life, Domestic interest rate, Word bank interest rate, Calculation years and O&M cost per person per km) is built to simulate the cost and revenue of the Beijing-Shanghai high-speed railway.

7.1 Ridership estimation

Ridership is a critical factor in determining the feasibility of any transportation system, and it is a key determinant of financial feasibility. Together with fares it determines revenues, and influences some system requirements such as the number of vehicles, the size of stations. Because of their nature, transport projects involve considerable uncertainty. So ridership forecast is usually a controversial element of any study that analyzes the feasibility of a transportation system. If there is a mistake about demand, society may be burdened with unused, costly investments. Thus, estimating demand should be as accurate as possible.

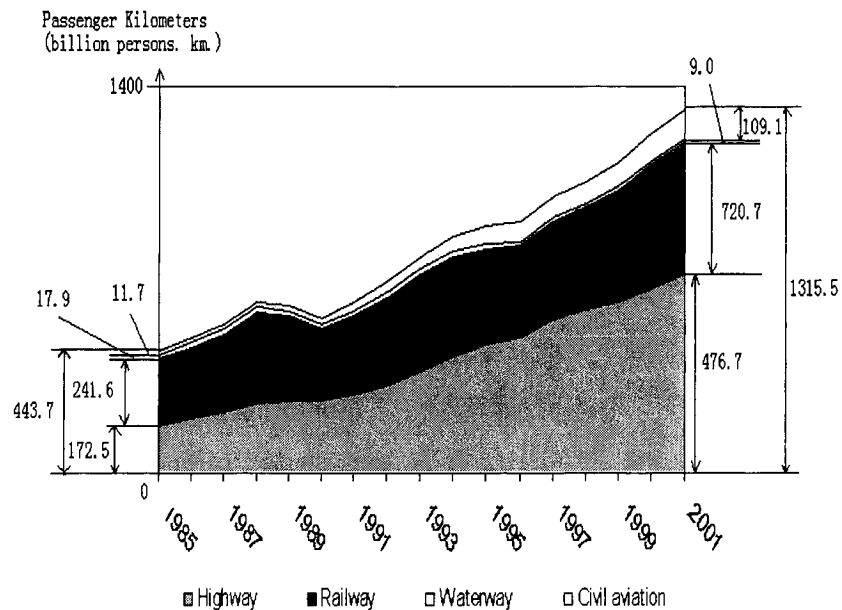
There are four traditional methods of forecasting rail demand: Market surveys, Delphi techniques, statistical methods and econometric methods. The first two are qualitative methods, and the latter two are quantitative methods. "Forecasting by statistical methods is the easiest method of forecasting the railway passenger demand by collecting the historical data and determines the trend curve of demand. Econometric

forecasting takes into account a quantitative relationship between rail demand and the explanation variables, which influence the development of demand.” (Vassilios, 2001).

7.1.1 Traffic volume

The amount of traffic volume has a direct impact on income of the project, which means that it is very important to the success or failure of this project. In 2001 China accumulated 1.3 trillion passenger-km of intercity travel. With growth averaging over 7 percent per year, this figure is about 3 times as many as that of 1985. So far with the population and economic development in China, passenger and freight turnover continue to grow. Detailed passenger traffic and passenger traffic turnover volume of the whole country and the Tianjin-Shanghai Railway are outlined in Appendix 3. The comparative passenger turnover volumes for each mode of transport are outlined in Figure 7-1 below. They demonstrate steady increase over the total period described (1985 – 2001).

Figure 7-1: China passenger traffic turnover for each mode from 1985 to 2001
Passenger-km (billions)



7.1.2 GDP growth rate

The statistic method of estimating the traffic demand that is generated by normal traffic volume is past trend extrapolation. In the meantime, it needs to assume that the growth remains unchanged in absolute and relative terms. However, forecast via economic method is an alternate approach. It associates the growth of traffic volume with domestic GDP, population growth, price of oil fuel and other relevant variables because the requirement of transport grows typically with population, personal income and time lapse. With an increase in people's income and fuel price, the ticket price will increase accordingly. This thesis has used growth in GDP as a primary method to forecast ridership in keeping with methodology developed by Petri Tapio (2003). Table 7-2 outlines China's GDP growth rate from 1985 to 2003.

Table 7-2: China GDP growth rate from 1985 to 2003 (Lin, 2003)

Year	GDP Growth Rate	Year	GDP Growth Rate
1985	13.5	1994	12.7
1986	8.8	1995	10.5
1987	11.6	1996	9.6
1988	11.3	1997	8.8
1989	4.1	1998	7.8
1990	3.8	1999	7.1
1991	9.2	2000	8.0
1992	14.2	2001	7.3
1993	13.5	2002	8
1994	12.7	2003	9.1

From the above table we can see that the average GDP growth rate from 1985 to 2002 is 9.5%. Especially from 1998 to 2002, the average growth rate is 7.6%, and the difference between the highest point and the lowest point is only 0.9%. The Chinese economy grows steadily through macroeconomic controls such as financial policy and monetary policy. According to China's ninth five-year plan, GDP growth rate would be

7.17% from 2000 to 2010. (Xinhuanet, 2001) The GDP growth rate of the Beijing-Shanghai corridor should be higher than China's average GDP growth rate due to faster economic development. To be moderate, GDP growth rate before 2020 is set to 7.2% and 6.2% after 2020 in the Beijing-Shanghai corridor.

7.1.3 Economic method to forecast ridership

There is a close relationship between GDP and traffic volume. "Decoupling of transport volume growth from economic growth can be expressed as elasticity value under 1, where the percentual change of GDP is divided by the percentual change of transport volumn in a given time period." (Petri, 2003)

$$\text{GDP elasticity coefficient of transport} = \% \Delta \text{VOL} / \% \Delta \text{GDP} \quad (1)$$

Here transport volume can be measured as passenger transport (passenger km).

For example, when passenger turnover volume is 47.4 billion passenger-kms in 2000 and 49.2 billion passenger-kms in 2001, then

$$\% \Delta \text{VOL} = (49.2 - 47.4) / 47.4 = 3.91\%$$

$$\% \Delta \text{GDP} = \text{GDP growth rate in 2001} = 7.3\%$$

$$\text{Elasticity Coefficient} = \% \Delta \text{VOL} / \% \Delta \text{GDP} = 3.91\% / 7.3\% = 0.54$$

The following table shows the change of passenger traffic and turnover volume of the whole country and the Tianjin-Shanghai railway calculated from the data of Chinese Bureau of statistics. (See Appendix 3)

Table 7-3: Growth rate of passenger traffic and passenger kilometers of Railway, Highway, and Beijing-Shanghai Railway (BSR)

	Passenger traffic				Passenger Kilometers			
	Total	Railway	Highway	BSR	Total	Railway	Highway	BSR
1985-1986	10.97	-3.15	14.22		10.37	7.06	14.89	10.41
1986-1987	8.46	3.59	9.08		10.50	9.91	10.53	10.63

1987-1888	8.46	9.04	9.57		14.75	14.68	15.42	14.40
1988-1989	-2.25	-7.21	-0.92		-2.16	-6.84	5.29	-5.80
1989-1990	-2.36	-15.89	0.55		-7.35	-13.99	-1.57	-8.72
1990-1991	4.32	-0.67	5.34		9.77	8.25	9.59	6.82
1991-1992	6.80	4.85	7.19		12.48	11.46	11.17	10.43
1992-1993	15.77	5.78	17.62		13.08	10.50	15.91	5.31
1993-1994	9.66	3.11	10.83		9.33	4.39	14.04	3.12
1994-1995	7.29	-5.51	9.11		4.78	-2.49	9.07	-2.99
1995-1996	6.15	-8.35	7.81	-7.77	1.56	-6.21	6.64	-11.74
1996-1997	6.48	-1.68	7.35	-0.15	9.58	6.70	12.89	1.17
1997-1998	3.87	0.45	4.38	0.49	5.34	4.02	7.24	2.41
1998-1999	1.15	5.66	0.93	7.95	6.26	9.75	4.31	10.78
1999-2000	6.18	6.94	6.18	-5.65	9.33	11.90	7.39	5.00
2000-2001	3.76	0.08	4.11	1.89	7.29	5.17	8.26	3.91

Base on the formula (1), the elasticity coefficient of passenger traffic and its turnover volume is shown as follows.

Table 7-4: Elasticity coefficient of passenger traffic and passenger kilometers

	Passenger traffic				Passenger Kilometers			
	Total	Railway	Highway	BS	Total	Railway	Highway	BS
1985-1986	1.25	-0.36	1.62		1.18	0.80	1.69	1.18
1986-1987	0.73	0.31	0.78		0.90	0.85	0.91	0.92
1987-1888	0.75	0.80	0.85		1.31	1.30	1.36	1.27
1988-1989	-0.55	-1.76	-0.22		-0.53	-1.67	1.29	-1.42
1989-1990	-0.62	-4.18	0.15		-1.94	-3.68	-0.41	-2.29
1990-1991	0.47	-0.07	0.58		1.06	0.90	1.04	0.74
1991-1992	0.48	0.34	0.51		0.88	0.81	0.79	0.73
1992-1993	1.17	0.43	1.31		0.97	0.78	1.18	0.39

1993-1994	0.76	0.24	0.85		0.73	0.35	1.11	0.25
1994-1995	0.69	-0.52	0.87		0.46	-0.24	0.86	-0.29
1995-1996	0.64	-0.87	0.81	-0.81	0.16	-0.65	0.69	-1.22
1996-1997	0.74	-0.19	0.84	-0.02	1.09	0.76	1.46	0.13
1997-1998	0.50	0.06	0.56	0.06	0.69	0.52	0.93	0.31
1998-1999	0.16	0.80	0.13	1.12	0.88	1.37	0.61	1.52
1999-2000	0.77	0.87	0.77	-0.71	1.17	1.49	0.92	0.63
2000-2001	0.51	0.01	0.56	0.26	1.00	0.71	1.13	0.54

According to analysis of elasticity coefficient from the above table except for the special year 1989, these statistics show a close correlation of GDP and national passenger traffic. From the numbers of the elasticity coefficients between 1985 and 2001 in the above table, we can calculate that the average elasticity coefficient of national passenger traffic was 0.6; the average elasticity coefficient of national passenger kilometers was 0.8; highway passenger traffic grew continually and its average elasticity coefficient was 0.72, but elasticity coefficient of railway passenger traffic was only 0.01; the average elasticity coefficient of railway passenger kilometers was 0.54; the average elasticity coefficient of the Beijing-Shanghai railway was 0.38. The lower elasticity coefficient of the Beijing-Shanghai railway was because this busy Beijing-Shanghai line had to reduce passenger traffic to ensure the freight traffic. Based on these calculations, we can confidently predict future ridership fluctuation, providing a level of confidence in the forecast of ridership used for this thesis.

