An Examination on Viable Pricing Strategies for the Chuo Shinkansen Maglev in Japan

by

Ryota Yasutomi

M.E., Mechanical Engineering, Kyoto University, 2006
B.E., Mechanical Engineering, Kyoto University, 2004

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Signature of Author: Signature redacted

Department of Civil and Environmental Engineering
May 19, 2016

Certified by: Signature redacted

Joseph M. Sussman
JR East Professor of Civil and Environmental Engineering and Engineering Systems
Thesis Supervisor

Accepted by: Signature redacted

Heidi Nepf
Donald and Martha Harleman Professor of Civil and Environmental Engineering
Chair, Graduate Program Committee

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Abstract

The Chuo Shinkansen Maglev project is the world's first application of the Superconducting Maglev for High-Speed Rail (HSR), which will provide a dramatic travel time saving for the main artery of Japan, the Tokyo-Nagoya-Osaka corridor. While the project is expected to bring a large economic and social benefit, it is required to be long-term/two-phase project, with 18-year long interval between the commencement of Tokyo-Nagoya in 2027 and that of Nagoya-Osaka in 2045, since the project has to be financed solely by a private company, Central Japan Railway Company (JR Central). In order to shrink the total project period and the long interval between two phases, the improvement in the financial viability of JR Central after the Tokyo-Nagoya operation is critical.

The thesis examines viable pricing strategies of the Chuo Shinkansen Maglev, in terms of the determination of the fare level as well as the application of dynamic pricing, taking into account some unique specifications of the Chuo Shinkansen Maglev.

First, the thesis proposes a framework to support the fare level determination of the Chuo Shinkansen Maglev. As a cost side approach, the upper-limit fare constrained by the full-cost principle regulation in Japan is discussed. As a demand side approach, the willingness to pay for the travel time saving of the Chuo Shinkansen Maglev, in comparison to the Tokaido Shinkansen, is analyzed. Based on the framework, the thesis suggests the appropriate scope of the fare level and proposes the implementation plans for the fare structure of the Chuo Shinkansen Maglev.

Second, this thesis proposes the application of dynamic pricing for the Chou Shinkansen Maglev, as a tool to increase the profitability of the project. The dynamic pricing behavior of TGV Paris-Lyon and Acela Express in Boston-New York-Washington DC are benchmarked from the customers' perspective. Based on the observed pricing behavior of each operator, as well as the specifications and market situation of the Chuo Shinkansen Maglev, the thesis recommends the customer-friendly pricing strategy, which can soften the negative impression of the price gouging, would be suitable in order to achieve the successful implementation of the dynamic pricing for the Chuo Shinkansen Maglev.

Thesis Supervisor: Joseph M. Sussman
Title: JR East Professor of Civil and Environmental Engineering and Engineering Systems

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Ryota "Tommy" Yasutomi

Cambridge, MA

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List of Abbreviations

DCA	Driving Control System
JNR	Japan National Railway
JR East	East Japan Railway Company
JR Central	Central Japan Railway Company
JR Freight	Japan Freight Railway Company
JR Kyushu	JR Kyushu Railway Company
JR Shikoku	Shikoku Railway Company
JR West	West Japan Railway Company
JR Hokkaido	Hokkaido Railway Company
JRTT	Japan Railway Construction, Transport and Technology Agency
HSR	High-Speed Rail
LCC	Low Cost Carrier
Maglev	Magnetic Levitation
MLIT	Ministry of Land, Infrastructure, Transportation and Tourism, Japan
NEC	Northeast Corridor (the United States)
NITAS	National Integrated Transport Analysis System
NSDA	Nationwide Shinkansen Railway Development Act
POCL	Paris-Orleans-Clermont-Ferrand-Lyon (France)
PCS	Power Conversion System
RM	Revenue Management
RTRI	Railway Technical Research Institute (Japan)
SCGE	Spatial Computable General Equilibrium
SC Maglev	Superconducting Magnetic Levitation
SHC	Shinkansen Holding Corporation
SNCF	Societe Nationale des Chemins de Fer Francais (France)
TPC-CSS	Transport Policy Council Chuo Shinkansen Subcommittee
WTP	Willingness to pay
YMTL	Yamanashi Maglev Test Line

Chapter 1 Introduction and Motivation

On December 25 2007, Central Japan Railway Company (JR Central) proposed a plan to build the second High-Speed Rail (HSR) linking Tokyo-Nagoya-Osaka, with the world-first application of the Superconducting Magnetic Levitation (SC Maglev) technology as an operating system. The new HSR, "the Chuo Shinkansen Maglev", is expected to cut the travel time between Tokyo and Osaka from the current 142 minutes[1] via the Tokaido Shinkansen[2] to 67 minutes. Since the Tokyo, Nagoya, and Osaka metropolitan areas and the other JR Central's operating areas along Tokyo-Nagoya-Osaka corridor accounts for 60.0% of the total population in Japan and 64.5% in the total GDP in Japan (Central Japan Railway Company 2015b), the Chuo Shinkansen Maglev is expected to bring a large impact on the nationwide economy as well as people's lifestyle along the prospective route.

The plan of building the second HSR in the Tokyo-Nagoya-Osaka corridor as the alternative of the Tokaido Shinkansen is not new. The route proposed by JR Central has already been stipulated as the "Chuo Shinkansen" in the basic plan built by the Ministry of Land, Infrastructure, Transportation and Tourism, Japan (MLIT) in 1973, based on Nationwide Shinkansen Development Act (NSDA). However, the plan has been suspended for more than 40 years mainly because of the limited government budget. JR Central's proposal ended up with breaking the long-lasted suspension of the Chuo Shinkansen project, which is enabled by the adoption of Maglev technology developed up to a practical level and by the adoption of the unprecedented financial scheme as a large-scale HSR project, in which JR Central is expected to bear the whole construction cost (estimated as ¥9 trillion ($75 billion[3])) as well as the operating cost without any subsidies from the government.

In order to secure financial safety as a private company throughout the project period, the project should be financed largely by JR Central's retained earnings, so that the issuance of new long-term debt should be restrained. As a result, the Chuo Shinkansen Maglev project is required to be two-phase project with a long interval period. The commencement of the Tokyo-Nagoya operation (First phase) is scheduled to be in 2027, and the commencement of the Tokyo-Osaka

[1] As of May 2016
[2] According to the timetable as of 2015
[3] We use $1=¥120 as a currency exchange rate throughout the thesis, unless otherwise noted.

operation (Second phase) is scheduled to be in 2045. This 18-year long interval between 2027 and 2045 is expected to restrain the benefit for the travelers from Tokyo to western cities located further west from Nagoya, which currently accounts for the majority of passenger flow in Tokyo-Nagoya-Osaka corridor. Therefore, in order to shrink the project period, the improvement in the financial viability of JR Central especially after the first-phase (Tokyo-Nagoya) commencement is critical.

While the SC Maglev technology has been already developed up to a practical level for revenue service, there is still a room to improve profitability by building a competitive operating strategy. Among various approaches in order for the profit maximization, the thesis focuses on pricing strategy of the Chuo Shinkansen Maglev.

The initial fare of the Chuo Shinkansen Maglev should be strategically decided upon, since rail fare in Japan is partly regulated by a law and thus it is politically difficult to change the fare responsively in accordance with the change in the business condition. Also, due to the parallel operation with the Tokaido Shinkansen, the appropriate differentiation of the fare of the Chuo Shinkansen from the fare of the Tokaido Shinkansen is critical for the overall profit maximization. This is discussed in Chapter 4 in this thesis.

In addition to the determination of the fare level, recent practices in the world's HSRs shows that the introduction of the dynamic pricing is another effective methodology to improve revenue without substantial increase in cost. So far, JR Central has adopted fixed fare system for the Tokaido Shinkansen, except a few kinds of discounted tickets with conservative discounts. The thesis recommends that an application of dynamic pricing should be considered for the Chuo Shinkansen Maglev in an appropriate way rather than keeping the current fixed fare system (Chapter 5).

Once a firm implements a specific fare system, it is not easy for the firm to change it. For example in Japan, since all JR companies (JR Central, JR East, and other JRs) use a shared ticket distribution system, it requires substantial costs to modify the pricing system. Also, since the upper bound of fare is regulated by the full-cost principle explained in Chapter Chapter 2, the fare increase often requires time-consuming legal process. Therefore, the pricing strategy of the Chuo Shinkansen Maglev should be examined before the commencement of the operation.

1.1 Thesis Purpose

To the best of the author's knowledge, there is no academic research specifically on pricing strategy of the Chuo Shinkansen Maglev. The thesis is aimed to offer a comprehensive discussion regarding the pricing strategy of the Chuo Shinkansen Maglev from two perspectives: the determination of the appropriate fare level and the application of dynamic pricing.

First, in order to discuss specific pricing strategies for the Chuo Shinkansen Maglev from these perspectives, some peculiar specifications of the Chuo Shinkansen Maglev should be taken into account. This is described in the following sections in Chapter 1.

After the review of pricing theory in rail transport in Chapter 2 and literature review in Chapter 3, the thesis proposes a framework to examine the fare level of the Chuo Shinkansen Maglev in Chapter 4. Based on the framework, first, the rational fare range in the context of price regulation in Japanese rail transport is proposed. Then, the appropriate fare level for the Chuo Shinkansen Maglev is discussed based on a proposed model with the value of travel time saving.

In order to analyze the application of dynamic pricing, the thesis examines the actual pricing behavior of two HSRs in other countries which have adopted dynamic pricing in Chapter 5: SNCF's TGV in Paris-Lyon and Acela Express in Amtrak Northeast Corridor (NEC). The differences in the pricing behavior between two HSRs are analyzed by the customers' perspectives. After the review of the specifications of the Chuo Shinkansen with respect to TGV, Acela, and the Tokaido Shinkansen, and the review of the projected market condition in Tokyo-Nagoya-Osaka corridor, recommendations are given regarding the introduction of dynamic pricing for the Chuo Shinkansen Maglev.