7.1.4 Diverted and induced passenger traffic

The most important element in any transportation plan is to understand who will potentially use the transportation service being considered. Except for the normal traffic volume, the ridership market will also consist of both diverted trips from a different mode to the Beijing-Shanghai HSR service, and induced trips that would be made only if the proposed Beijing-Shanghai HSR rail service is available.

From 1985 to 1997, the volume of passenger traffic in China increased from 6.19 billion to 13.25 billion. Although the extent of its increase was big, the structure of passenger flow carried by different transport vehicles did not change much. Medium and short distance passenger dominated the market all the time, with short-distance passenger traffic under 100km occupying 90 percent of the total volume of passenger traffic. If passenger type and traffic is view by percentages under 500 km, short and medium-distance passenger traffic under 500km occupied more than 97 percent of the total volume of passenger traffic and long-distance passenger traffic over 500km occupied less than 3 percent (see Table 7-5 and Table 7-6)

Table 7-5: 1985-1997 passenger traffic in China (%) (Statistics China, 1997)

	1985	1990	1995	1997
Less than 100km	89.1	89.8	89.9	90.5
100-200km	5.1	4.8	4.6	4.5
200-500km	3.4	3.1	3.0	2.7
500-1000km	1.2	1.2	1.2	1.1
1000-2000km	0.9	0.8	1.0	0.9
More than 2000km	0.3	0.3	0.3	0.3

Table 7-6: Market share in 1997 by different traffic mode (Statistics China, 1997)

	Railway		Highway		Ship		Air	
	Share (%)	Volume (million)	Share (%)	Volume (million)	Share (%)	Volume (million)	Share (%)	Volume (million)
Less than 100km	3.05	358	95.3	11443	1.7	204	-	-
100-200km	26.5	157	71.0	422	2.5	12	-	-
200-500km	49.9	181	46.8	169	2.5	9	0.8	3
500-1000km	81.4	119	8.3	12	0.6	0.9	9.7	13
1000-2000km	68.4	85	4.0	5	0.2	0.2	27.4	35
More than 2000km	82.0	26	-	-	-	-	18.0	5.2

In 1997, the volume of passenger traffic under 100km was 11.99 billion, accounting for 90 percent of the total passenger traffic volume. Bus service advantage was obvious and it dominated the market, accounting for about 95 percent of the total volume. Train service accounted only 3 percent, and it was only a supplement for the roadway service. But for train service itself, the under-100 km volume accounted 40 percent of its own total passenger volume. Passenger volume between 100 and 200km was 596 million about 4.5% of the total passenger traffic volume, but bus service still occupied more than 70% and train service occupied up to 26.5%. Train service advantage began to appear over 100km. Between 200km and 500km, passenger traffic volume was 362 million and accounted for 2.7% of the total passenger traffic volume, and among it highway accounted for 46.8% and railway accounted for 49.9%, so this distance is the competition focus for railway and highway. Passenger traffic volume between 500km and 1000km was 146 million and accounted for 1.1% of the total volume. Railway had complete advantages on this distance and occupied more than 80% of market share, and bus and air services occupied 10% separately. Between 1000km and 2000km passenger traffic volume was 119 million and accounted for 0.9% of the total volume, and railway occupied 70% of this market.

In order to ensure freight traffic, the railway department has had to reduce running passenger trains. And also according to the profit, they focus on the medium and long distance trip and have to decrease short distance passenger trains. The Beijing-Shanghai HSR will be used only for passenger transport. There are two stopping patterns, one for express service (high-speed service) and the other for local service (medium-speed service). The local service can divert short distance passengers from highway, and even a little percent of highway traffic will be huge to railway traffic. According to other country's experience, a new HSR can divert and induce a lot of passenger traffic. In France, for example, "the French TGV line from Paris to Lyons constructed in a corridor where existing rail ridership was 12 million riders per year. 8 million switched to TGV and 4 million stayed on the lower-cost conventional trains that continued running." (Walrave, 1990)

Since the first time speed was improved in 1997, and with each of six times improved train speed was noted, the railway's competitive power has been enhanced and the railway's passenger kilometers have increased dramatically. When the proposed Beijing-Shanghai high-speed railway becomes available with better service, the railway's passenger kilometers will increase continually. It is reasonable to improve the elasticity coefficient of the Beijing-Shanghai HSR by 20% to 0.465, but it is still lower than the national railway's 0.54. If the Beijing-Shanghai HSR starts in 2005 and need 6 years for construction, it will be completed in 2011. Generally the financial calculation for full return on investment of a transportation project is 30 years. Based on the GDP's growth rate and elasticity coefficient, the growth rate of the Beijing-Shanghai passenger turnover volume will be 3.29% before 2020 and 2.82% after 2020.

7.2 Fare estimation and O&M cost estimation

The cost of air ticket from Beijing to Shanghai is 1130 RMB in 2004. If we calculate air ticket by a discount of 25% averagely per year, the fare will be 847 RMB ($1130 \times 75\% = 847$), plus airport construction cost 50 RMB, the total cost will be 897 RMB. (For domestic airline, the cost was 0.68 RMB per passenger-km with a seat occupied rate of 0.608 in 2001, which meant the cost for Beijing-Shanghai air travel was 897 RMB) (Zhang, 2003) If one travels by driving a car, road tolls will cost 535 RMB, exclusive of gas. It is obvious that this way is not suitable to the public travel. The cost of express bus is 300 RMB from Beijing to Shanghai.

A Korea high-speed train ticket from Seoul to Busan costs 45,000 won (\$37), about one third higher than the Saemaul trains and 80 percent higher than a luxury express bus, but three-quarters lower than the cost of an air ticket. (Kim, 1998) If we calculate the ticket price of the Beijing-Shanghai high-speed train based on 70% of the actual air ticket cost, it will be 678 RMB ($897 \times 70\% = 628$ plus 50RMB airport improvement fee), equivalent to an average fare rate of 0.48 RMB/km. If we calculate the

ticket price of the Beijing-Shanghai high-speed train based on 1.8 times as much as the express bus, it will be 540 RMB ($300 \times 1.8 = 540$), equivalent to an average fare rate of 0.41 RMB/km. So the average fare rate for the high-speed train should be between 0.41~0.48 RMB/km.

Currently the train speed is 160km/h, and the fare is 283 RMB for the carriage with cushioned seats from Beijing to Shanghai and 327 RMB for carriage with semi-cushioned berths. Based on the Ministry of Railways' principle "higher speed without fee change", after the speed is improved to 200km/h, it is reasonable that the ticket price for local (medium-speed) trains ranges between 283 and 327, equivalent to average fare rate 0.22~0.25RMB/km.

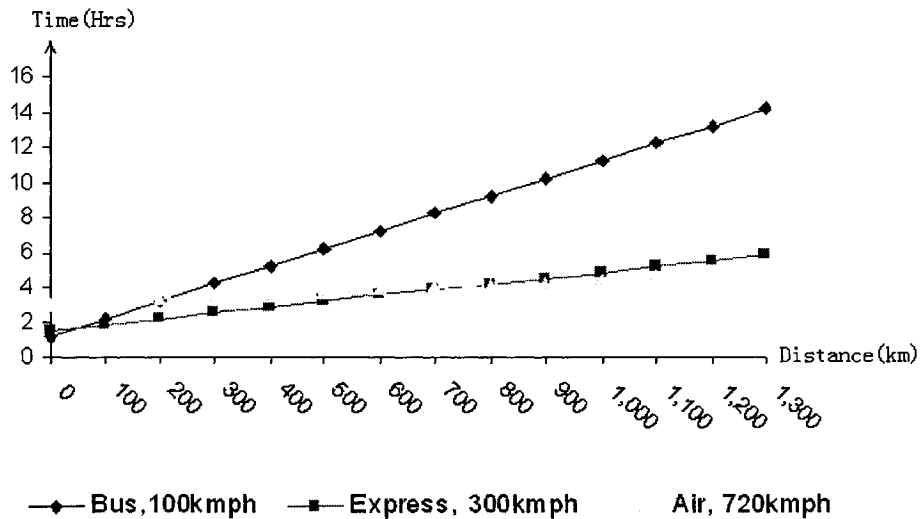
"The components of operating and maintenance (O&M) costs were the following: maintenance of way, maintenance of equipment, energy, train operation, signal and communications operation, station operation, and administration, sales, and insurance." (Railway Industry, 2001) The O&M cost of conventional Beijing-Shanghai railway is about ¥0.06 per passenger-km. The O&M cost for HSR may be between ¥0.1 and ¥0.12 per passenger-km. The O&M cost for middle-speed railway is set to 60% of that of high-speed train.

7.3 Competitiveness

"The lower bound of the public travel market is set by bus, which has lower operating speeds but the advantage of convenience for trips less than 200km. The upper bound is set by air travel because faster air service speeds provide it with considerable competitive advantage for trips more than 1000km." (National Research Council, 1991) Most travelers are very interested in travel time and travel cost between their point of origin and final destination. Thus the time and cost of any access trips for a door-to-door

trip should also be considered. The following figure shows the relationships between travel time and distance.

Figure 7-7: travel time and distance relationship for Bus, Express and Air



Assumptions:

Air: 3hr for terminal access/egress and waiting time, cruise speed of 720kmph

Express: 1.5hr for terminal access/egress and waiting time, average speed of 300kmph

Bus: 1.2hr for terminal access/egress and waiting time, average speed of 100kmph

Many experts believe high-speed railway has advantages on a trip between 200 and 800 kilometers based on Japan’s Shinkensin experience. The distribution of population along the Shinkensin line is concentrated in the middle, giving it the visual shape of a sphere. Along the Beijing-Shanghai railway in China, the population density is converged in the Beijing and Shanghai terminal areas, giving the line the visual shape of a dumbbell. Even though this line is 1320km, if traveling at a speed of 300km/h, the total traveling time will be 5 hours, and it will still have advantages. For example, as outlined in Table 7-8, from Beijing to Shanghai, it will take 5.8hr by high-speed train, one hour more than by airplane, but it costs about 300RMB less than the air ticket. Although the trip costs more than bus, it can save 9 hours for passengers without calculating the time of stopping for meals. So compared with bus, high-speed railway is very competitive.

Generally, the bus is competitive to high-speed railway only in short distance trips under 200 km.

Table 7-8: travel time from Beijing to Shanghai by Air, HSR and Bus

	Access time (hr)	Waiting time (hr)	Beijing-Shanghai (hr)	Meals (hr)	Egress time (hr)	Total (hr)
Air	1	1	1.8		1	4.8
HSR	0.5	0.5	4.3		0.5	5.8
Bus	0.5	0.2	13.2	1	0.5	15.4

For air travel, if either the departure city or the arrival city has only one airport, such as Beijing to Suzhou, or in cases where both cities have no airport, the passenger will have to make a transition via other transport modes to get to destination. In such cases the competitiveness of airplane will be weaker.

High-speed railway is an all-weather running transport vehicle with high-density frequency of services and potential for high punctuality ratio. The train has seldom been late on JR New Tokaido line in Japan since its first running, and 99.8% of trains arrive within a deviation of 3 minutes on the Madrid-Seville high-speed line in Spain. (National Research Council, 1991) Airplane and bus cannot compete for the reliability of scheduled time with high-speed train because they are both easily affected by storm, fog and other weather factors.

High-speed railway systems are systematic engineering with many high technologies applied and have their own exclusive track. They have a good record in safety. Also travel by train is more comfortable than by air and bus because the noise in the coach is lighter, ride is smoother and has more activity space.

In a word, among all the transportation methods, the Beijing-Shanghai high-speed railway is more competitive on service, safety and cost.

7.4 Financial analysis

To test the financial feasibility of the Beijing-Shanghai HSR, based on the above analysis, a model was developed to examine the plausible range of key cost and revenue parameters. The parameters considered include passenger density, construction investment, high-speed train fare, medium-speed train fare and high-speed train operation cost. For these reasonable values of costs and fares, the model can compute NPV (Net Present Value), IRR (Internal Rate of Return) which is the interest rate that makes net present value of all cash flow equals to zero, and payback period of the project.

Since it is a dedicated passenger line, the income mainly comes from fares. According to fare estimation calculations, the fare for high-speed train will be 0.41~0.48 RMB/km and the fare for medium speed train will be 0.22~0.25 RMB/km. Considering the Chinese standards of living and the competitive power of railway, the fare for high-speed train can be adjusted to 0.41~0.44 RMB/km. Other income includes income from luggage and parcel post etc., which is considered to be 1% of income of passenger traffic. The expenses include construction cost, payback loan and interest, operation cost and cost for rolling stock. Unlike construction cost, rolling stock needed mainly depends on the passenger density and it is hard to compare with other countries. So I separate the rolling stock cost from the total investment. Based on the analysis of the investment in the project in Chapter 6, the construction cost will be between \$16.4 billion and \$19.7 billion, equivalent to between 135 billion RMB and 168 billion RMB. The following table is the construction cost exchange from US dollars in table 7-9 to RMB. (Exchange rate 8.28 is used)

Table 7-9: cost of Beijing-Shanghai HSR (billion RMB)

BSHSR 1320km Scenario	Rolling stock	Construction			Total cost	Unit Construction cost (Million)
		The four systems	Land acquisition	Civil Engineering		
1	29.0	25.7	14.9	94.7	164.2	102.5
			135.2			

2	29.0	28.2	14.9	100.5	172.5	108.7
		143.5				
3	29.0	30.6	14.9	106.3	180.8	115.0
		151.8				
4	29.0	33.1	14.9	112.1	189.1	121.3
		160.1				
5	29.0	35.6	14.9	117.9	197.3	127.5
		168.4				

The cost of rolling stock depends on the number of train sets that are required within the first year's operation after completion of engineering. In Chapter 6, calculations estimate that 98 high-speed trains and 44 medium-speed trains would be needed and they could carry 36 million persons/km of passenger density. Using GDP-based estimation of passenger density with addition of a conservative diverted and induced trips calculation for the Beijing-Shanghai corridor, the passenger density will be between 20 million persons/km and 30 million persons/km. In theory, density of passenger flow in each section is different along Beijing-Shanghai high-speed railway, but considering that accurate data about the actual variability is not available, this thesis uses an average density of passenger flow so that the whole distance can be calculated on an average basis.)

Train Requirement Calculation Formula

$$N_t = N_h + N_m$$

$$N_t = \frac{D * \text{coefficient of passenger flow fluctuation}}{\text{Fixed number of seats in a train} * \text{annual coefficient of seat occupied} * 365}$$

Where

N_t is the number of trains needed in one segment

N_h is the number of high-speed trains (300kmph)

N_m is the number of medium-speed trains (200kmph)

D is one-way density of passenger flow

In above formula, except that average fixed numbers in a train are determined, for example, average fixed numbers in a high-speed train are 1000 people and average fixed numbers in a medium-speed train are 1100 people, we still have two parameters that are worth investigating: the coefficient of passenger flow fluctuation and the coefficient of seat occupied. Regarding coefficient of passenger flow fluctuation, coefficient 1.1 will be used in main trunks under normal circumstance. (Railway, 1984)

In comparison with coefficient of occupation of seats among Beijing, Shanghai and Jinan Railway Bureaus, we can see that coefficient of seat occupied in 1997 apparently decreased compared with one in 1994 (Table 7-10). There are two factors that resulted in this change. One is that 1994 was a peak year of annual passenger flow statistics, and passenger traffic volume started decreasing after 1994 so that the congestion on passenger trains was relieved to some extent. The other is that traveling conditions have been improved, which is caused by each sold ticket having its own seat and the increase of trains that depart in the evening and arrive in the morning. So we can deduce that the trend of coefficient of seat occupied will be lower when traveling conditions are further improved. This should be especially visible with an increase in density of high-class trains and the decrease in numbers of stops in the line has. Such changes are projected to have a great impact on the coefficient of occupation of seats. Thus, 0.75 is used as a planning number in designing annual coefficient of occupation of train seats in this thesis. (Railway, 1984)

Table 7-10: passenger load rate of Beijing, Jinan and Shanghai bureaus (China transportation statistics yearbook, 1997)

Bureau \ Year	Beijing	Jinan	Shanghai
1994	0.97	0.99	0.93
1997	0.79	0.82	0.83

For example, if one-way passenger traffic density is 30 million persons/km and the average trainset fixed numbers are 1000 for high-speed trains and 1100 for medium-speed trains respectively, and if we consider that the number of high-speed trains

accounts for 60% and the number of medium-speed trains accounts for 40% of the total traffic volume, then we can get the following results.

$$\text{Number of high-speed trains} = 3000 \times 10000 \times 60\% \times 1.1 / (1000 \times 0.75 \times 365) = 73$$

$$\text{Number of medium-speed trains} = 3000 \times 10000 \times 40\% \times 1.1 / (1100 \times 0.75 \times 365) = 44$$

Since the estimation of passenger traffic density in the first operation year was different, the cost for rolling stock would also change with the passenger traffic density. With an increase in traffic volume, trainsets will also need to increase. When the project is completed, all of the new trains required will be locally manufactured. This would lower the trainset cost to half of the imported high-speed train cost, which is \$16.5 million equivalent to 130 million RMB for one high-speed train. The medium speed trainset is about 55 million RMB, equivalent to 40% of the high-speed train cost.

The operation cost is associated with the turnover volume of passenger traffic. According to the Ministry of Railway, the operation cost of high-speed train is 0.1~0.12 RMB per persons-km, and operation cost of medium-speed train is about 60% of that of the high-speed train. The parameters used in the model are as follows:

Table 7-11: parameters of Beijing-Shanghai HSR

	Parameters	Value
Ridership and Revenue	1 st year passenger flow density (million passenger-km)	24~28
	Passenger Density growth rate before 2020	3.29%
	Passenger Density growth rate after 2020	2.82%
	Express fare (¥/passenger-km)	0.41~0.44
	Local fare (¥/passenger-km)	0.22~0.25
Train utilization	Route length (km)	1320
	Express capacity (seats/train)	1000
	Local capacity (seats/train)	1100
	Load Factor	0.75
	Fluctuation rate	1.1

Capital cost	Construction cost (¥ billions)	135.2~168.4
	Trainset cost (¥ millions)	273
	Trainset life (years)	30
	Domestic interest rate	7%
	World Bank interest rate	6%
	Calculation year	30
O&M cost	Per passenger-km of express (¥)	0.12

7.5 Monte Carlo model simulation

Monte Carlo involves the random sampling of each probability distribution within the model to produce hundreds or even thousands of scenarios (or iterations). Since it is hard to determine their possibility distribution, I choose the triangle distribution, which means selecting the minimum, maximum and most possible values. The mean is selected as the most possible value for most of above values, but due to the relatively low personal income in China and considering the competition with air and highway, this thesis lowered the value for local fares and allowed for higher value for express fares for the most possible fares. The following table lists some values for some parameters in the model.