1.2 The Chuo Shinkansen Maglev Project

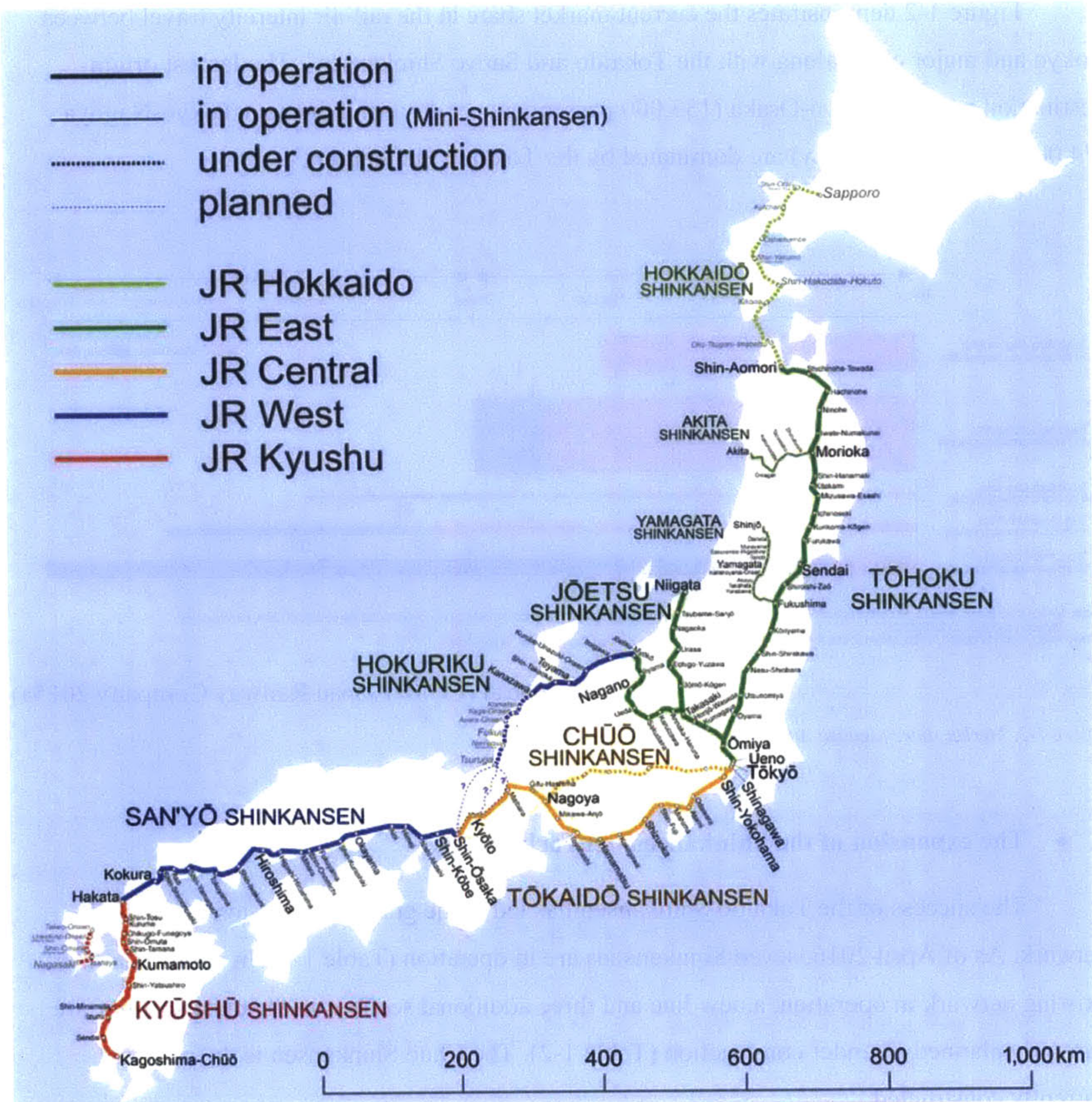
1.2.1 Background

- **The Tokaido Shinkansen**

Figure 1-1 demonstrates the HSR network in Japan as of April 2015. The world-first HSR, the Tokaido Shinkansen, started operation in 1964 between Tokyo and Osaka in Japan. By the mid-1950s, a conventional rail line existing in the corridor was heavily saturated with both passenger and freight trains, and was seriously congested (Kasai 2003). The lack of the capacity in the corridor was a bottleneck for the Japanese economy because these three metropolitan area were the centers of business in Japan; thus there was clearly a need to build additional transportation capacity. At that time, most of the Japanese railway network was owned and operated by a state-owned company, Japan National Railway (JNR). In order to maximize the capacity of the Tokyo-Nagoya-Osaka corridor, JNR developed the current Tokaido Shinkansen system, on which track for high-speed trains and that for conventional trains are physically separated. When JNR planned to build several successive Shinkansens (Figure 1-1), it also adopted this "separate and dedicated" track structure.

Today, the Tokaido Shinkansen works as the main transportation artery linking Japan's principal metropolitan areas of Tokyo, Nagoya, and Osaka. It is the most densely scheduled HSR in the world with 15 trains per hour per direction in a peak hour. In FY2014, the average of 350 trains per day were operated on the Tokaido Shinkansen (Central Japan Railway Company 2015b) and 157 million passengers used the Tokaido Shinkansen.

In addition to the high frequency, safety and punctuality of the Tokaido Shinkansen are also noteworthy. The Tokaido Shinkansen has suffered no train accidents resulting in fatalities of passengers onboard since the beginning of the operation in 1964. As for on-time performance, the Tokaido Shinkansen keeps on-time operation with annual average delay of 0.9 minutes per train in 2013 (Suyama 2014).

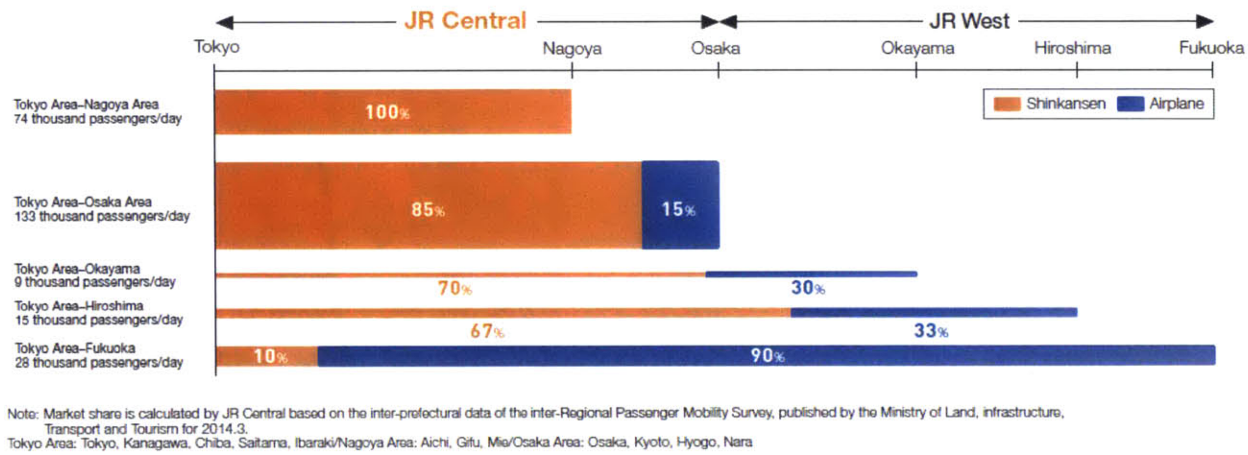


A part of the Hokkaido Shinkansen (From Shin-Aomori to Shin-Hakodate-Hokuto) began operation in March 2016, which is not reflected in the map.

Source: Wikipedia (https://en.wikipedia.org/wiki/Shinkansen)

Figure 1-1: High-Speed Rail (Shinkansen) map in Japan

Figure 1-2 demonstrates the current market share in the rail-air intercity travel between Tokyo and major cities along with the Tokaido and Sanyo Shinkansen[4]. The largest origin-destination market, Tokyo-Osaka (133,000 passengers per day), and the next Tokyo-Nagoya (74,000 passengers per day) are dominated by the Tokaido Shinkansen.



Source: JR Central (Central Japan Railway Company 2015a)

Figure 1-2: Market share (against Airlines)

- **The expansion of the Shinkansen network**

The success of the Tokaido Shinkansen has led to the gradual expansion of the HSR network. As of April 2016, seven Shinkansens are in operation (Table 1-1). In addition to the existing network in operation, a new line and three additional sections in the existing lines are currently planned or under construction (Table 1-2). The Chuo Shinkansen is the new line currently constructed.

[4] JR Central and JR West offer direct trains from Tokyo through Hakata.

Table 1-1: Overview of Shinkansens

Name of Shinkansen	Start Station	End Station	Length		Operator	Opened
			km	mile		
Tokaido	Tokyo	Shin-Osaka	515	320	JR Central	1964
Sanyo	Shin-Osaka	Hakata	554	344	JR West	1972–1975
Tohoku	Tokyo	Shin-Aomori	675	419	JR East	1982–2010
Joetsu	Omiya	Niigata	270	168	JR East	1982
Hokuriku	Takasaki	Kanazawa	345	215	JR East and JR West	1997–2015
Kyushu	Hakata	Kagoshima-Chuo	257	160	JR Kyushu	2004–2011
Hokkaido	Shin-Aomori	Shin-Hakodate-Hokuto	148	92	JR Hokkaido	2016

Source: (Central Japan Railway Company 2015b; East Japan Railway Company 2015a; West Japan Railway Company 2015)

Table 1-2: Overview of construction project planned or currently underway

Name of HSR line	designated route	Current project status (and estimated opening)	Constructor	Operator
Chuo Shinkansen	Tokyo-Nagoya-Osaka	**Tokyo-Nagoya: Under construction (FY2027)** **Nagoya-Osaka: planned (FY2045)**	JR Central	JR Central
Hokuriku Shinkansen	Tokyo-Kanazawa-Osaka	Tokyo-Takasaki: Shared with the Joetsu Shinkansen Takasaki-Nagano: Opened in 1997 Nagano-Kanazawa: Opened in 2015 **Kanazawa-Tsuruga: Under construction (FY2022)** **Tsuruga-Osaka: planned (TBD)**	JRTT	JR West
Kyushu Shinkansen (Nagasaki route)	Fukuoka-Nagasaki*	**Takeo Onsen-Nagasaki: Under construction (FY2022)**	JRTT	JR Kyushu
Hokkaido Shinkansen	Aomori-Sapporo	Shin Aomori-Shin Hakodate Hokuto: Opened in 2016 **Shin Hakodate Hokuto-Sapporo: Under construction (FY2030)**	JRTT	JR Hokkaido

* Hakata station (Fukuoka) - Takeo Onsen section is planned to share the track with the conventional line instead of building a dedicated HSR track, by using the Gauge Change Train, which is currently developed and expected to be operated in both the HSR track (gauge width 1435mm) and the conventional rail track (gauge width 1067mm).

Source: (Ministry of Land, Infrastructure, Transport and Tourism 2015)

- **Division and privatization of JNR**

Aside from the expansion of the Shinkansen network, another important aspect of the history of the Japanese railway industry is the division, and privatization of JNR in 1987. JNR's inflexible management could not deal with the rapid motorization in 1960s-70s and increased its debt sharply (Kasai 2003). JNR accumulated debt of ¥37 trillion ($308 billion) at the end of its life in 1987. In addition to the increasing threat from the rapid motorization, the JNR's labor union significantly contributed to the low-level of productivity (Kasai 2003).

In order to stop the growth of JNR's debt, the government divided JNR into six regional passenger railway companies JR Hokkaido, JR East, JR Central, JR West, JR Shikoku, and JR Kyushu and a freight railway company JR Freight operating nationwide. According to Kasai, the regional division scheme was adopted mainly in order to divide JNR passenger service into two groups: One group comprises JR East, JR Central, and JR West, which are allowed to serve populated operating area such as Tokyo, Nagoya, and Osaka metropolitan areas in the main Honshu Island in Japan. They seemed to be commercially viable entities without any subsidization. The other group comprises JR Hokkaido, Shikoku, and Kyushu, which operate trains in less-populated area; thus they require government subsidy to keep a certain level of rail services in these areas.[5] Division of nationwide standardized passenger service in JNR according to the operating area was intended to increase efficiency in management and accountability of subsidization from the government.

In order to understand the background of the Chuo Shinkansen Maglev project and the financial challenge of JR Central, it is worthwhile to describe the managerial scheme on the Shinkansens adopted at the division and privatization in 1987 and its historical transition in following years. According to the division scheme adopted by the Japanese government, all railway infrastructure except HSRs (Shinkansen) were regionally divided and allocated to each passenger JRs. As of 1987, the Tokaido Shinkansen, the Sanyo Shinkansen, the Joetsu Shinkansen, and a part of the Tohoku Shinkansen were in operation. Land and the surface infrastructure such as tracks, bridges, tunnels, and signal systems of these Shinkansens were taken over by a state-owned infrastructure entity, the Shinkansen Holding Corporation (SHC) and leased to each operator (JR East, JR West, or JR Central) with imposing infrastructure charges. Although each operator did not own the surface facilities, each operator was required to maintain those facilities by their own budget.

The SHC scheme was originally aimed to repay the JNR's loan early but also aimed to balance the profitability of these three companies (Kasai 2007). The SHC bore ¥8.5 trillion ($71 billion) debt, which is equivalent to the market value of the land and infrastructure of Shinkansens as of 1987[6]. In order to secure the source of the repayment of ¥8.5 trillion ($71 billion) debt, the sum of the annual infrastructure charge for JR East, JR Central and JR West

[5] The freight service was taken over by a nationwide freight company, JR Freight. JR Freight basically does not own tracks and operates freight trains on tracks owned by passenger railway companies, with paying infrastructure charges.

[6] The reason why the value of the land and infrastructure was revalued to the market value is to make the SHC bear as large debt as possible in order to repay the debt of JNR. The book value of the asset was ¥5.65 trillion ($47 billion), which is much smaller than the market value of ¥8.5 trillion ($71 billion). Although JNR went bankrupt with a huge debt, the profitability of the Shinkansens was promising.

was fixed to about ¥710 billion ($5.9 billion). This amount was allocated to three companies in accordance with the passenger-km and each Shinkansen's market value of the land and infrastructure of the SHC revalued every two years.

The SHC scheme had two fatal points as a privatization of a public rail entity. First, the substantial debt of the JRs in their balance sheets were unclear and murky, because the debt amount depended not only on the market value of the assets but also the other JR's operating performance under the revaluation scheme. Second, JRs did not own the Shinkansen infrastructure but was obliged to maintain and repair it by their own capital. The operators could not put the depreciation cost on their income statement. This forced them to increase their debt, because they could not make necessary investment by their small retained earnings[7].

A few years after the inauguration of these three JRs, their financial performance turned out to be better than expected. The listing on the Tokyo Stock Exchange started to be intensively discussed in the Japanese Parliament and in public via the media in order to reduce the JNR's debt taken over by the government. However, the Tokyo Stock Exchange required for JRs to fix their murky balance sheet due to unclear substantial debt based on the SHC scheme. Eventually, the SHC was disbanded in 1991, just four years after its inauguration. The land and infrastructure of each Shinkansen was bought by each operator (three JRs) at the revalued market value as of 1990, which was total ¥9.2 trillion ($77 billion) and allocated to each JR according to the profitability of each company[8]. JR Central took over the Tokaido Shinkansen assets, by making ¥5 trillion ($42 billion) long-term debt in nominal value. Although JR Central had to put ¥5 trillion ($42 billion) debt in its balance sheets in 1991, the amount has been significantly reduced, due to the increasing operating profits and long-lasting low interest rate in Japan.

If the SHC scheme had not been abandoned at that time, the profitability of the Tokaido Shinkansen would have been lower than the current condition and therefore the decision to launch the Chuo Shinkansen Maglev would not have been realized (Kasai 2007). The release from the SHC scheme enabled JR Central to make the necessary investments by its retained earnings, by taking advantage of the depreciation cost on its income statement. Otherwise, JR

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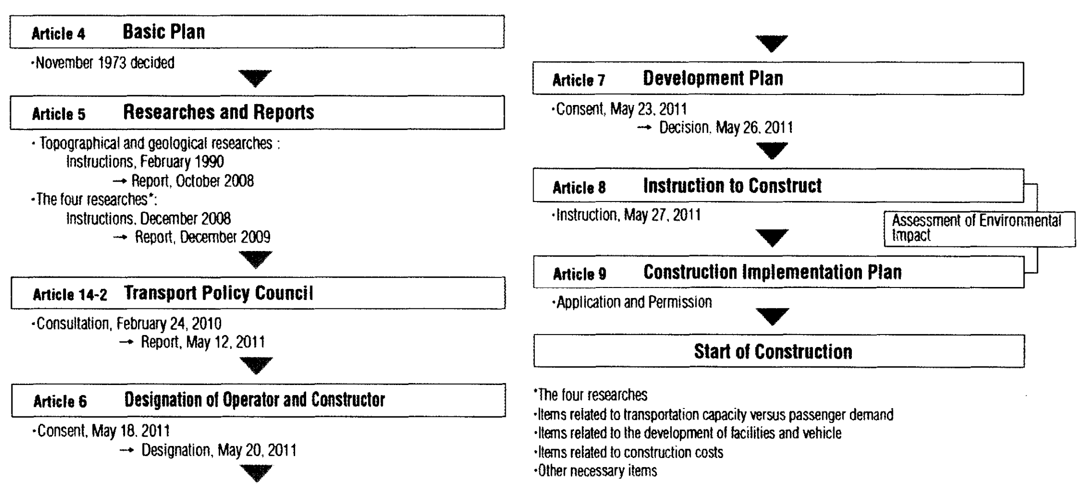
[7] There are much more interesting arguments regarding the flaws of the SHC scheme. If interested, please see Kasai(2007), and Makido (1990).

[8] The price of each HSR was determined by the government to reflect "replacement value" instead of its original construction cost. Therefore, the construction cost of the Tokaido Shinkansen is the cheapest among other Shinkansens (see "*Japanese National Railways: Its Break-up and Privatization*" for further information), but it was valued the highest according to the profitability.

Central could not have invested enough capital to increase the operating speed and the frequency of the Tokaido Shinkansen. Hence, JR Central would not have enough ability to finance the Chuo Shinkansen.

- **Procedure for a new HSR construction in Japan**

The construction of a new HSR is regulated by the Nationwide Shinkansen Railway Development Act (NSDA), established in 1970 and last amended in 2002. When JNR was privatized, most of laws regarding the construction and operation of JNR railway lines were abolished or integrated into the Railway Business Act and Railway Operation Act, which were intended for private railway companies. However, NSDA has not been abolished at the privatization because of the strong political support for the construction of Shinkansen. In fact, the Tohoku Shinkansen (from Morioka to Shin-Aomori segment), the Hokuriku Shinkansen, the Kyushu Shinkansen, and the Hokkaido Shinkansen were built based on the NSDA. Figure 1-3 shows the flow of the procedure based on the NSDA regarding the Chuo Shinkansen project.



Source: (Central Japan Railway Company 2015a)

Figure 1-3: Flow of the procedure of the Chuo Shinkansen project based on NSDA

1.2.2 Brief History of the Chuo Shinkansen Maglev project

The Chuo Shinkansen was stipulated as one of the 12 prospective lines (total 3,510km or 2181mile) in the basic plan in 1973. However, the project had been frozen for decades because of the following reasons:

- The government budget for public investment became limited due to the huge increase in government debt.
- Other Shinkansen projects (such as the Tohoku Shinkansen, the Hokuriku Shinkansen, and the Kyushu Shinkansen), which aimed to build a vast HSR network linking Tokyo and regional centers in Japan, were more prioritized than the Chuo Shinkansen. Those projects are strongly supported by a large number of local communities and thus politically backed up by Diet members elected by the regions.

- **SC Maglev technology development**

Railway Technical Research Institute (RTRI), which was the subordinate organization of JNR prior to the privatization in 1987, started the research on a linear motor propulsion system two year prior to the commencement of the Tokaido Shinkansen operation. The system was intended to become a next generation high-speed surface transportation, which is expected to connect Tokyo and Osaka within one hour journey. In 1977, RTRI built 1.3km (0.8mile) Miyazaki text line in Kyushu Island, in order to conduct fundamental tests. On the Miyazaki test track, RTRI recorded the world-fast maximum running speed at that time as 517km/h (321mile/h) in 1979 (Sawada 2011). The basic technology of the SC Maglev had been developed by RTRI until its privatization in 1987. Since the Miyazaki test line did not have tunnels, curves, or gradients, a longer test line with these practical features was required. The construction of the Yamanashi Maglev Test Line (YMTL) was decided in 1989, two years after the privatization of JNR, and began in 1990. Since the decision of the construction of the YMTL, JR Central has been in charge of the development of the SC Maglev with the cooperation of RTRI. The construction of the YMTL began in 1990 and the 18.4km (11.4mile) primary section was completed in 1997.

Various tests were conducted in order to develop the functions required in revenue service, such as high-speed passing tests, multiple train control tests, and five car trainset running tests. The maximum speed of 552 km/h was recorded in 1999. In 2003, the SC Maglev technology received an evaluation at Maglev Technological Practicality Evaluation Committee (organized by MLIT), in which the committee states that "Superconducting Maglev technology has reached a stage that makes it a viable ultra-high speed mass transportation system" (Ishii

2007). In 2005, the committee evaluated the SC Maglev technology as follows: "all the technologies of the Superconducting Maglev necessary for the future revenue service were established as a result of great progress in running tests and technological developments by the end of FY 2004" (Sawada 2011).

In 2006, JR Central decided to invest ¥355billion ($3.0billion) in order to improve the experimental facilities in the test line and to extend the 18.4km (11.4mile) line to 42.8km (26.6mile) in order to evaluate more practical features regarding revenue operation, such as the 12-car trainset operation, long-distance durability, and the establishment of maintenance schemes. The construction of the entire 42.8km (26.6mile) line was completed in 2013. The 42.8km test line is intended to become a part of the revenue line after the commencement of the Chuo Shinkansen Maglev operation.

- **After the proposal in 2007**

In 2007, JR Central proposed the plan to build a new HSR linking Tokyo, Nagoya, and Osaka metropolitan areas by applying the SC Maglev technology. JR Central regarded the new line as the "Chuo Shinkansen", which was stipulated in the basic plan based on the Nationwide Shinkansen Railway Development Act (NSDA) more than decades ago. Based on the procedure required by NSDA (Table 1-2), JR Central and JRTT conducted the research on the topological and geographic issues, demand and cost, operating technology, and public opinions of residents along with the prospective line.

In May 2011, after a-year long discussion, Transport Policy Council Chuo Shinkansen Subcommittee (TPC-CSS)[9] submitted the final report, which includes the benefits and feasibility of the Chuo Shinkansen project proposed by JR Central (Transport Policy Council Chuo Shinkansen Subcommittee 2011). This report led to the approval of the plan by the minister of the MLIT. At this time, JR Central was legally designated as a principal constructor as well as a principal operator of the Chuo Shinkansen based on the NSDA procedure.

After the designation as a principal constructor of the Chuo Shinkansen Maglev, JR Central has conducted Environmental Impact Assessment between Tokyo and Nagoya. It

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[9] Transport Policy Council is a standing advisory council in MLIT, which comprises experts in a transportation policy. Transport Policy Council Chuo Shinkansen Subcommittee (TPC-CSS) is a legal advisory panel based on the NSDA, which is organized in March 2010.

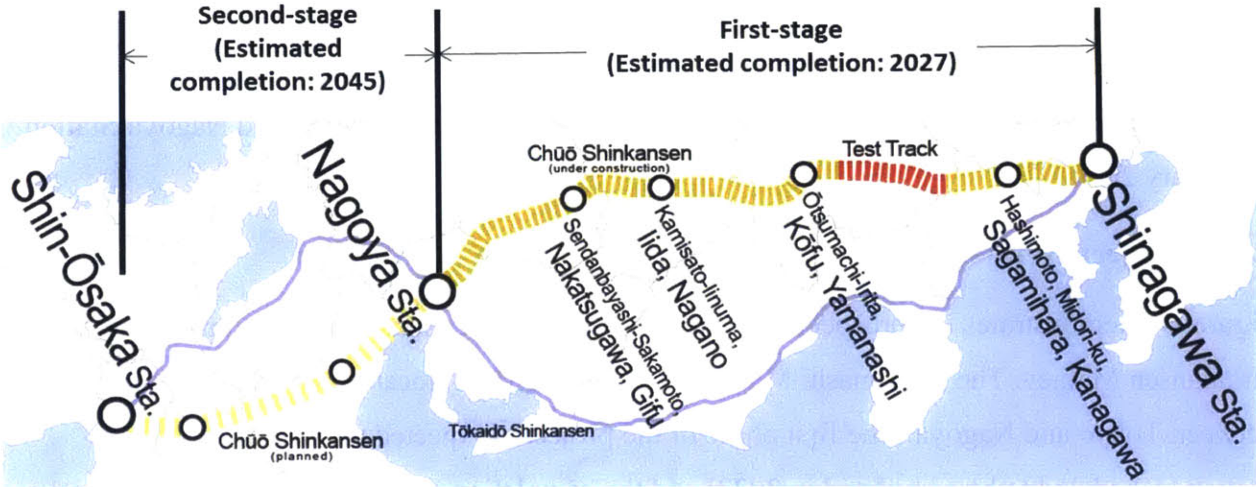
submitted the construction implementation plan to MLIT in August 2014 based on the assessment (Central Japan Railway Company 2015b), which was approved in October 2014. JR Central started the preliminary construction work both in Shinagawa Station and Nagoya Station in January 2016.

1.2.3 Project overview

Figure 1-4 demonstrates the prospective route as well as the locations of the stations of the Chuo Shinkansen Malgev. The Yamanashi Maglev Test Line (YMTL) locates in Yamanashi prefecture between Tokyo and Nagoya. The first phase of the project is expected to be Tokyo-Nagoya section (scheduled to be completed in 2027) and the completion of second phase, Nagoya-Osaka section, is scheduled to be 18 years after the completion of the first phase.

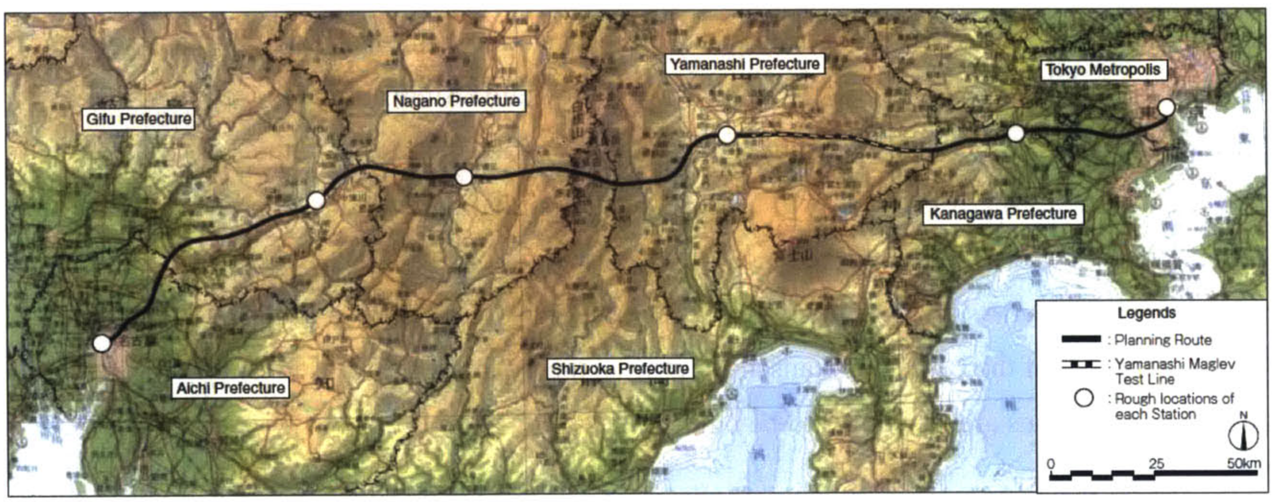
As for the location of the stations, the terminal in Tokyo metropolitan area is expected to be Shinagawa Station, which is the second easternmost station in the Tokaido Shinkansen (the easternmost is Tokyo Station, also the terminal of the Tokaido Shinkansen) as well as several conventional lines which densely connect the station to various locations in the Tokyo metropolitan area. Nagoya Station will also be the station sharing with the Tokaido Shinkansen. There is expected to be four intermediate stations between Tokyo and Nagoya in the Chuo Shinkansen Maglev. As for the second-phase section, Shin-Osaka Station is expected to be the western terminal of the Chuo Shinkansen as same as the Tokaido Shinkansen, and two intermediate stations are scheduled to be built.