Table 7-12: range of parameters in the model

Factor	Max	Min	Most	Expectation
Passenger Density	2.8E+007	2.4E+007	2.6E+007	2.6E+007
Construction Investment	1.7E+011	1.3E+011	1.5E+011	1.5E+011
Express fare	0.44	0.41	0.43	0.428
Local fare	0.22	0.25	0.23	0.232
Hi operation cost	0.12	0.1	0.11	0.11

In order to simulate the project by computer, random calculation of each variable is required. Most computer languages provide functions that generate pseudo-random

uniform variables on $[0, 1]$, so we need to generate our own random values. Based on the values shown in the above table, we could get the probability mass function for the value of each variable and their distribution function, and then we can get the needed random values through inverse transform method. For example, the probability mass function of local train fare is:

$$h(x) = \begin{cases} \frac{2(x-0.22)}{(0.25-0.22)*(0.23-0.22)} & \text{if } 0.22 \leq x \leq 0.23 \\ \frac{2(0.25-x)}{(0.25-0.22)*(0.25-0.23)} & \text{if } 0.23 \leq x \leq 0.25 \\ 0 & \text{if } x < 0.22 \text{ or } x > 0.25 \end{cases} \quad (1)$$

And the distribution function of express fare is:

$$H(x) = \begin{cases} 0 & \text{if } x < 0.22 \\ \frac{(x-0.22)^2}{(0.25-0.22)*(0.23-0.22)} & \text{if } 0.22 \leq x \leq 0.23 \\ 1 - \frac{(0.25-x)^2}{(0.25-0.22)*(0.25-0.23)} & \text{if } 0.23 \leq x \leq 0.25 \\ 1 & \text{if } x < 0.25 \end{cases} \quad (2)$$

After inverse transformation, the random variables can be generated by the following function:

$$d = \begin{cases} 0.22 + 0.01\sqrt{3R} & \text{if } 0 \leq R \leq \frac{2}{5} \\ 0.25 - 0.01\sqrt{6(1-R)} & \text{if } \frac{2}{5} < R \leq 1 \end{cases}$$

R is uniform distribution random between 0 and 1.

In a similar manner, the random variable of passenger density is:

$$a = \begin{cases} 2.4 + 0.2\sqrt{2R} & \text{if } 0 \leq R \leq \frac{1}{2} \\ 2.8 - 0.2\sqrt{2(1-R)} & \text{if } \frac{1}{2} < R \leq 1 \end{cases}$$

The random variable of construction cost is:

$$b = \begin{cases} 1.3 + 0.1\sqrt{6R} & \text{if } 0 \leq R \leq \frac{1}{2} \\ 1.7 - 0.1\sqrt{6(1-R)} & \text{if } \frac{1}{2} < R \leq 1 \end{cases}$$

The random variable of express train fare is:

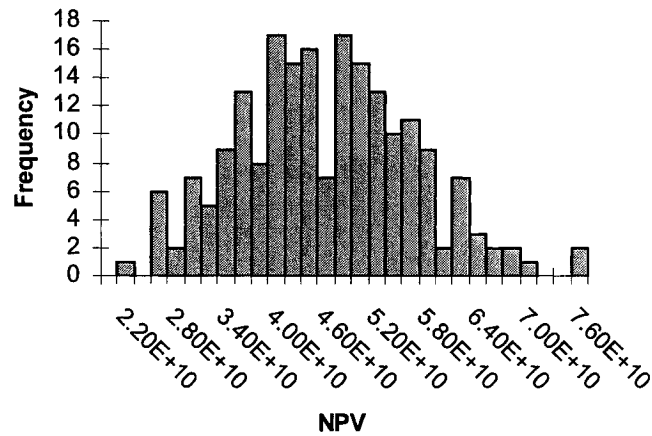
$$c = \begin{cases} 0.41 + 0.01\sqrt{6R} & \text{if } 0 \leq R \leq \frac{2}{3} \\ 0.44 - 0.01\sqrt{6(1-R)} & \text{if } \frac{2}{3} < R \leq 1 \end{cases}$$

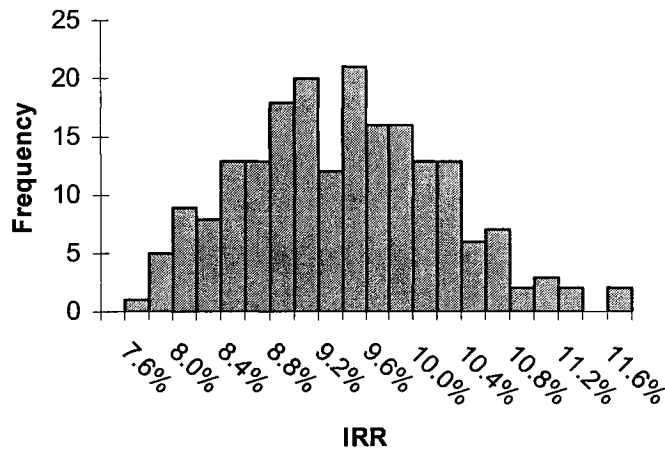
The random variable of express train operation cost is:

$$e = \begin{cases} 0.1 + 0.01\sqrt{2R} & \text{if } 0 \leq R \leq \frac{1}{2} \\ 0.12 - 0.01\sqrt{2(1-R)} & \text{if } \frac{1}{2} < R \leq 1 \end{cases}$$

After each simulation of construction cost, fare revenue, operation cost and cost for rolling stock, we can calculate NPV and IRR. After 200 simulations, the result was sent to Excel and the following graph was generated about the frequency of NPV and IRR. (See Appendix 6 for C++ program)

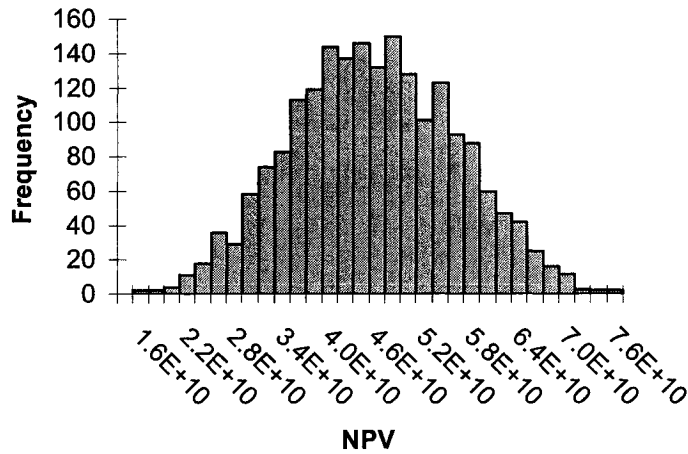
Figure 7-13: Monte Carlo Results – 200x iteration





From these graph we can hardly determine the distribution of the NPV and IRR, so it was simulated 2000 times. This resulted in a well-defined bell shape of IRR and NPV as outlined in Table 7-15. Statistical description of IRR and NPV confirm the following: 95% confident that the NPV is between 2.58 billion RMB and 6.74 billion RMB , IRR between 7.74% and 11.02% and payback period between 15~19 years. (See Appendix 6 for C++ program used for 2000x iteration)

Figure 7-14: Monte Carlo Results – 2000x iteration



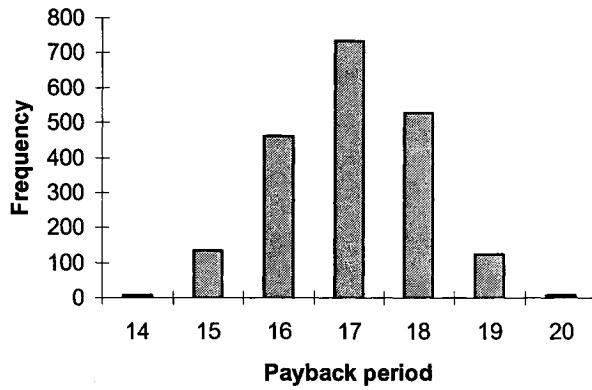
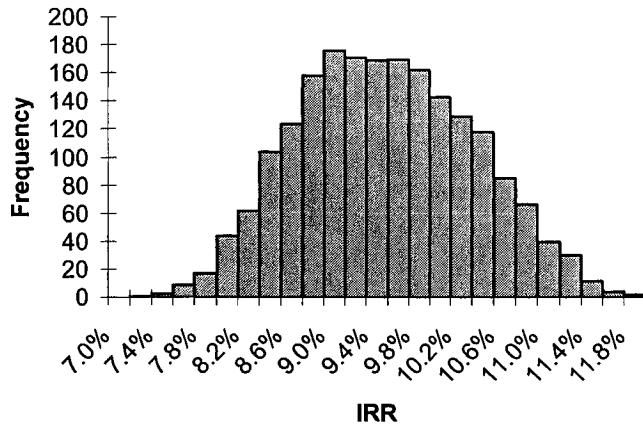


Table 7-15: 2000x statistics data of NPV, IRR and payback period

	NPV (RMB)	IRR	Payback Period (Year)
Min	1.62E+10	7.16%	14
Max	7.62E+10	11.67%	20
Mean	4.66E+10	9.38%	17
Standard deviation	1.04E+10	0.82%	1
95% within	2.58E+10~6.74E+10	7.74%~11.02%	15~19

7.6 Uncertainty analysis of project

7.6.1 Breakeven point of traffic volume

Under precondition of unchanging passenger fare, breakeven point of traffic volume is traffic volume that can make total revenue and total cost even. For the year 2020 with the largest liability, 23 million of passenger traffic density is the breakeven point of traffic volume. From previous analysis, the possibility of passenger traffic density smaller than 23 million for each operation year is very small.

For Beijing-Shanghai high-speed railway, 20 million passengers per kilometer for the first operation year and an increase by 3.29% before 2020 and 2.82% after 2020 will make the Beijing-Shanghai HSR profitable (NPV>0). The passenger density has already reached 18.5 million passengers per kilometer in 2001. It will be definitely more than 20 million after 10 years in 2011 when the Beijing-Shanghai HSR begins to operate.