Since the underground space in the city center of the Tokyo, Nagoya, Osaka metropolitan area are densely developed with subways and other facilities, the stations in these area are expected to be built in deep underground more than 40m (131ft) below the surface. Also, the majority of the section between Tokyo and Nagoya are located in a mountainous region (Figure 1-5), 86% of the length of the line between Tokyo and Nagoya is expected to be in tunnels.



Source: Wikipedia, modified by the author

Figure 1-4: The prospective route and stations of the Chuo Shinkansen Maglev



Source: (Central Japan Railway Company 2015a)

Figure 1-5: The geographical feature along the route of the Chuo Shinkansen Maglev (between Tokyo and Nagoya)

Table 1-3 shows the basic features of the Chuo Shinkansen Maglev and the comparison with the Tokaido Shinkansen[10]. As mentioned above, the route of the Chuo Shinkansen Maglev between Tokyo and Nagoya is expected to penetrate the mountainous region around; thus the distance between Tokyo and Nagoya in the Chuo Shinkansen will be shorter than that of the Tokaido Shinkansen. The maximum design speed is 505 km/h, which is expected to shrink the

[10] The travel time, maximum speed, frequency of the Tokaido Shinkansen are as of 2010.

travel time between Tokyo and Nagoya by 60 minutes in 2027, and the travel time between Tokyo and Osaka by 40 minutes in 2027 and 81 minutes in 2045. In order to utilize the high speed of the Chuo Shinkansen, a smaller number of the intermediate stations will be constructed in the Chuo Shinkansen.

Table 1-3: The summary of the Chuo Shinkansen Maglev

Tokyo-Nagoya	**Chuo**	**Tokaido**
Distance	286km (178mile)	342km (213mile)
The number of stations	6 (Total)	4 (Nozomi) 13 (Total)
Travel time	40min	100min (Nozomi)
Maximum speed	505km/h (314mi/h)	270km/h (168mi/h)
Frequency (per day each way)	72 (Tokyo-Nagoya opened) 130 (Tokyo-Osaka opened)	114 (Nozomi)

Tokyo-Osaka	**Chuo**	**Tokaido**
Distance	438km (272mile)	515km (320mile)
The number of stations	9 (Total)	6 (Nozomi) 17 (Total)
Travel time	108min (Tokyo-Nagoya opened)* 67min (Tokyo-Osaka opened)	148 Nozomi
Maximum speed	505km/h (314mi/h)	270km/h (168mi/h)
Frequency (per day each way)	72 (Tokyo-Nagoya opened) 130 (Tokyo-Osaka opened)	114 (Nozomi)

Source: (Ministry of Land, Infrastructure, Transport and Tourism 2010c)

The frequency of the Chuo Shinkansen Maglev is designed to accommodate the projected demand. Table 1-4 demonstrates the demand estimation (in passenger-km) for the Chuo Shinkansen as well as the Tokaido Shinkansen, estimated by MLIT (Transport Policy Council Chuo Shinkansen Subcommittee 2011). When the first-phase Tokyo-Nagoya section is to be completed in 2027, 16.7 billion passenger-km (30% of the sum of the Chuo and Tokaido) is estimated to be carried by the Chuo Shinkansen Maglev, while the 40.2 billion passenger-km (70% of the sum of the Chuo and Tokaido) is estimated to be carried by the Tokaido Shinkansen. After the whole-line completion in 2045, 40.8 billion passenger-km (over 60% of the sum)[11] is expected to be carried by the Chuo Shinkansen Maglev, while 25.4 billion passenger-km (less than 40% of the sum) will be carried by the Tokaido Shinkansen. The reason that the projected frequency of the Chuo Shinkansen Maglev after the Tokyo-Nagoya completion (72 trains per day each direction) is lower than the present Tokaido Shinkansen Nozomi (114 trains per day each direction) is because considerable proportion of users will still use the Tokaido Shinkansen.

Table 1-4: Demand estimation of the Chuo Shinkansen and the Tokaido Shinkansen

	Forecasted Demand (**billion passenger-km/year**)			Conditions
	Chuo	Tokaido	Sum	
Present (2005)	-	**44.2**	**44.2**	-
Without project in 2045	-	**49.6**	**49.6**	1% annual growth in GDP
With Maglev Tokyo-Nagoya in 2027	**16.7**	**40.2**	**56.8**	
With Maglev Tokyo-Osaka in 2045	**40.8**	**25.4**	**66.1**	
With Maglev Tokyo-Osaka in 2045	**32.8**	**20.5**	**53.3**	0% GDP growth

- Assume that all conditions of the competing transport mode are not changing: toll and capacity of the parallel highway, fare and frequency of airlines between Tokyo and Osaka

Assumption for the demand estimation (Tokyo-Osaka)	**Tokaido Nozomi (in 2010)**	**Chuo Maglev (in 2027)**	**Chuo Maglev (in 2045)**
Travel time (minutes)	**148**	**108**	**67**
Fare (yen)	**14,100**	**14,900**	**15,000**
Frequency (trains per day each way)	**114**	**72**	**130**

Source: (Ministry of Land, Infrastructure, Transport and Tourism 2010c)

As for the costs of the Chuo Shinkansen Maglev project, Table 1-5 summarizes the construction cost, the operating cost, and the renewal cost of the Chuo Shinkansen Maglev. The table also shows the costs, which would be required if the conventional HSR system, similar to the Tokaido Shinkansen, were adopted as the comparison. While SC Maglev will cut the travel time 0.51-0.56times as that in the conventional HSR, it requires 1.23-1.32 times as large

[11] The reason that the number is still not 100% is because the route of the Chuo Shinkansen is not identical to the Tokaido Shinkansen. Users from/to Kyoto, for example, still prefer the Tokaido Shinkansen to the Chuo Shinkansen even after the completion of the whole line.

construction cost, 1.57-1.74 times as large operating cost, and 1.79-2.10 times as large renewal cost than the conventional HSR.

Table 1-5: Cost comparison of Maglev vs. conventional HSR as the Chuo Shinkansen

Tokyo-Nagoya

			Maglev (A)	Conventional HSR (B)	A/B
Travel time		min	40 min	79 min	0.51
Traffic demand (FY2025)		billion passenger-km/year	16.7	8.2	2.04
construction cost		¥trillion ($billion)	¥5.43 ($45.3)	¥4.42 ($36.8)	1.23
operating cost		¥billion ($million)	¥162 ($1,350)	¥103 ($858)	1.57
renewal cost	Total for 50 year accumulation	¥trillion ($billion)	¥3.05 ($25.4)	¥1.70 ($14.2)	1.79
	Yearly average	¥billion ($million)	¥61 ($508)	¥34 ($283)	1.79

Tokyo-Osaka

			Maglev (A)	Conventional HSR (B)	A/B
Travel time		min	67 min	120 min	0.29
Traffic demand (FY2045)		billion passenger-km/year	41.6	21.9	1.90
construction cost		¥trillion ($billion)	¥9.03 ($75.3)	¥6.83 ($56.9)	1.32
operating cost		¥billion ($million)	¥308 ($2,567)	¥177 ($1,475)	1.74
renewal cost	Total for 50 year accumulation	¥trillion ($billion)	¥6.04 ($50.3)	¥2.88 ($24.0)	2.10
	Yearly average	¥billion ($million)	¥121 ($1,008)	¥58 ($483)	2.09

Source: (Japan Railway Construction, Transport and Technology Agency 2009)

The total construction cost of the Chuo Shinkansen Maglev in Tokyo-Nagoya-Osaka is estimated as large as ¥9trillion ($75billion) (Table 1-5). The amount of the cost is significantly larger than those of the recent Shinkansen projects (Table 1-6). The per-km unit construction cost for infrastructure (excluding rolling stock) of the Chuo Shinkansen Maglev is estimated as ¥21billion ($281.6million per mile), which is 3.0-4.5 times larger the unit costs of the three recent Shinkansen projects. The cost drivers of the Chuo Shinkansen is explained from two perspectives by JRTT (Japan Railway Construction, Transport and Technology Agency 2010).

Cost drivers regarding the route:

- Construction works in large metropolitan areas requires:
  - Underground stations in metropolitan areas
  - Deep underground construction work more than 40m (131ft) below
  - Large land acquisition cost for car depot
- Tunnel construction in steep mountainous areas is required between Tokyo and Nagoya.
- Large electricity facilities are required due to the high train frequency.

Cost drivers regarding the operating system (Maglev):

- A larger cross section in tunnels is required for the Maglev due to the trains operated at over 500km/h (311mile/h) in both direction.
- Infrastructures peculiar to the SC Maglev such as ground coils and power conversion systems are required.

Table 1-6: The comparison of construction cost: the Chuo Shinkansen project vs. recent Shinkansen projects[12]

Name of Shinkansen		Hokuriku		Tohoku		Kyushu		Chuo Maglev	
Start-End station		Takasaki-Nagano		Morioka-Hachinohe		Shin Yatsushiro-Nishi Kagoshima		Shinagawa-ShinOsaka	
Service commencement		Opened in 1997		Opened in 2002		Opened in 2004		will be opened in 2045	
Total distance km (mile)		117.4 (72.9)		96.6 (60.0)		126.8 (78.8)		438 (272.2)	
Construction cost		Total ¥bn ($bn)	¥bn per km ($mil per mi)	Total ¥bn ($bn)	¥bn per km ($mil per mi)	Total ¥bn ($bn)	¥bn per km ($mil per mi)	Total ¥bn ($bn)	¥bn per km ($mil per mi)
	Structural infrastructure	¥730 ($6.1)	¥6.2 ($83.4)	¥390 ($3.3)	¥4.0 ($54.1)	¥540 ($4.5)	¥4.3 ($57.1)	¥5,840 ($48.7)	¥14.8 ($198.5)
	Electric infrastructure	¥80 ($0.7)	¥0.7 ($9.1)	¥60 ($0.5)	¥0.6 ($8.3)	¥70 ($0.6)	¥0.6 ($7.4)	¥2,460 ($20.5)	¥6.2 ($83.1)
	Total	¥810 ($6.8)	¥6.9 ($92.5)	¥450 ($3.8)	¥4.7 ($62.5)	¥610 ($5.1)	¥4.8 ($64.5)	¥8,300 ($69.2)	¥21.0 ($281.6)

Source: (Japan Railway Construction, Transport and Technology Agency 2010)

1.2.4 Benefits of the Chuo Shinkansen

- **Redundancy for the risk of the Great Tokai Earthquake and the aging Tokaido Shinkansen**

Table 1-7 shows an excerpt from the final report of the Council issued on May 23 2011, regarding the importance of the Chuo Shinkansen Maglev as a national project defined by the committee.

Table 1-7: The role of the Chuo Shinkansen Maglev as a national HSR project

1. Enhance a high-speed and stable rail network linking the three metropolitan areas
2. Benefit also to the area along the route rather than the three metropolitan areas
3. Change the role of the Tokaido Shinkansen and re-develop the urban areas along it
4. Directly connect the three metropolitan areas with trips of short duration
5. Establish the world's leading-edge rail technology and provide a ripple effect on other industries

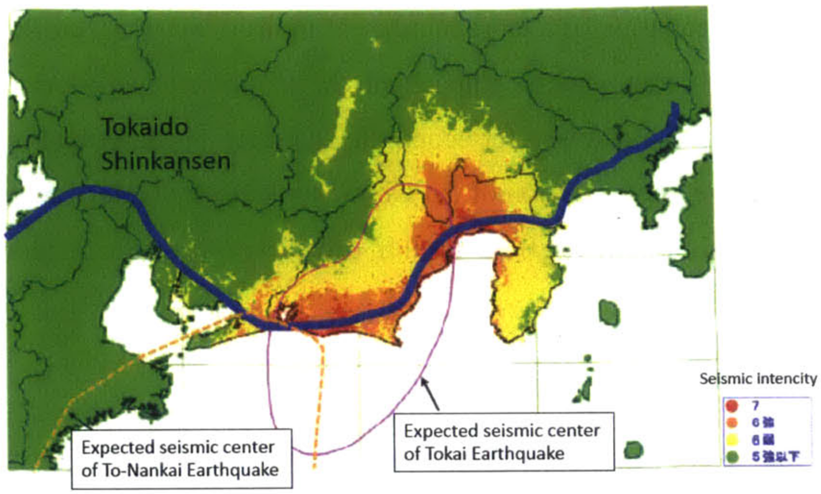
[12] The calculation of the unit cost of the Chuo Shinkansen Maglev excludes the YMTL section (42.8km).