7.6.2 Sensibility analysis

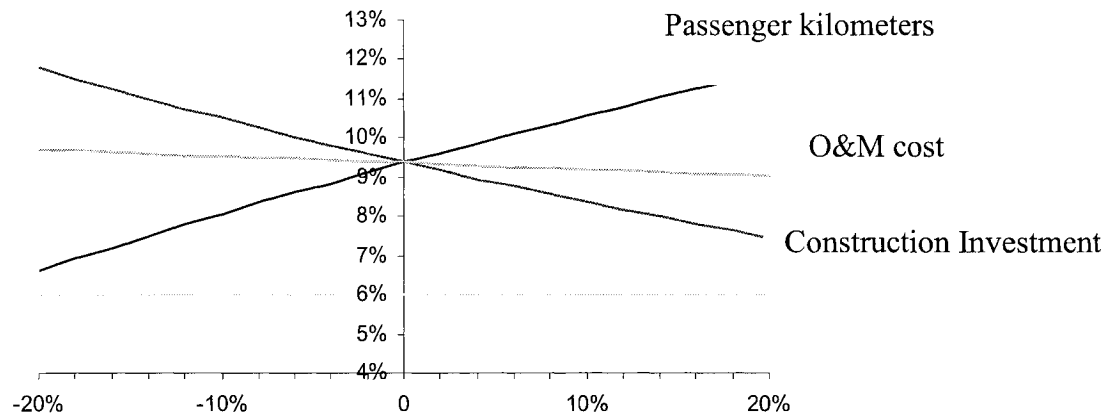
In the model, three cost variables are critical in determining the investment profit: passenger turnover volume, construction cost and operating and Maintenance (O&M) cost per passenger-km.

Table 7-16: sensitivity of passenger-km, construction cost and O&M cost

Factor	Index	-20.0	-10.0	0.0	10.0	20.0
Passenger Kilometers	IRR	6.64%	8.06%	9.38%	10.56%	11.67%
	Payback	21	19	17	16	14
Construction Investment	IRR	11.80%	10.51%	9.38%	8.37%	7.46%
	Payback	14	16	17	18	19
O&M cost	IRR	9.72%	9.55%	9.38%	9.21%	9.03%
	Payback	17	17	17	17	17

Based on the above results, the graph of sensitivity analysis using Microsoft Excel graphing function is as follows:

Figure 7-15: sensitivity of Passenger kilometers, O&M cost and Construction Investment



From the sensitivity analysis, we can see that for Beijing-Shanghai HSR, the most sensitive factors are ridership and construction cost, with O&M a secondary consideration. When above three factors move in their disadvantageous direction by 20% respectively, the IRRs are still higher than the industry benchmark's 6%. Thus, this project's ability to resist against risk is high.

7.7 Economic analysis

Benefit that is generated from this project includes direct and indirect benefits. Apart from the revenue from this project discussed above, the users of this Beijing-Shanghai high-speed railway would also be the direct beneficiaries, and they could choose this new HSR because of the service and price advantages that it offers over other modes. Nonusers will also benefit from this Beijing-Shanghai HSR from reduced congestion and delays on other transportation modes. As traffic is diverted to the new HSR, air and automobile travel will become less congested, benefiting the remaining users of these modes.

Additional indirect benefits come from the merits of HSR as an economic, energy effective, environmentally attractive, and safe mode of intercity transport. Railway offers a more efficient mode of moving people and freight than air travel or highway travel because of frequent service and carrying capacity. Without the Beijing-Shanghai high-speed railway, due to limited capacity of the existing Beijing-Shanghai railway, the volume of railway passenger and freight using other transport modes will increase so that time and transport cost increases. After building the Beijing-Shanghai high-speed railway, large volume of passenger traffic can be transferred from other transport modes such as highway and air to railways, and lots of time and transport cost can be saved, as well as cost on extension or improvement of some relevant lines.

In comparison with air and automobile travel, energy efficiency of railway travel is also an advantage. For example, consumed energy ratio of train, small automobile and airplane is 1:4:5 with the same distance. (National Research Council, 1991) HSR could also utilize power sources that are cleaner than those of competing modes. Since the structure of energy resources is projected to change to more environmentally friendly generation modes, such shifts will also bring the benefit from environmental improvement and electrically powered HSR could reduce dependency on foreign oil. Moreover since the Beijing-Shanghai HSR operates exclusively with the application of improved safety devices, it reduces traffic accidents and increases benefit from passenger transport safety.

New high technologies will be adopted in the Beijing-Shanghai high-speed railway. During the process of technology transfer, technology will be absorbed and equipment will be locally manufactured, consequently it will increase the whole manufacturing level in China.

8.0 Risk analysis of project

The purpose of risk analysis on invested projects is to recognize various risk factors that exist in a project, to reveal the sources of risk factors, to determine influence degree of risk and to offer some countermeasures against risk. The Beijing-Shanghai high-speed railway will adopt new and high technologies. Since the scale of investment is large and completion time of the project is long, it will be a very complicated and tough engineering project. Project risk depends on the whole process of the project. According to time sequence of project progress, this particular project can be divided into two phases: construction/development phase and operating phase. According to risk's manifestation and influence degree at various phases, this project includes 6 kinds of risks: policy risk, technology risk, completion time risk, fund-raising risk, market risk and management risk.

8.1 Policy risk

8.1.1 Risk of land purchasing and residents relocating

According to Section 1 in Article 13 of the latest updated Chinese constitution, citizen's legal private properties cannot be encroached. Because of this regulation, for future operating mode of purchasing land and residents relocating in the infrastructure construction, there will have to be major shifts from past practice in China. In addition, since the price of land per square meter will have a big increase in the future, this will be a risk factor to the control of the total investment scale.

8.1.2 Risk of passenger traffic volume

Due to rapid economy growth in the area between Beijing and Tianjin as well as extension of Beijing districts, the volume of passenger traffic is increasing quickly, so it is becoming more and more necessary to build interurban railway between Beijing and Tianjin. If Beijing-Tianjin interurban light railway is completed before or during the

construction of the Beijing-Shanghai HSR or soon after the opening of the Beijing-Shanghai HSR, it will have a huge impact on the volume of passenger traffic within the Beijing-Tianjin segment of the whole Beijing-Shanghai HSR. This will be a risk factor affecting passenger traffic growth. If dealt with properly, the Beijing-Tianjin interurban light railway could be used to replace the Beijing-Tianjin segment of the Beijing-Shanghai HSR in the short term. The Beijing-Tianjin segment of the Beijing-Shanghai HSR could be constructed after the volume of traffic increases to a certain degree, reducing the total investment of the Beijing-Shanghai HSR.

8.1.3 Risk of implementing Maglev solution

The Chinese government has invested considerable money in building a small segment of Maglev line near Shanghai. If construction of Maglev cannot be continued, it will waste previous investments that have already been made. The current projected plan was to build a Maglev line between Shanghai and Nanjing. If such a line is built to a location other than Nanjing where economic development is not high, profit will not be good. If the government decides to offer preferential policies to build a Maglev line that runs parallel with Beijing-Shanghai high-speed railway between Nanjing and Shanghai, it will have a negative impact on the volume of high-speed railway passenger traffic, which will result in the profit of high-speed railway being affected. The risk is that the Chinese Government, having made a significant investment in Maglev technology, may feel for reasons of image or other political considerations, that it is necessary to continue with the Maglev technology in some way.

8.2 Project management risk

The Beijing-Shanghai HSR is a very large public investment project. Its execution will be contracted out to domestic and foreign enterprises. There is thus a need to choose the enterprise that will be responsible for undertaking the project. For an enterprise,

getting a contract to execute a project, and especially a large one, can be very profitable. Therefore, the managers of these enterprises may be willing to pay a 'commission' to the government officials that help them win the contract and such 'commissions' will be calculated as part of the total cost of the projects. If corruption plays a large role in the selection of contractor, as a result, the capital budget may be highly distorted. Some projects may be much larger and more complex than what they actually need. Some may be of such low quality that they will need continuous repairs, so their output capacity will not meet initial expectations. In these circumstances, capital spending will not generate the results that had been expected.

8.3 Technical risk

Because the Beijing-Shanghai HSR will adopt new high technologies that are different from high technologies used by existing railways, the risk brought by these new technologies is technical risk. High-speed railway technologies are very mature in the world and high-speed railways have already been running for many years in countries such as Japan, France, Germany and Spain. But for the Beijing-Shanghai HSR, it is the first time for China to design and construct it and these technologies are new to China. Some technologies, such as soft soil roadbed disposal and various bridge and tunnel design still need to be mastered in China.

Even though China has already obtained some experimental successes in manufacturing high-speed trainsets, a high-speed railway system is a system integrated with a lot of complex technologies such as mechanization, electrification, automation and new material. These technologies will encounter difficulties of localized manufacture and key of technology transfer.

8.4 Capital risk

The investment in the Beijing-Shanghai HSR is huge, and the total investment may reach around 180 billion RMB based on preliminary estimation. Confronted with this huge amount, it will be very hard for the government to bear all of them within several years, so the government will need to raise funds publicly. Even though some enterprises promise to make some investments in this project, all of money may not be in place on time. So, whether or not the capital can be in place on time will have a direct impact on the Beijing-Shanghai HSR's progress, and it may place the project at risk of being financially impossible.

8.5 Risk of completion time

The main projects that would affect the completion time may include the Yangtze tunnel, the Yellow River Bridge, track laying and soft soil roadbed's disposal.

The Yangtze tunnel and the Yellow River Bridge projects underwater engineering can be greatly affected by geology, climate, hydrology and other unforeseen factors. This may prolong the project's completion time. In addition, due to difficulties with track laying, high-speed trains need continuous-welded rail. The construction of continuous-welded rail has certain seasonal requirements. If the construction is implemented in very hot summer and cold winter, it is hard to guarantee locked rail temperature (rail temperature at zero stress), so this will also influence the HSR's completion time. Finally, subsidence is the main problem of building embankments on soft soil roadbed. This problem already appeared in China's Pudong Maglev line, and this may be another factor in affecting the completion time.