Source: (Transport Policy Council Chuo Shinkansen Subcommittee 2011), with the author's translation from Japanese

As a primary role of the project, the redundancy for the risk of the Great Tokai Earthquake and for the aging Tokaido Shinkansen is emphasized in the report.

"The three metropolitan areas in Japan (Tokyo, Nagoya, and Osaka) are some of the most densely-populated urban areas around the world and the high-speed and stabilized transportation service offered by the Tokaido Shinkansen so far is the most important artery, which has sustained Japanese economy and society. The construction of the Chuo Shinkanen is expected not only to enhance the function of the artery by increasing the speed, but also prepare for the risk of disasters such as the Great Tokai Earthquake which is expected to happen in the region along the Tokaido Shinkansen. Through the experience of the Great East Japan Earthquake in 2011, making a dual artery turned out to be more important in order to prepare for the risk of disasters. Moreover, the construction of the Chuo Shinkansen is expected to offer valuable options for the large-scale repair work needed for the future risk of time-oriented deteriorations of the Tokaido Shinkansen, and reduce the impact of the repair work on the operation of the Tokaido Shinkansen." (Transport Policy Council Chuo Shinkansen Subcommitee Final report 2011, translated by the author)

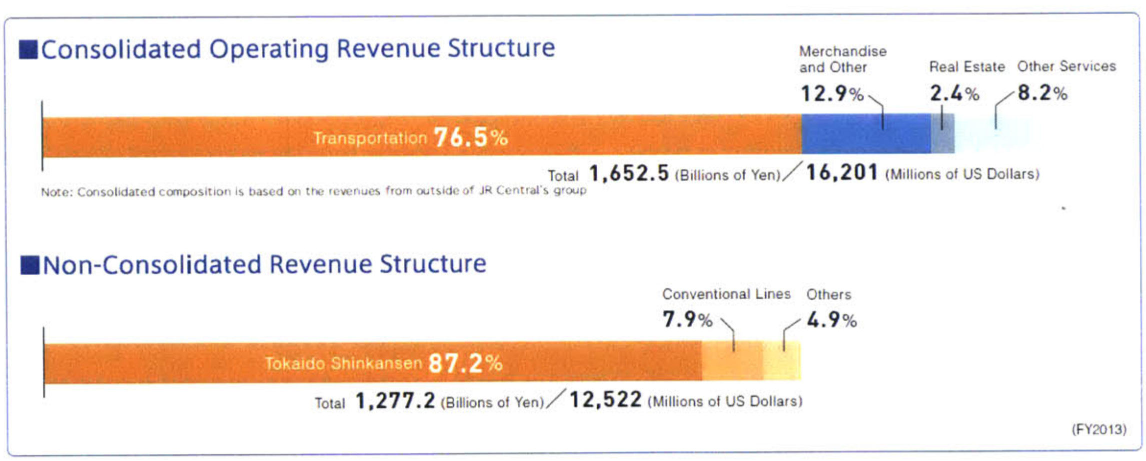
Figure 1-6 shows the projected seismic intensity distribution caused by the Great Tokai Earthquake and the expected area of the seismic center. The figure suggests that the region along the Tokaido Shinkansen are expected to be significantly affected by the earthquake. The incidence of the Great Tokai Earthquake with a level of magnitude 8 occurring within 30 years from now is estimated for 87% (Ministry of Land, Infrastructure, Transport and Tourism 2010b). Since the Tokaido Shinkansen carries more than 430,000 passengers per day (FY2014), clearly, there is no other transportation mode which can replace the role of the Tokaido Shinkansen. Therefore, the economic impact of the Great Tokai Earthquake is expected to be significant for the entire economy in Japan. The Chuo Shinkansen Maglev could be the major alternative of the Tokaido Shinkansen even if the Tokai Earthquake occurs, thus the economic damage can be significantly mitigated.



Source: *(Transport Policy Council Chuo Shinkansen Subcommittee 2011)*

Figure 1-6: The seismic intensity projection for the Tokai Earthquake (colored area) and the expected area of seismic center (pink-colored circle)

Also, JR Central relies heavily on the revenue from the Tokaido Shinkansen (Figure 1-7). Although JR Central runs 12 conventional railway lines centered on Nagoya metropolitan area, 87.2% of the revenue came from the Tokaido Shinkansen in FY2013 (in parent-only financial statement, excluding subsidiaries and affiliates). If the Tokai Earthquake occurs, the fiscal loss depends on how long the Tokaido Shinkansen has to stop the operation.



Source: JR Central

Figure 1-7: Operating revenue structure of JR Central in FY2013

In addition, further more than 50 years already passed since the Tokaido Shinkansen started its operation; thus the fundamental repair works on the infrastructures are needed, which is expected to require cancellation of a large number of trains (Central Japan Railway Company 2012). It will impose significant negative impacts on the economy of Japan, due to the high contribution of the Tokaido Shinkansen for economic activities. As described in the quotation from the final report above, the operation of the Chuo Shinkansen Maglev between Tokyo and Nagoya will offer variable options for JR Central in order to mitigate the economic damage of repair work.

- **Economic Benefits**

The high speed of the Chuo Shinkansen Maglev will shrink the travel time between three major metropolitan areas, which will bring a large economic benefit. The direct benefit due to the travel time saving is estimated as ¥8.4 trillion in 2010 value (Table 1-8).

Table 1-8: NPV and B/C ratio of the Chuo Shinkansen Maglev

		SC Maglev		Measured terms
		¥trillion	$billion	
Total benefit		**8.4**	**70**	
	Consumer surplus	**5.0**	**42**	Travel time saving for users
	Producer surplus	**3.2**	**26.7**	Changes in profit for railway operators (JR Central, East, West)
	Environmental improvements	**0.0 (¥11billion)**	**0.0 ($92million)**	Emission of CO_2, NO_x Reduction in the number of road accidents
	Residual value	**0.1**	**0.8**	
Total Cost		**5.5**	**45.8**	
NPV		**2.9**	**24.2**	
B/C ratio		**1.51**		
IRR		**6.0%**		

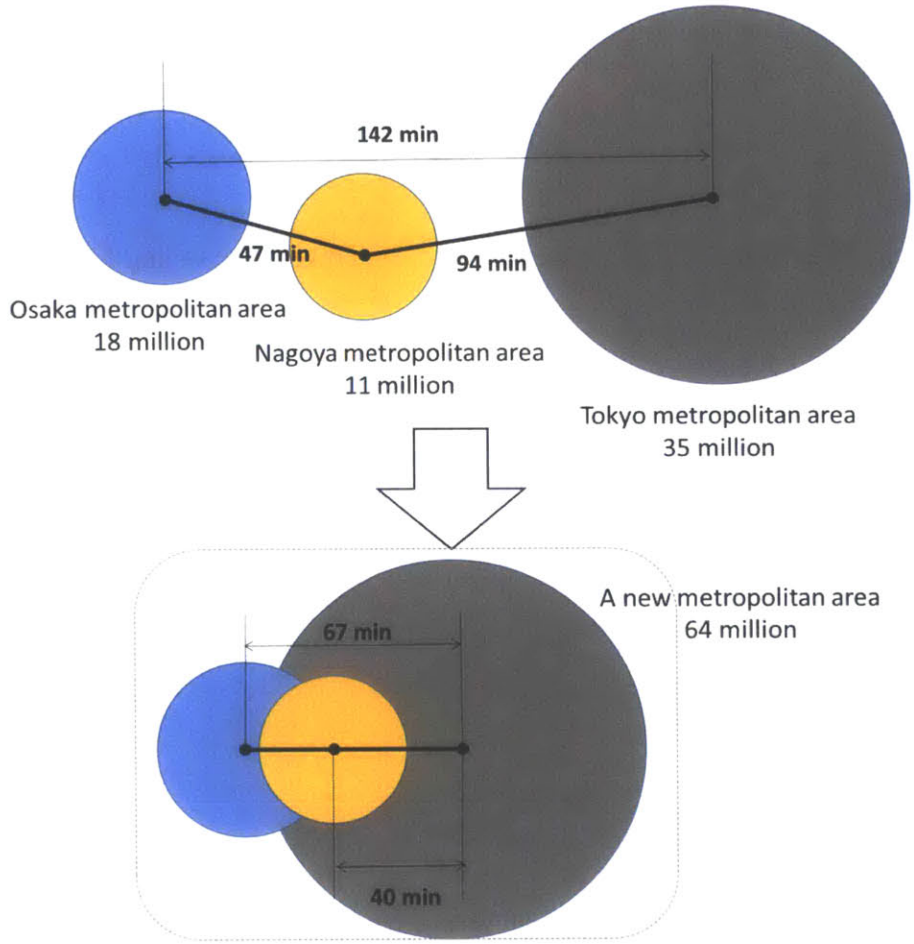
- The project period: 2010-2095 (accounted by 50 years after the commencement of Tokyo-Osaka in 2045)

- Benefit and cost are discounted to the present value as of 2010 by the discount rate of 4%

- The redundancy gain and the cost-reduction effect to the large-scale repair work of the Tokaido Shinkasen are excluded from benefits above. Consumer surplus only account for the direct benefit due to the travel time saving.

Source: (Transport Policy Council Chuo Shinkansen Subcommittee 2011)

Also, the significant travel time saving of the Chuo Shinkansen Maglev is expected to result in the formation of a new extra-huge economic zone, combining the three major metropolitan areas (Figure 1-8). The effect on business activities as well as life style would be significant. Although it is not included in the benefit-cost analysis in Table 1-8, a large agglomeration effect on this region is expected.



Tokyo metropolitan area: Tokyo, Kanagawa, Saitama, and Chiba

Nagoya metropolitan area: Aichi, Gifu, and Mie

Osaka metropolitan area: Osaka, Kyoto, Nara, and Hyogo

Population as of 2009

Source: the author

Figure 1-8: Formation of the extra-huge economic zone by the Chuo Shinkansen Maglev

1.2.5 The Uniqueness of the Chuo Shinkansen Maglev project

This section summarizes the uniqueness of the Chuo Shinkansen Maglev project and illustrates the potential influence on the pricing strategy due to these characteristics.

- **Maglev as an operating system**

The Chuo Shinkansen Maglev adopts the SC Maglev as an operating system instead of conventional HSR system, for the first time in the world. Hence, there may be a lot of unique technical features. Among them, the thesis proposes two characteristics would influence pricing strategy: dedicated track system and capacity constraints due to the number of Power Conversion Systems (PCSs)

Dedicated track system (incapable of being shared with conventional HSR)

The propulsion of the SC Maglev is based on the electromagnetic force between the propulsion coils on the guideway and the superconducting magnets on a vehicle, which is totally different from the traditional propulsion system in conventional HSR. Therefore, the Chuo Shinkansen requires a dedicated track and never shares the track with the Tokaido Shinkansen. There is an analogy in the relationship between HSR and conventional line (e.g. commuter rail). While Japanese Shinkansen and Chinese HSR adopt the dedicated track system, European HSRs such as TGV in France and ICE in Germany adopt the shared track system. Positive aspects of the dedicated track system are as follows:

- Operating system for the line can be **simple and efficient**. For example, the axle load of Series N700 in the Tokaido Shinkansen is 11t at full passenger capacity, which is far less than that of 17t for TGV-POS and 16t for ICE3 (Morimura 2010). The reduction of the axle load is achieved by the "crash avoidance" scheme, which is only available in dedicated track without any grade crossings.
- It allows **an increase in the track capacity**. In dedicated track system such as the Tokaido Shinkansen, the specification of all rolling stock (such as acceleration and deceleration) as well as signal system can be basically common; thus the use of the track capacity is maximized.