Conclusion and Final thoughts

The Beijing-Shanghai high-speed railway is a subject under a continuous dispute. After an investigation on current situation of traffic demand and forecast of future traffic demand, this research introduces the conclusion that it is imperative to expand the traffic capacity of the Beijing-Shanghai railway. Through comparison of four different proposed technologies on expanding traffic capacity, new HSR technology is demonstrated to be a very mature technology capable of meeting China's traffic requirement in the Beijing-Shanghai corridor while remaining compatible with conventional rails.

The feasibility analysis of this Beijing-Shanghai HSR has focused on the financial analysis. The range of estimated total cost is from \$20 million to \$23 million. Through Monte Carlo simulation, the expected IRR is 9.38%, expected NPV is 4.66E+10 RMB and payback period is 17 years. The analysis concludes that potential passenger traffic demand will be adequate to guarantee profits of the new high-speed railway and it is likely to be self-supporting. Therefore, new HSR technology should be chosen in this project.

Based on the research and investigations, in order for the successful construction and future operation of Beijing-Shanghai high-speed railway, the following recommendations are made for consideration in any project implementation related to the Beijing-Shanghai HSR project:

Firstly, the delay of completion time will enlarge the investment while shortening of the completion time will enlarge the cost. China has no experience in building such a long high-speed railway. Current Chinese politics favor reducing construction time to coincide with the Olympics in 2008. If the completion time is shortened in order to serve the Olympic Game in Beijing in 2008 or the world's fair in Shanghai in 2010, extra cost is needed and also this may cause quality issues. So the project should be implemented on a more gradual schedule to ensure quality of the final project outcome.

Secondly, some core railway stations, such as Beijing and Shanghai stations, need to be increasingly integrated with intracity transportation system. In this fast growing society, time is becoming an important concern in people's lives. If a passenger takes a long time to arrive at railway station or get home from railway station, we can image how this will affect people and people may choose a different transport vehicle such as bus or airplane.

Thirdly, because the new HSR runs through Beijing, Jinan and Shanghai bureau, the Beijing-Shanghai HSR Company should manage the relationship with these three bureaus carefully. Even though Chinese Ministry of Railway takes part in the operation of the Beijing-Shanghai HSR, each local bureau will consider its own profit. If the relationship and management systems are not handled and managed properly among them, it will not make the operation of the HSR run smoothly.

Fourthly, in order to achieve acceptable revenue targets, it is important to reasonably assign the workload of carrying passenger between the new HSR and the old Beijing-Shanghai railway. The new HSR should be scheduled for medium and long-distance passenger transport and the old railway should be used for freight transport and short-distance passenger transport. This will prevent internal competition and conflict among railways.

Fifthly, the railway department should efficiently schedule the departure and arrival of trains at the transportation joints of the trunk line and extensions. For example, higher priority should be set for those medium-speed trains that will run on the HSR in comparison with other medium-speed trains that will not run on the HSR, and this will prevent trains from being late and waiting a lot of time to get onto the HSR.

Sixthly, stock companies need enough return on their investment, so financial benefit should be placed in appropriate places. China wishes to establish a high-speed railway network in the whole country, and the Beijing-Shanghai HSR is just the first HSR of this whole HSR network. Whether this project can make profits or not will affect

investors' interest in future HSRs' construction, generating a direct impact on future HSRs' development. This first investment must be managed carefully and professionally by international standards.

Finally, localized manufacture of the HSR is one of main aims in this project and technology transfer must be handled properly. From the Chinese perspective, the importance of localized manufacture should be understood and agreed to by all international partners. If the attempt of localized manufacture fails in the project, China has to depend on foreign companies again when trying to build other HSR railways. This project should build a strong base for mass production of high-speed railways in China in the future.

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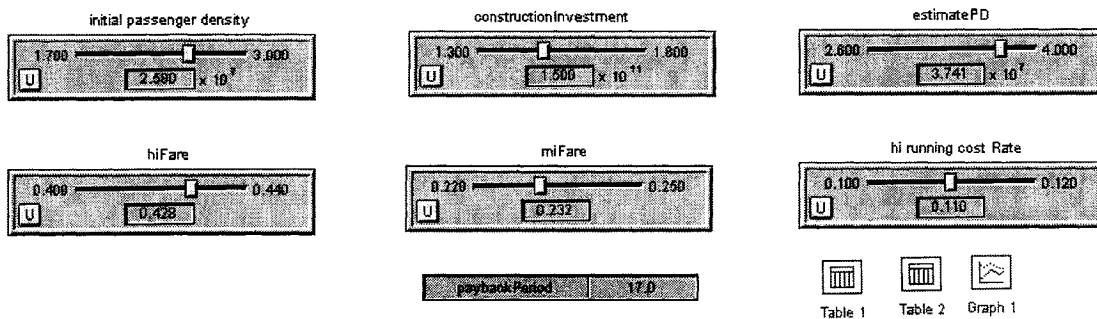
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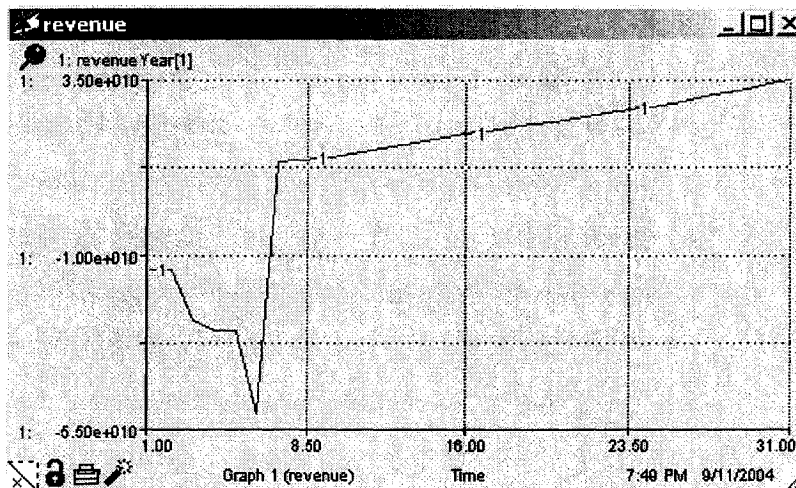
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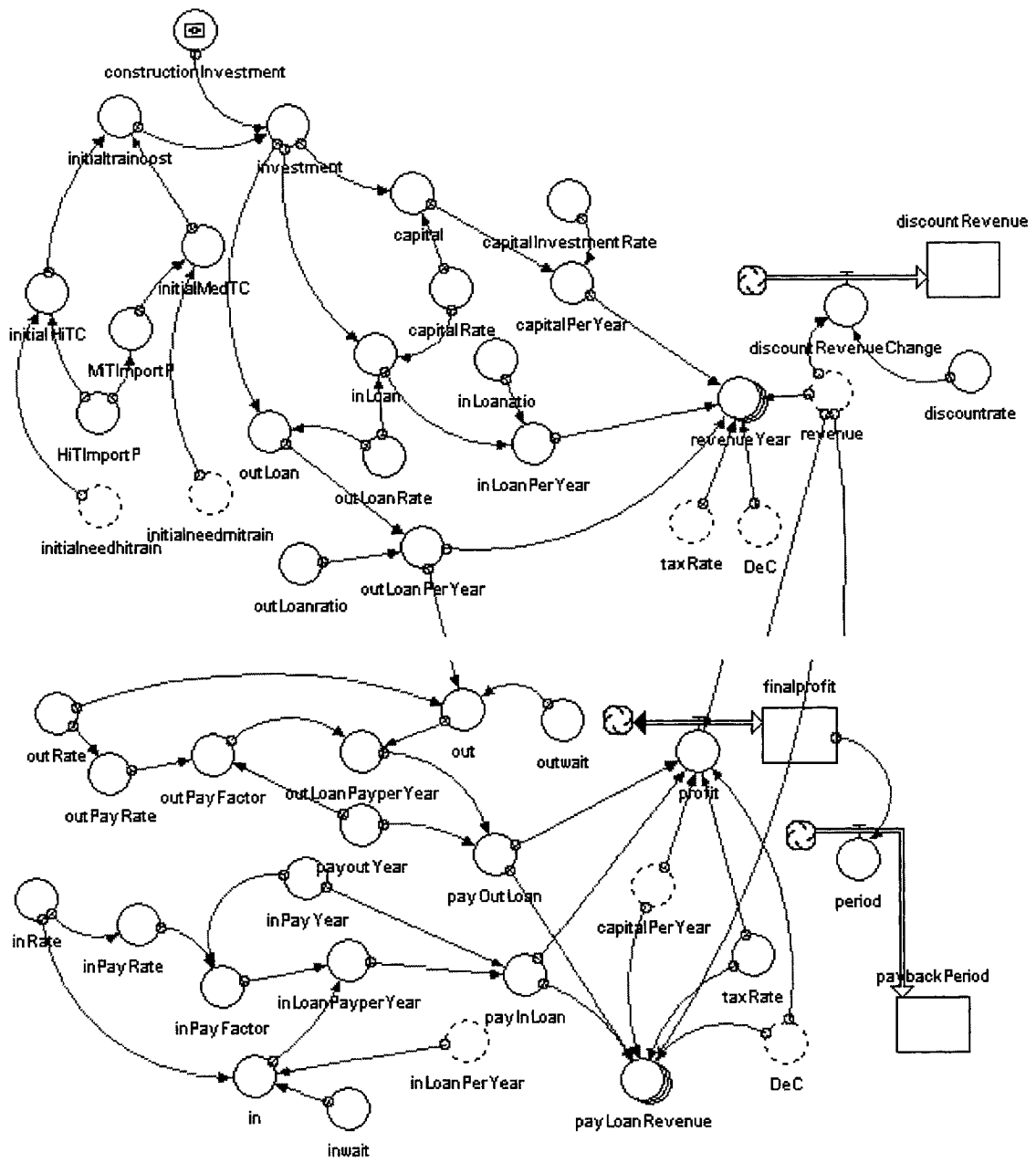
Appendix 1: Stella model

In order to better understand the model and communicate the results with other people, the modeling program Stella is used in the research. Stella provides a very user-friendly interface. The model enables the user to see the cost and revenue under different situations for 30 years. Through the use of panels of slides, investment changes, passenger volume changes, fare changes and maintenance cost changes can be easily made and their effects can be seen immediately. The following figure shows the parameters that have big impact on the model results.



In this Stella model, inaccurately estimated annually passenger volume is considered to better understand the effect of passenger volume on the revenue. The results can show each parameter's change within 30 years including revenue, passenger density, train cost, capital cost, maintenance cost etc. The following figure is an example of revenue within 30 years.





Appendix 2: Carrying capacity utilization

The percentage of carrying capacity utilization is calculated by the following formula.

$$\text{Utilization rate} = (N_p * \text{COC} + N_f + N_m) / \text{Carry Capacity of parallel train working graph}$$

Where

N_p is the number of passenger train;

N_f is the number of freight train

N_m is the number of mail train;

COC is Coefficient of Compensation.

$$\text{Capacity of parallel running graph} = \frac{24 \times 60 \text{ minutes} - \text{time of maintenance window}}{\text{Headway}}$$

Where,

Coefficient of compensation=2.4

Maintenance time of gas engine motor is 30 minutes,

Before 1995 interval between two trains was 8 minutes and after 2000, it is 7 minutes.

It has triple lines between Beijing and Tianjin, the third line can run about 20 cargo trains a day.

Appendix 3: Passenger traffic

Table 1: China National passenger traffic (Statistics China, 2001)

Year	Passenger traffic (10,000 persons)				
	Total	Railway	Highway	Waterway	Civil aviation
1985	620206	112110	476486	30863	747
1986	688212	108579	544259	34377	997
1987	746422	112479	593682	38951	1310
1988	809592	122645	650473	35032	1442
1989	791376	113807	644508	31778	1283
1990	772682	95721	648085	27225	1660
1991	806048	95080	682681	26109	2178
1992	860855	99693	731774	26502	2886
1993	996634	105458	860719	27074	3383
1994	1092881	108738	953940	26165	4038
1995	1172596	102745	1040810	23924	5117
1996	1244722	94162	1122110	22895	5555
1997	1325364	92578	1204583	22573	5630
1998	1376623	92991	1257332	20545	5755
1999	1392502	98253	1269004	19151	6094
2000	1478573	105073	1347392	19386	6722
2001	1534122	105155	1402798	18645	7524

Table 2: National turnover volume of passenger traffic (Statistics China, 2001)

Year	Turnover Volume of Passenger traffic (100,000,000 persons. Km.)				
	Total	Railway	Highway	Waterway	Civil aviation
1985	4437	2416.14	1724.88	178.65	116.72
1986	4897	2586.71	1981.74	182.06	146.31
1987	5411	2843.06	2190.43	195.92	182.95
1988	6209	3260.31	2528.24	203.92	216.95
1989	6075	3037.41	2662.11	188.27	186.79
1990	5628.3	2612.6	2620.3	164.9	230.5
1991	6178.4	2828.1	2871.7	177.2	301.3
1992	6949.4	3152.2	3192.6	198.4	406.1
1993	7858.1	3483.3	3700.7	196.5	477.6
1994	8591.4	3636.1	4220.3	183.5	551.6
1995	9001.9	3545.7	4603.1	171.8	681.3
1996	9142.6	3325.4	4908.8	160.6	747.8
1997	10018.9	3548.3	5541.4	155.7	773.5
1998	10554.3	3691	5942.8	120.3	800.2
1999	11214.5	4050.7	6199.2	107.3	857.3
2000	12261	4532.6	6657.4	100.5	970.5
2001	13155.1	4766.8	7207.1	89.9	1091.4

Table 3: Tianjin-Shanghai passenger traffic, passenger kilometers and passenger traffic density (Statistics China, 2001)

	Passenger traffic (10 000 persons)	Passenger kilometers (1 000 000persons. km.)	Passenger traffic density
1985		29860	2257
1986		32969	2492
1987		36475	2757
1888		41727	3154
1989		39306	2971
1990		35880	2712
1991		38327	2897
1992		42323	3199
1993		44572	3369
1994		45961	3474
1995	9595	44585	3370
1996	8849	39349	2974
1997	8836	39810	3009
1998	8879	40771	3082
1999	9585	45167	3414
2000	9043	47426	3585
2001	9214	49280	3725

Appendix 4: Fund structure of some HSR projects

Project	Investment	Capital		Debt	
		Amount	Ratio	Amount	Ratio
Japan Takasaki-Karuizawa	12.6 billion Japan yuan	6.4 billion Japan yuan	50%	6.3 billion Japan yuan	50%
France TGV EST Paris-Strasbourg	20.5 billion France franc	15.7 billion France franc	76.6%	4.8 billion France franc	23.4%
Spain A Coruña -Vigo	160 billion Spain peseta	160 billion Spain peseta	100%		
Italy HSR by TAV			40%		60%
Korea Seoul-Busan	12.7 trillion Korea won	5.7 trillion Korea won	45%	7.0 trillion Korean won	55%
USA Northeast corridor	\$3 billion	\$2.2 billion	73.4%	\$8 billion	26.6%

(Vlasta Molak, 1997)

Note: Japanese government has made a new principle for future Shinkansen that the government and domestic enterprises afford 65% of expenses.

In Italy, the government will be responsible for all expenses of new HSR.

In Korea, investment partially comes for liability financing signed by Ministry of Finance and enterprises.

Appendix 5: high-speed railway costs in some countries

(Safford, 1990, Eungcheol, 2000 & Gleave, 2004)

Line	Length (km)	Length of bridge (km)	Length of tunnel (km)	Bridge & tunnel percent (km)	Highest speed (km/h)	Build time	Operation Time	Rolling stock	Four electric system	ROW	Engineering Cost	Total
Korea Seoul - Busan	412	112	189	73.06	300	1992-2008	Part in 2002	Cost	1518	1492.75	8479.25	13425
								Cost index	3.68	4.70	20.58	32.58
								Percent	11.31%	14.41%	63.16%	1
Taiwan Taipei - Keelung	345	257	52	89.57	300			Cost	1074.4	289	11237	14399
								Cost index	3.11	0.84	32.57	41.74
								Percent	7.46%	12.49%	78.04%	1
France Sud-Estline	390				270	1976-1983	1981-1983	Cost	403.1	25.78	1555.18	2320.79
								Cost index	1.03	0.07	4.02	5.95
								Percent	17.37%	14.04%	67.48%	1
Italy Turin - Naples	864.5	58.5	41.5	11.57	300	1994-2006		Cost	2223.6	1698.97	10129.23	14051.8
								Cost index	2.57	1.97	11.72	16.25
								Percent	15.82%	12.09%	72.08%	1
Spain Madrid - Seville	471	10	16	5.52	300	1987-1992	1992	Cost	451	750	2233	3434
								Cost index	0.96	1.59	4.74	7.29
								Percent	13.13%	21.84%	65.03%	1

Appendix 6: C++ code for Mote Carlo simulation

```
#include <iostream.h>
#include <fstream.h>
#include <math.h>
#include <iomanip.h>
#include <stdlib.h>
#include <stdio.h>
#include <time.h>

typedef double array[30];

double power(double x,int n);
double IRR(double &NetR);
double NPV(double &NetR);
double payLoan(double rate, int n);
int paybackPeriod(double &NetR);
double deCost(double cost,double deRate,int year);

double power(double x,int n)
{
    double val = 1.0;
    while (n-->0)
        val *=x;
    return(val);
}

double IRR(array &NetR)
{
    double k[30],m[30];
    int i,n;
    double FIRR,FIRR1,FIRR2,FNPV1,FNPV2;

    FNPV1=FNPV2=1e-6;
    FIRR2=0.01;
    while (FNPV2>0)
    {
        FNPV2=0;
        FIRR1=FIRR2;
        m[0]=1+FIRR1;

        FIRR2=FIRR2+0.0001;
        k[0]=1+FIRR2;
        for (i=0;i<29;i++)
        {
            n=i+2;
            m[i+1]=power(m[0],n);
            k[i+1]=power(k[0],n);
        }
        for (i=0;i<30;i++)
        {
            FNPV1+=NetR[i]/m[i];
            FNPV2+=NetR[i]/k[i];
        }
    }
}
```

```

        }
    }

    for (i=0;i<30;i++)
    {
//        cout<<NetR[i]<<" ";
    }

    FIRR=FIRR1;//(FIRR2-FIRR1)*FNPV1/(FNPV1-FNPV2);//the formula is
used to hand calculating
//because FNPV1 is very close to 0, so FIRR1 is more accurate
    return(FIRR);
}

double NPV(array &NetR)
{
    const double discountRate=0.06;
    double fnpv[30],DR[30];
    int i,n;
    double NPV=0.0;

    DR[0]=1+discountRate;
    for(i=0;i<29;i++)
    {
        n=i+2;
        DR[i+1]=power(DR[0],n);
    }
    for(i=0;i<30;i++)
    {
        fnpv[i]=NetR[i]/DR[i];
        NPV+=fnpv[i];
    }
//    cout<<endl;
    return NPV;
}

int paybackPeriod(array &NetR)
{
    double r;
    int i=0;
    r=NetR[0];
    while (r<0)
    {
        i++;
        r+=NetR[i];
    }
    return i;
}

double payLoan(double rate, int n)
{
    double k,a;
    int i;

    k=a=0.0;
    a=1+rate;
    for( i=n;i>0;i--)