A negative aspect is as follows:

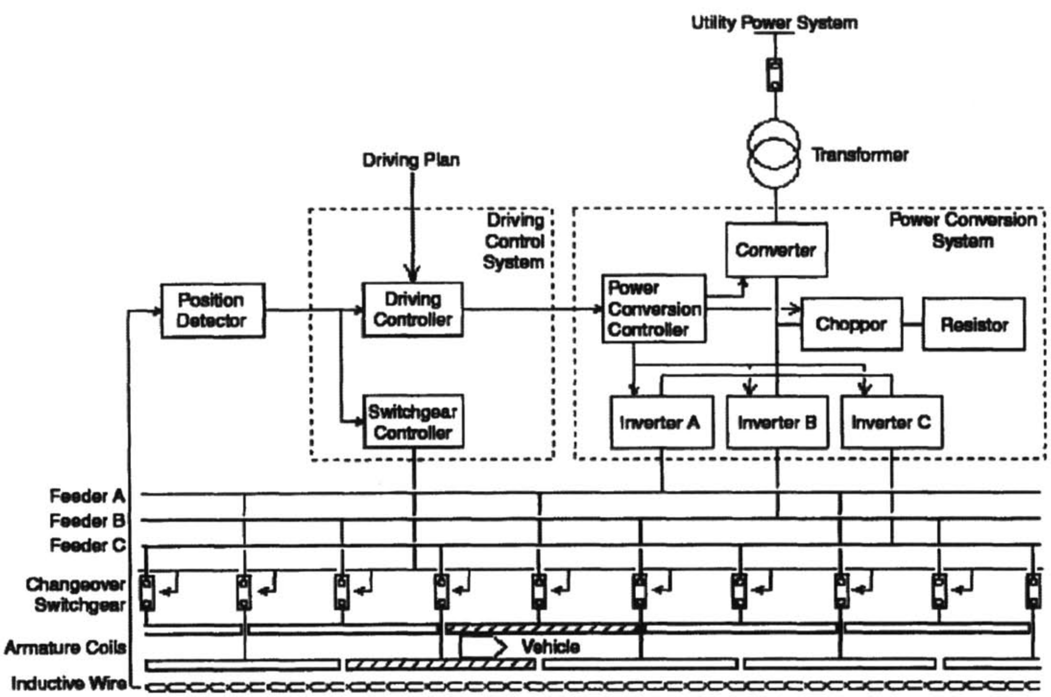
- Train operating pattern in the dedicated track system is **less flexible** than the shared track system; thus it cannot serve as many various origin-destination pairs as the shared track system. In France, since TGV can be operated also in conventional lines, passengers can reach various cities without transfers.

Influence on pricing strategy:

Since the track is physically separated from other HSRs, the pricing system is also expected to be more likely to be independent and separated from the other. As for the Chuo Shinkansen Maglev, it is easier for JR Central to differentiate fare level as well as fare structure from those of the Tokaido Shinkansen. If the operating pattern is complicated, it is much harder to differentiate fare structure only for a certain section.

Capacity constraints due to the number of PCSs

Unlike a conventional high-speed or non-high-speed train controlled by an engineer on the train, a Maglev train is controlled by a Power Conversion System (PCS) along the track. Figure 1-9 demonstrates an overview of the PCS in the Yamanashi Maglev Test Line. Driving Control System (DCS) generates the running pattern based on the programed operating plan and the current vehicle speed and position. Current vehicle position is detected by the cross-inductive wire system, and then the current speed is calculated from the positon information. DCS sends the phase and amplitude references of the current to PCS so that the PCS can control the vehicle.



Source: Ishii (Ishii 2007)

Figure 1-9: Power Conversion System and Drive Control System for the Yamanashi Maglev Test Line

Because of the technical limitation, one PCS can control only one train for each direction in its territory. Unlike the traditional train operating system, in which a power substation can send electricity to multiple trains, the Maglev operating system is not capable of operating trains more than the number of PCSs. According to JR Central, PCSs is expected to be constructed every 20-40km along the track and 12 PCSs are scheduled to be built in 285.6km (177.5mile) Tokyo-Nagoya section (Central Japan Railway Company 2014b). The initial cost for the construction of the 12 PCSs between Tokyo and Nagoya is estimated as ¥186billion ($1.55billion). Hence, once the alignment is fixed at the beginning of the project phase, it may no longer be an option for JR Central to increase the number of PCSs by just adding a PCS in the alignment since it becomes an inefficient allocation of PCSs. Therefore, an initial plan of the spatial allocation for PCSs along the entire track fixes the maximum number of trains operated simultaneously.

This fundamental feature of the Maglev system makes the schedule planning inflexible compared to the conventional train system. As for the Tokaido Shinkansen, the maximum number of trains per hour each direction has been increasing from two in 1964 to 15 in 2015 mainly by means of the additional procurement of rolling stock and the reinforcement of the power substations. However, as mentioned above, the maximum number of the Chuo Shinkansen Maglev is fixed at the construction stage, which becomes a capacity constraint.

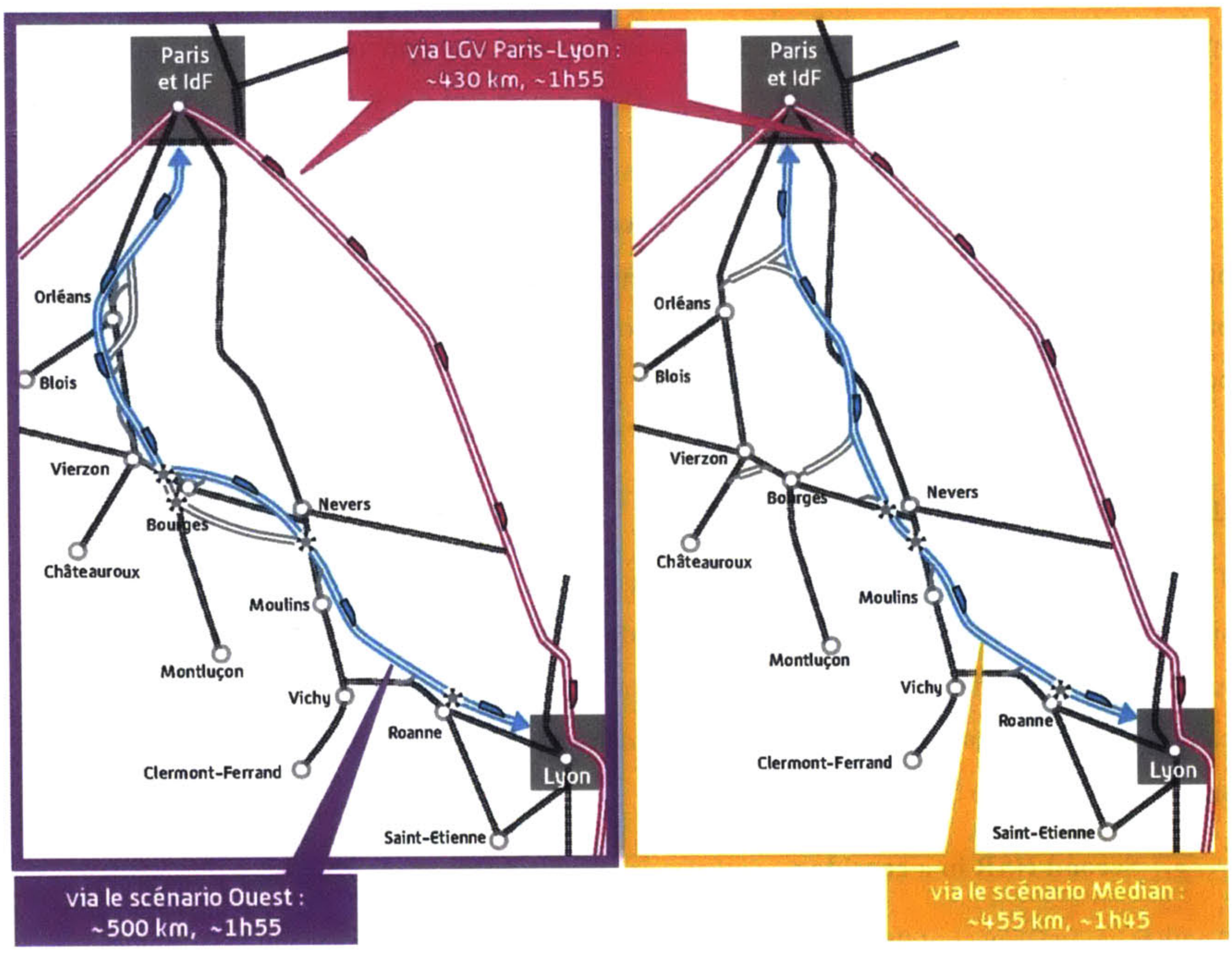
Influence on pricing strategy:

The fare of the Tokaido Shinkansen has been basically fixed as mentioned in the later chapter, since it changes the capacity offered in the corridor by adding a large number of additional trains in accordance with demand fluctuation. On the other hand, because of the inflexibility in capacity, the price variation in accordance with demand fluctuation would be an important strategy for the Chuo Shinkansen Maglev.

- **Second HSR in a corridor**

Another unique aspect of the Chuo Shinkansen is that this becomes the second HSR in the Tokyo-Nagoya-Osaka corridor. There has been no place in the world which has multiple HSR lines in the same corridor. Based on the microeconomics theory, infrastructure with a large fixed cost such as railway has a feature of natural monopoly. Therefore, high utilization of a single line instead of building multiple lines lead to efficient management of the railway business.

Aside from Japan, there is another plan for building the second HSR in Paris-Lyon corridor in France. According to SNCF Reseau website (http://www.sncf-reseau.fr/en/paris-orleans-clermont-ferrand-lyon-pocl-high-speed-lgv-line), Paris-Orleans-Clermont-Ferrand-Lyon (POCL) line is currently under consideration as a prospective HSR. Figure 1-10 shows the projected route of the POCL line. The project is expected to improve the accessibility between the central area of France and Paris, and also add extra capacity for the Paris-Lyon line which is getting saturated (pink colored in Figure 1-10).



Source: SNCF Reseau

Figure 1-10: Paris-Orleans-Clermont-Ferrand-Lyon high-speed LGV plan (blue colored)

Influence on pricing strategy:

Appropriate pricing strategy for the multiple HSRs in a same corridor may require careful consideration of price and service differentiation between two HSRs. As for the Chuo Shinkansen Maglev, in order to maximize the profitability, JR Central should avoid cannibalization of the potential demand for the Chuo Shinkansen Maglev by the Tokaido Shinkansnen.

- **Private project progressed by the company running the first HSR**

Although the Chuo Shinkansen Maglev is apparently a large scale and long-term project, it is expected to be funded by JR Central. The project entity, JR Central, gains a large profit from the existing line (the Tokaido Shinkansen); thus the company can fund the majority of capital by accumulated earned surplus brought by the existing line (Table 1-9, Table 1-10, and Table 1-11). However, due to this financial scheme, the progress of the construction of the Chuo Shinkansen Maglev will be restricted by the JR Central's financial capability, namely the amount of the annual net income and the capability of the issuance of long-term debt. In the plan proposed by JR Central, in order to fund the project with keeping stable dividends as a healthy private company, the net financing cash flow will be restrained at a modest level prior to the commencement of the full-service between Tokyo and Osaka, as the annual average ¥100 billion ($833million) during FY2010-2027 and negative ¥10 billion ($83million) during FY2028-2045, respectively (Table 1-10). As a result, the maximum amount of the JR Central's long-term debt is expected to be below ¥5 trillion ($42billion) (Table 1-9, Figure 1-11).

Table 1-9: Financial projection for JR Central

		2027	2028	...	2038	...	2045	2046	...	2050	2053
Operating revenue ¥trillion ($billion)	Government estimation [1]	¥1,317 ($11.0)	¥1,356 ($11.3)	...	¥1,310 ($10.9)	...	¥1,373 ($11.4)	¥1,467 ($12.2)	...	¥1,438 ($12.0)	¥1,417 ($11.8)
	JR Central estimation [2]	¥1,213 ($10.1)	¥1,247 ($10.4)	...	¥1,298 ($10.8)	...	¥1,354 ($11.3)	¥1,467 ($12.2)	...	¥1,467 ($12.2)	N.A. N.A.
Operating profit [3] ¥trillion ($billion)	Government estimation	¥436 ($3.6)	¥332 ($2.8)	...	¥279 ($2.3)	...	¥237 ($2.0)	¥194 ($1.6)	...	¥244 ($2.0)	¥222 ($1.9)
	JR Central estimation	¥331 ($2.8)	¥223 ($1.9)	...	N.A. N.A.	...	¥218 ($1.8)	¥194 ($1.6)	...	¥272 ($2.3)	N.A. N.A.
Debt balance ¥trillion ($billion)	Government estimation	¥4.87 ($40.6)	¥4.61 ($38.4)	...	¥2.28 ($19.0)	...	¥4.45 ($37.1)	¥4.16 ($34.7)	...	¥2.88 ($24.0)	¥2.23 ($18.6)
	JR Central estimation	¥4.92 ($41.0)	N.A. N.A.	...	N.A. N.A.	...	¥4.69 ($39.1)	N.A. N.A.	...	¥3.04 ($25.3)	N.A. N.A.