```

```

        k+=1/power(a,i);
    return k;
}

double deCost(double cost, double deRate,int year)
{
    double fDeC,DeC;

    fDeC=cost*deRate;
    DeC=fDeC*power((1-deRate),year-1);
    return DeC;
}

void main()
{
    const double hiMedRate=0.6, flucRate=1.1,seatRate=0.75;
    const int year=365, line=1320,hiFixedNo=1000,medFixedNo=1100;
    int
i,j,n,PP,runtimes,randomNo,inWait,outWait,inLoanYear,outLoanYear; //i;
    double HI[30],MED[30];
    double hiTO[30],medTO[30],TO[30];
    double hiR[30],medR[30],fareR[30],R[30],Ran[10000];
    double hiTC[30],medTC[30],TC[30],OC[30];
    double PD[30]; //m;
    double
a,b,HTN,MTN,hiCapacity,medCapacity,inLoanInterest,outLoanInterest,inLoa
nFactor,outLoanFactor;
    double hiFare,medFare,hiOC,medOC,medTP,hiTP,Finvest,FpassengerD;
    double TrainIn,hiIn,medIn,initialIn,Capital,inLoan,outLoan;
    double
CA[30],IL[30],OL[30],NR[30],PIL[30],POL[30],PayILi[30],PayOLi[30];
    double FIRR,FNPV,taxRate,hiDe,medDe,ceDe;
    double
ceC,ceDeFactor,hiDeFactor,medDeFactor,DeC[30],ceDeC[30],hiDeC[30],medDe
C[30];
    double hiTDe[30],medTDe[30],c[30],d[30];

    Finvest=1.5e+011;          //initial construction investment
    ceC=0.7*Finvest;
    ceDeFactor=0.04;
    hiDeFactor=0.05;
    medDeFactor=0.06;
    hiFare=0.43;              //hi-speed train fare
    medFare=0.23;            //med-speed train fare
    hiOC=0.11;               //hi-speed operation cost

    inLoanInterest=0.07;
    outLoanInterest=0.06;
    inWait=4;
    outWait=10;
    inLoanYear=8;
    outLoanYear=7;
    taxRate=0.0324;
    hiDe=0.05;
    medDe=0.06;

```

```

ceDe=0.04;

a=0.0329;          //growth rate in the first 10 year
b=0.0282;          //growth rate after 10 years
medOC=hiOC*0.6;
hiTP=1.3e+008;     //local hi-speed train cost
medTP=3.3e+007*8.28*0.2; //local med-speed train cost
FpassengerD=2.6e+007; //initial passenger Density
HTN=hiMedRate*flucRate/year/seatRate/hiFixedNo;
MTN=(1-hiMedRate)*flucRate/year/seatRate/medFixedNo;
hiCapacity=seatRate*hiFixedNo*year/flucRate;
medCapacity=seatRate*medFixedNo*year/flucRate;

cout<<"please input the run times: ";
cin>>runtimes;
randomNo=runtimes*5;

srand((unsigned)time(NULL));

for(i=0;i<randomNo;i++)
    Ran[i]=(double)(rand())/(double)RAND_MAX; //rand() is
random between 0-RAND_MAX(32767)

for (i=0;i<randomNo;i=i+5)
{
    cout<<"Waiting..."<<endl;

    if (Ran[i]<=0.5)
FpassengerD=(2.4+0.2*sqrt(2*Ran[i]))*1e+07;
    else FpassengerD=(2.8-0.2*sqrt(2*(1-Ran[i]))) *1e+07;

    if (Ran[i+1]<=0.5)
Finvest=(1.3+0.1*sqrt(6*Ran[i+1]))*1e+011;
    else Finvest=(1.7-0.1*sqrt(6*(1-Ran[i+1]))) *1e+011;

    if (Ran[i+2]<=2/3) hiFare=0.41+0.01*sqrt(6*Ran[i+2]);
    else hiFare=0.44-0.01*sqrt(6*(1-Ran[i+2]));

    if (Ran[i+3]<=1/3) medFare=0.22+0.01*sqrt(3*Ran[i+3]);
    else medFare=0.25-0.01*sqrt(6*(1-Ran[i+3]));

    if (Ran[i+4]<=0.5) hiOC=0.1+0.01*sqrt(2*Ran[i+4]);
    else hiOC=0.12-0.01*sqrt(2*(1-Ran[i+4]));

//    cout<<FpassengerD<<" "<<Finvest<<" "<<hiFare<<"
"<<medFare<<" "<<hiOC<<endl;

    initialIn=Finvest;

/*    m[0]=0; //m is a ratio to keep PD growth rate relate to PD
for (n=0;n<11;n++)
{
    m[n+1]=m[n]+0.0003;
}*/
for(j=0;j<30;j++)

```

```

    PD[j]=HI[j]=MED[j]=hiTO[j]=medTO[j]=TO[j]=hiR[j]=medR[j]=fareR[j]
=OC[j]=0;

```

```

    PD[6]=FpassengerD;

```

```

    for (j=6;j<15;j++)
    {

```

```

        PD[j+1]=PD[j]*(1+a);//-m[i]);

```

```

    }

```

```

    for (j=15;j<29;j++)
    {

```

```

        PD[j+1]=PD[j]*(1+b);//-m[i]);

```

```

    }

```

```

    for (j=6;j<30;j++)
    {

```

```

        HI[j]=ceil(PD[j]*HTN);

```

```

    }

```

```

    for (j=6;j<30;j++)
    {

```

```

        MED[j]=ceil(PD[j]*MTN);

```

```

    }

```

```

    for (j=6;j<30;j++)
    {

```

```

        hiTO[j]=HI[j]*hiCapacity*line;
        medTO[j]=MED[j]*medCapacity*line*2/3;
        TO[j]=hiTO[j]+medTO[j];

```

```

    }

```

```

    for (j=6;j<30;j++)
    {

```

```

        hiR[j]=hiTO[j]*hiFare*2;
        medR[j]=medTO[j]*medFare*2;
        fareR[j]=hiR[j]+medR[j];
        fareR[j]=fareR[j]*1.01;

```

```

    }

```

```

    for (j=6;j<30;j++)
    {

```

```

        OC[j]=hiTO[j]*hiOC+medTO[j]*medOC; //unit million

```

```

    }

```

```

    for(j=0;j<30;j++)
    {

```

```

        hiTC[j]=0;

```

```

        medTC[j]=0;
        TC[j]=0;
    }
    for (j=7;j<30;j++)
    {

        hiTC[j]=HI[j]-HI[j-1];
        hiTC[j]=hiTC[j]*hiTP;
        medTC[j]=MED[j]-MED[j-1];
        medTC[j]=medTC[j]*medTP;
        TC[j]=hiTC[j]+medTC[j];

    }

    hiIn=HI[6]*3.3e+007*8.28;
    medIn=MED[6]*0.2*3.3e+007*8.28;
    TrainIn=hiIn+medIn;
    initialIn=initialIn+TrainIn; // initial investment
    Capital=initialIn*0.55;
    inLoan=initialIn*0.3;
    outLoan=initialIn*0.15;

    for (j=0;j<30;j++)
    {
        CA[j]=IL[j]=OL[j]=0;
        PIL[j]=POL[j]=0;
        PayILi[j]=PayOLi[j]=0;
        if (j==0 || j==1)

            CA[j]=Capital*0.15*(-1);

        if (j==2)
        {
            CA[j]=Capital*0.15*(-1);
            OL[j]=outLoan*0.05;
            IL[j]=inLoan*0.25;
        }
        if (j==3 || j==4)
        {
            CA[j]=Capital*0.15*(-1);
            OL[j]=outLoan*0.15;
            IL[j]=inLoan*0.25;
        }
        if (j==5)
        {
            CA[j]=Capital*0.25*(-1);
            OL[j]=outLoan*0.65;
            IL[j]=inLoan*0.25;
        }
    }

    inLoanFactor=payLoan(inLoanInterest, inLoanYear);
    outLoanFactor=payLoan(outLoanInterest,outLoanYear);

    for (j=0;j<outWait+outLoanYear;j++)

```

```

    {
        PIL[j+inWait]=IL[j]*power(1+inLoanInterest,inWait);
POL[j+outWait]=OL[j]*power(1+outLoanInterest,outWait);
    }

for (j=0;j<6+inWait;j++)
{
    PIL[j]=PIL[j]/inLoanFactor;

    for (n=j;n<j+inLoanYear;n++)
        PayILi[n]+=PIL[j];
}

for (j=0;j<6+outWait;j++)
{
    POL[j]=POL[j]/outLoanFactor;

    for (n=j;n<j+outLoanYear;n++)
        PayOLi[n]+=POL[j];
}

for (j=0;j<30;j++)
    ceDeC[j]=hiDeC[j]=medDeC[j]=0;

for (j=6;j<30;j++)
{
    ceDeC[j]=deCost(ceC,ceDeFactor,j-5);
    hiDeC[j]=deCost(hiIn,hiDeFactor,j-5);
    medDeC[j]=deCost(medIn,medDeFactor,j-5);
}

for (j=0;j<30;j++)
{
    hiTDe[j]=hiTC[j]*hiDeFactor;
    medTDe[j]=medTC[j]*medDeFactor;
    c[j]=hiTDe[j];
    d[j]=medTDe[j];
}

for (j=7;j<30;j++)
{
    hiTDe[j]=hiTDe[j-1]*(1-hiDeFactor)+c[j];
    medTDe[j]=medTDe[j-1]*(1-medDeFactor)+d[j];
}

for (j=0;j<30;j++)
DeC[j]=ceDeC[j]+hiDeC[j]+medDeC[j]+hiTDe[j]+medTDe[j];

for (j=0;j<6;j++)
    R[j]=0;

```

```

        for (j=6;j<30;j++)
        {
            R[j]=(fareR[j]-TC[j]-OC[j]-PayILi[j]-PayOLi[j]-
DeC[j])*(1-taxRate);

        }

        for (j=0;j<30;j++)
        {
            NR[j]=CA[j]+R[j];

//            cout<<NR[j]<<" "; // revenue
        }

        FIRR=IRR(NR);

        FNPV=NPV(NR);

        PP=paybackPeriod(NR);

        ofstream file1("hispeed.txt",ios::app);
        file1 <<setiosflags(ios::scientific)<<PD[6]<<" "
            <<Finvest<<" "<<initialIn<<"
"<<resetiosflags(ios::scientific)
            <<hiFare<<" "<<medFare<<" "<<hiOC<<" "<<FIRR<<" "
            <<setiosflags(ios::scientific)<<setw(8)<<FNPV
            <<resetiosflags(ios::scientific)<<" "<<PP<<endl;
        file1.close();

    }
}

```