[1] Government's estimation on operating revenue shown here assumes that 0% GDP growth in demand forecasting. This is the most conservative scenario among three alternatives (0%, 1%, and 2% growth). This is intended to examine whether JR Central's estimation is too optimistic or not.
[2] JR Central's estimation on operating revenue is based on the assumption following:
- 2011-2026: keep constant growth rate same as the average of five years between 2006 and 2010,
- 2027-2036: 5% growth in 2027(Tokyo-Nagoya opens) and gradually increase up to 10%,
- 2037-2044: remain constant
- after 2045: 15% growth in 2045(Tokyo-Osaka opens) and remain constant

[3] Operating cost is based on the report from JRTT and JR Central (Japan Railway Construction, Transport and Technology Agency 2009). This is commonly used by both the government and JR central in the estimation.

Source: (Ministry of Land, Infrastructure, Transport and Tourism 2012d)

Table 1-10: The projection of the annual cash flow of JR Central

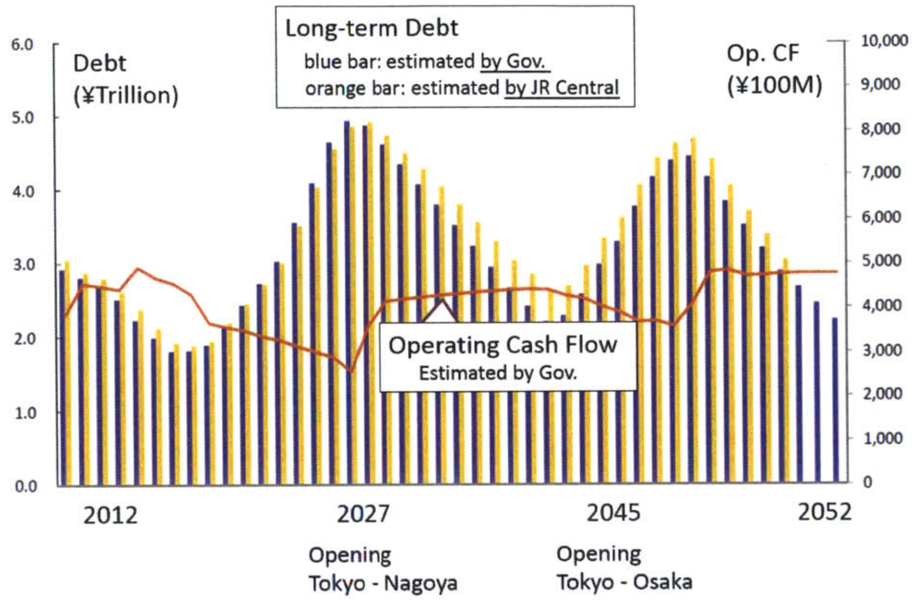
numbers in ¥billion ($million)	FY2010-2027 average	FY2028-2045 average	FY2046-2050 average
Net Operating Cash Flow.	¥380 ($3,167)	¥400 ($3,333)	¥500 ($4,167)
Net Income before Extraordinaries	¥180 ($1,500)	¥80 ($667)	¥80 ($667)
Depreciation, Depletion & Amortization	¥200 ($1,667)	¥310 ($2,583)	¥410 ($3,417)
Others	¥0 ($0)	¥10 ($83)	¥10 ($83)
Net Investing Cash Flow	-¥480 -($4,000)	-¥390 -($3,250)	-¥170 -($1,417)
Purchase of assets for Tokaido Shinkansen and YMTL	-¥190 -($1,583)	-¥150 -($1,250)	-¥150 -($1,250)
Purchase of assets for the Chuo Shinkansen	-¥290 -($2,417)	-¥240 -($2,000)	-¥20 -($167)
Net Financing Cash Flow	¥100 ($833)	-¥10 -($83)	-¥330 -($2,750)
Issuance of long-term debt	¥300 ($2,500)	¥300 ($2,500)	¥90 ($750)
Reduction in long-term debt	-¥200 -($1,667)	-¥310 -($2,583)	-¥420 -($3,500)
Change in cash	¥0 ($0)	¥0 ($0)	¥0 ($0)

Source: (Ministry of Land, Infrastructure, Transport and Tourism 2012d)

Table 1-11: The projection of the equity Ratio of JR Central

number's in ¥billions ($billions)		*End of FY2009*	*End of FY2027*	*End of FY2045*
Assets	Fixed assets	¥4,840 ($40.3)	¥9,280 ($77.3)	¥10,130 ($84.4)
	Other assets	¥170 ($1.4)	¥170 ($1.4)	¥170 ($1.4)
	Total assets	¥5,010 ($41.8)	¥9,450 ($78.8)	¥10,300 ($85.8)
Liabilities	Long-term debt	¥3,117 ($26.0)	¥4,920 ($41.0)	¥4,690 ($39.1)
	Other liabilities	¥837 ($7.0)	¥580 ($4.8)	¥620 ($5.2)
	Total liabilities	¥3,954 ($33.0)	¥5,500 ($45.8)	¥5,310 ($44.3)
Stock holder's equity	**Total stock holder's equity**	¥1,057 ($8.8)	¥3,950 ($32.9)	¥4,990 ($41.6)
	Equity ratio	*21%*	*42%*	*48%*

Source: (Ministry of Land, Infrastructure, Transport and Tourism 2012d)



Source: Ministry of Land, Infrastructure, Transport and Tourism, 2012a, modified by the author

Figure 1-11: Transition of the long-term debt and operating cash flow

The funding scheme may also be considered rational from customers' point of view, in the context that current users who are paying future construction cost are potential users of the Chuo Shinkansen Maglev.

However, because of the large capital required to fund construction cost in this financial scheme, JR Central has to take a two-phase and long-term project period. The projected 18-year interval between the commencement of Tokyo-Nagoya and that of Tokyo-Osaka will function as a fiscal adjustment period for JR Central in order to constrain the issuance of the long-term debt. While the interval may shrink if the operating cash flow is larger than the estimation, the interval may extend further if the operating cash flow turns out to be below the estimation. Since the largest number of passengers traveled between Tokyo-Nagoya-Osaka corridor is Tokyo-Osaka (Figure 1-2), a large number of passengers of the Chuo Shinkansen Maglev in the interval period will have to transfer trains at Nagoya Station from the Chuo Shinkansen Maglev to the Tokaido Shinkansen, and vice versa. Also, as it will be described in section 3.1, the 18-year interval will disadvantage the western area of Japan such as Osaka.

Therefore, in order not to extend the 18-year interval, or possibly shrink it, it is critical to increase the profitability of the Chuo Shinkansen Maglev. From a viewpoint of pricing strategy, the determination of the appropriate fare of the Chuo Shinkansen Maglev as well as the introduction of an advanced pricing tool, such as dynamic pricing, can be pivotal factors to achieve it, as it will be discussed in the later chapters.

Table 1-12 summarizes uniqueness and its influence on pricing strategy of the Chuo Shinkansen.

Table 1-12: Summary of uniqueness and its influence on pricing strategy of the Chuo Shinkansen

Uniqueness of the Chuo Shinkansen	Operating features due to the uniqueness	Influence on pricing strategy
Maglev as an operating system	Dedicated track system not capable of being shared by conventional HSR	Price system might be more likely to separate from the Tokaido Shinkansen
	Capacity constraints due to the number of PCS	Price discrimination gets more important
Second HSR in a corridor	JR Central will determine both the fare of the Chuo Shinkansen Maglev and the Tokaido Shinkansen	Appropriate price differentiation from the Tokaido Shinkansen is critical factor
Private project progressed by the company running the first HSR	Two-phase scheme and 18-year long interval are inevitable, but needed to be shrunk in order to maximize social benefit	Increase in profitability is important. Appropriate fare level and Introduction of pricing tools such as a dynamic pricing might be beneficial.

1.3 An outline of the rest of this thesis

In this chapter, the background and some unique specifications of the Chuo Shinkansen Maglev project are explained.

In Chapter 2, we will review pricing theory and its practice for HSR, from classic pricing theory to recent revenue management tactics. As an important factor which affects rail operator's pricing strategy, pricing regulation scheme for rail transport will be explained. Also, a historical review of the revenue management application for world's HSRs will be performed.

In Chapter 3, literature review on the Chuo Shinkansen Maglev project as well as on pricing strategy for HSR will be performed.

In Chapter 4, we will focus on the pricing strategy regarding the determination of the appropriate fare level for the Chuo Shinkansen Maglev. The thesis proposes a 3-step framework to examine the fare level of the second HSR in a corridor. Based on the framework, the upper-limit fare constrained by price regulation is discussed. Then, the willingness to pay (WTP) for the travel time saving of the new HSR, in comparison to the existing HSR in the same corridor, is analyzed.

In Chapter 5, application of dynamic pricing for the Chuo Shinkansen Maglev will be discussed from the customers' perspective, by benchmarking the current practice in French TGV and US Acela Express.

Finally, Chapter 6 presents the conclusion about the fare level and the application of dynamic pricing for the Chuo Shinkansen, and summarizes the recommendations obtained from the analysis in the thesis.

We now move onto the review of pricing theory and the historical practices of the pricing strategy for HSR in the next chapter.

Chapter 2 Pricing Theory

2.1 Economic Characteristics of Rail Transport

It is worthwhile to start with describing economic features of transportation in order to understand the basis of pricing in rail transport. In the view of economists, pricing is a central tool for resource allocation. The requirements for the pricing of the railway service are as follows:

- ***Economic efficiency***

  Compared to large demand, supply is generally limited in transportation. Thus efficient resource allocation is important, and pricing is a tool to achieve it.
- ***Fairness***

  Even though efficient resource distribution is achieved in a certain fare scheme, if the scheme enforces unaffordable price for low-income people, this may not be politically acceptable. Discounted fare for students and disabled people can be used to meet this aspect.

While marginal cost pricing is said as the best method to maximize social benefit in economic textbooks, transportation is one of the services which are difficult to archive marginal cost pricing. In addition, historically, public sector has involved in providing transportation services; for example, in Japan, the government provides the highways, roads, and airports, as well as most railroads before Japan National Railway (JNR) was privatized in 1987. The private sector operates automobiles, trucks, buses, airlines, and ships, which use the public infrastructure.

While the private sectors are more likely to provide their transportation services at the price close to their marginal costs, the public sector usually doesn't (Gomez-Ibanez, Tye, and Winston 1999). The typical reason is that the private firms are in a competitive market. The competition brings the price down toward the production cost. On the other hand, the price deviates from the marginal cost either when the firms can enjoy monopoly power or when the price is regulated by the government.

HSR is a peculiar type of rail transport. The nature of HSR is to some extent close to airlines in terms of the intercity transportation suppliers, and in fact, HSR and airlines are competing in markets with each other. On the other hand, the regulatory framework and the pricing system in HSR have basically common characteristics with conventional rail transport. This is partly because historically HSR has been developed as an advanced mode of conventional rail service, and still in many countries both HSR and conventional rail are provided by a same company or government agency.

Gomez-Ibanez summarizes the peculiar nature of transportation system, which inhibits both marginal cost pricing and private provision (Gomez-Ibanez, Tye, and Winston 1999). These points are the common characteristics of transportation in general, including HSR.

1. Different transportation users usually share the same services or facilities. For example in HSR, business and leisure travelers occupy the same row in a train. Short-distance and long-distance travelers share the same coach class. Joint use of the facilities allows the transportation firms to reduce the average cost per user by increasing the utilization rate of the expensive facilities. But the joint use also makes it difficult for the firms to allocate the cost among the different type of users or determine the marginal cost of each user. This ambiguity in the cost evaluation and allocation leads to what often seems to be arbitrary pricing by the transportation firms; thus there needs to be regulation from the public sectors to ensure the fair allocation of costs and to protect vulnerable classes of users.
2. Transportation facilities and services often have economics of scale and large sunk costs. Firms with these characteristics usually have marginal costs which is lower than their average costs, so that the pricing at the marginal costs does not provide enough money to the firms for financially sustainable management[13]. One solution for the problem is public subsidies that usually come from the government's budget. It is often accompanied by public ownership; that can make the firms' management inefficient.
3. Transportation often raises equity concerns which conflict with both marginal cost pricing and private provision. Unlike health and education, the equity concerns, such as equality of opportunity, are not the central issues in transportation. However,

[13] In the case of major Japanese rail companies, their profitability from fare revenues can cover the total cost, including the depreciation costs for their facilities. However, if we look at the financial conditions of these firms at each operating line level, the majority of lines are not profitable. A few lines such as the Tokaido Shinkansen, the urban lines in the Tokyo and Osaka metropolitan area provide "internal subsidy" or "cross-subsicy" for the unprofitable lines within the firm. .

transportation provides access to jobs, education, and other necessary services; thus equity concerns are often reflected in regulatory policies to ensure a basic level of transportation services to all communities and households.

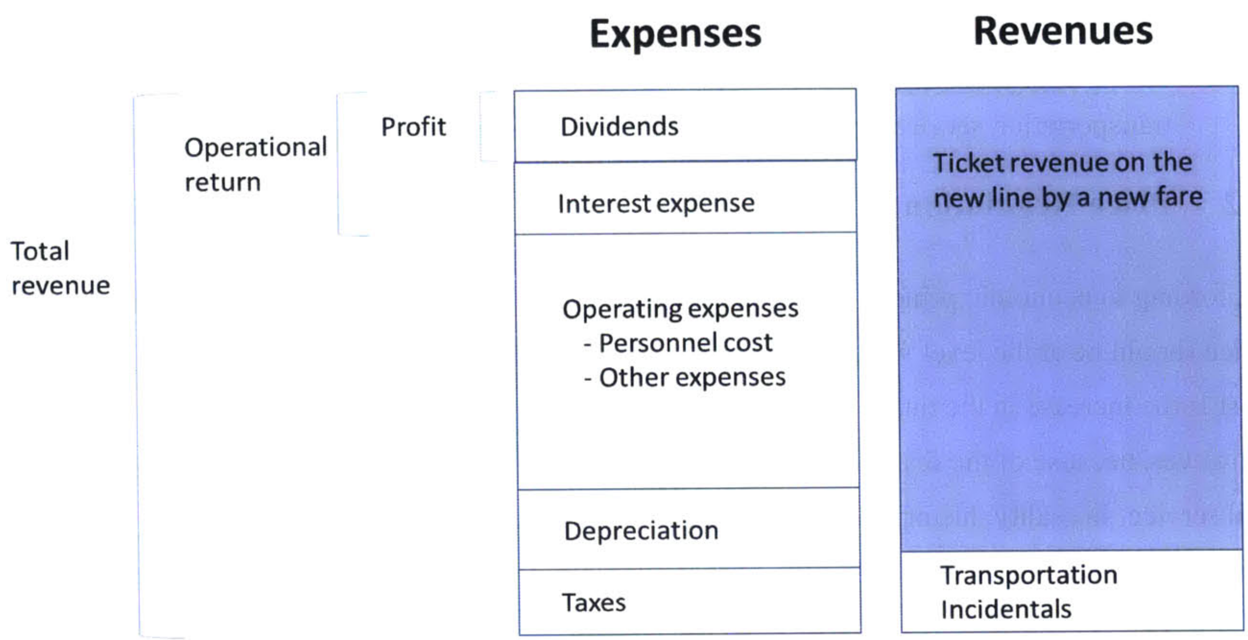
2.2 Price Regulation

According to economic principles, in order to achieve the most efficient use of resources, the price should be at the level which it matches the social marginal cost of the production. Marginal cost is the increase in the total cost which occurs from producing one additional unit of output. However, because of the features described in 2.1, this is difficult to achieve for the pricing of rail service. In reality, historically the pricing of railway services have been regulated by the government, regardless of whether the service suppliers are the public or the private sectors.

The traditional price regulation used in the rail transport is the "full cost principle", which is explained in the following section. In addition, two major methods of the incentive regulation, which complement the shortcoming of the traditional full-cost principle, are also explained.

2.2.1 Full-Cost Principle

"Full-cost principle", in other words "rate of return regulation", has been the most typical regulatory framework and applied in Japan as well as many countries such as United States (Campos and Cantos 1999). The principle behind this is that it restrains the operator's earning within the "fair rate of return" on its capital investment, in order to prevent naturally or legally monopolized firms from price gouging. Figure 2-1 demonstrates how the full-cost principle is applied for the fare determination, when a new rail line is opened in Japan. Based on the principle, the revenue from a new line should be equal to or less than the total cost, which includes fair return on the capital investment (operational return), in addition to the operating expenses, taxes, and depreciation.



Source: Author

Figure 2-1: Explanation of full-cost principle in rail fare regulation in Japan

Total cost is calculated as the sum of the operating cost, taxes, depreciation, and operational return (dividends and interest expenses). As for the operating cost, while the current price regulation in Japan takes full-cost principle as a basic framework, it also incorporates "yard-stick competition" as an incentive factor, which is explained in detail in the next chapter. In short, the operating cost accounted in the full-cost principle should be checked not to exceed "proper operating cost", based on the yard-stick competition.

The operational return is calculated as the product of rate base and rate level (2-1). Rate base is the sum of fixed assets for railway operation, construction in progress, deferred assets, and working capital (2-2). Rate base reflects the investment only for the railway operation, and does not include the cost required for other business, such as real estate. Rate level is calculated by the weighted average of the rate of return on equity and the rate of return on borrowed capital (2-3).

$$Operational\ return = Rate\ base \times Rate\ level \tag{2-1}$$

$$Rate\ base = Fixed\ assets\ for\ railway\ operation + Construction\ in\ progress + Deferred\ assets + Working\ captal \quad (2\text{-}2)$$

$$Rate\ level = Equity\ ratio^{14} \times Rate\ of\ return\ on\ equity^{15} + Borrowed\ Capital\ ratio \times Rate\ of\ return\ on\ borrowed\ capital^{16} \quad (2\text{-}3)$$

Operational return should reflect the proper opportunity cost of assets, which mainly depends on the evaluation of the rate base; thus, the evaluation method of the rate base is the most important regulatory task. Inadequate estimation of it might either jeopardize the sustainable business of the firms or allow them to earn excessive profit (Campos and Cantos 1999). However, in reality, the evaluation of the proper rate base is not a simple task. For example, whether the evaluation of assets is based on historical cost (acquisition cost or book value) or present value (replacement cost) makes large difference in the outcome

2.2.2 Incentive Regulation

In addition to the difficulty in calculation described above, traditional full cost principle involves several problems as follows (Fujii and Chujo 1997):

- It reduces the incentive for cost reduction.
- The regulation makes it difficult for the firms to adapt to dynamically changing market.
- All cost information provided by the firms to the government may not be necessarily correct, since it is difficult for the government to check the accuracy of the cost information.
- If the firms run other business, which is not regulated but under competition, then there might be an incentive for the firm to allocate the cost for the business to the cost of the regulated rail business.

In order to address these problems, various regulatory frameworks have been considered in each infrastructure business including railway.

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[14] Equity ratio is 30% and borrowed capital ratio is the rest of 70% for calculation by MLIT direction.
[15] Rate of return on equity is the average of three index: yield to subscribers for public and corporate bonds, overall-industry average of return on equity, and dividend on equity ratio etc (11%)
[16] Real average rate of liabilities

- **Yard-stick competition**

Yard-stick competition is a regulation method intended to give the incentive to reduce the operating cost for railway operators (operating expenses in Figure 2-1). In Japan, this regulation scheme was applied to 15 major private railway companies[17] (this did not include JNR) in the 1970s. Since 1997, after the division and privatization of JNR, the yard-stick competition has been applied also for JR companies.

Currently, the Ministry of Land, Infrastructure, Transportation and Tourism (MLIT) applies the yard-stick competition for three groups: 6 JR companies[18], 15 major private companies, and 10 public subway systems[19]. MLIT collects operating cost data from rail operators and calculates "the standard cost" for each group every year. Then, based on the comparison between the calculated standard cost and the "real cost" of the company, which proposes a new fare, the "proper cost" is calculated as follows:

- If real cost > standard cost (inefficient company)

$$Proper\ cost = Standard\ cost \qquad (2\text{-}4)$$

- If real cost < standard cost (efficient company)

$$Proper\ cost = (Standard\ cost + Real\ cost) \div 2 \qquad (2\text{-}5)$$

If the real operating cost of the firm is higher than the standard cost (2-4), the standard cost of the group is regarded as the proper cost of the firm. As a result, the firm cannot shift the real cost, which comes from the inefficient operation of the firm, onto the fare of a new line. On the other hand, if the real cost of the firm is lower than the standard cost of the group (2-5), half of the difference between the real cost and the standard cost can be rewarded as a proper cost. As a result, the firm gets the benefit from the efficient operation[20]. Therefore, the yard-stick competition gives the incentive to reduce the operating cost for rail operators through the competition in cost reduction. Mizutani et al. demonstrates by the empirical data that the yard-

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[17] 15 major private companies: Tobu Railway, Seibu Railway, Keisei Electric Railway, Keio Corporation, Odakyu Electric Railway, Tokyu Corporation, Keikyu Corporation, Sagami Railway, Nagoya Railroad, Kintetsu Corporation, Nankai Electric Railway, Keihan Electric Railway, Hankyu Railway, Hanshin Electric Railway, and Nishi-Nippon Railroad

[18] 6 JR Companies: JR Hokkaido, JR East, JR Central, JR West, JR Shikoku, JR Kyushu

[19] 10 public subway systems: Tokyo Metro, Sapporo city, Sendai city, Tokyo Metropolitan Bureau of Transportation, Yokohama city, Nagoya city, Kyoto city, Osaka city, Kobe city, and Fukuoka city

[20] Consumers also get benefit by the other half of the difference between the real cost and the standard cost, because it is not shifted onto the fare.

stick competition effectively reduces the operation cost of 15 major private companies in Japan during 1995-2000 (Mizutani, Kozumi, and Matsushima 2009).

- **Price cap mechanism**

Another common method to complement the shortcomings in full cost principle is price cap mechanism. Although there are minor variations of the price cap mechanism, the most common way in rail industry is RPI-X formula (Campos and Cantos 1999). In this scheme, the price increase from one year to another year cannot exceed the increase in the retail price index (RPI) minus a certain fixed cost (efficiency related) parameter X.

$$\frac{Price_{year\ t}}{Price_{year\ t-1}} \leq RPI - X \tag{2-6}$$

The advantage of the price cap is that it can give the incentive to reduce the operating cost, and also give the managerial freedom for rail operators. Price cap mechanism is the basis of price regulation in UK rail industry after its deregulation. It is also common in public utility such as telecommunication, gas and airport in many developed counties.

2.3 Differential Pricing

The latter half of the discussion regarding the pricing strategy for the Chuo Shinkansen Maglev in this thesis is the application of differential pricing for the pricing in HSR (Chapter Chapter 5), which is often called "revenue management (RM)" as a representative terminology in many literatures. As will be introduced later, the development of various differential pricing techniques has been achieved in airline industry. Hence, it is useful to introduce the basic concept and development history before moving into the practical examples of the RM applications in rail industry.

2.3.1 Terminology

Although RM is currently used in many other businesses than airlines, we follow the use of the basic terminologies in the airline sector. In order to avoid confusions, it is useful to start with the clarification of some terminologies. This thesis follows the terminology used in the airline pricing: "***Pricing***" refers to the process of determining the fare levels for a set of fare products in an origin-destination (O-D) market. "***Revenue management (RM)***" is the subsequent process of determining how many seats to make available at each fare level (Belobaba, Odoni, and Barnhart 2016).

Another important distinction regarding airline pricing is the difference between price discrimination and price differentiation. "***Price discrimination***" is the practice of charging different prices for the same (or very similar) products that have the same costs of production, based solely on different consumers' willingness to pay[21]. "***Product differentiation***" involves charging different prices for products with different quality of service characteristics and therefore different costs of productions. The term "***differential pricing***" reflects both product differentiation and price discrimination principles. Traditional Japanese railway pricing under regulation incorporated only product differentiation. Today, most rail companies adopt price discrimination to some extent as a form of discounted tickets.

A large number of papers have focused on quantitative approach for the optimal seat allocation at given number of fare products (McGill 1999). On the other hand, from the customer's perspective, opening and shutting down of a seat class are viewed as changes in price. The term "***dynamic pricing***", is often used when the revenue maximization problem is treated from the view of the change in the price. The thesis basically uses "***dynamic pricing***" instead of RM, since our approach in Chapter 5 is based on the customers' perspective.

2.3.2 Differential Pricing Theory

- **Economic principle**

In order to illustrate the concept of differential pricing, we start with the theoretical basis of a simple price discrimination method. Assume that there is a single transportation mode in an O-D market. The demand in transportation service is defined by O-D market. Hence, the willingness to pay (WTP) for the service is defined by the price-demand curve in the O-D market. As following microeconomics textbooks, people have different level of WTP for an identical quality

[21] In general microeconomics textbook, price discrimination also includes the discounted price for specific user groups from the view of social equity, such as student discount and elder discount. However, in the context of airline pricing, price discrimination basically refers to the differentiated price in terms of consumers' willingness to pay. The discounts for the specific user groups are out of the scope of this thesis.

of services, because they have each individual preference such as trip purpose, budget constraints, and value of time. Figure 2-2 demonstrates a simple price-demand curve for an O-D market. If a firm sells a ticket for the service at the price P1, Q1 consumers are expected to purchase the tickets, because their WTP for the service is greater or equal to P1. If the firm also offers discounted tickets with the price P2, the additional Q2 consumers will purchase the tickets, and similarly if the firm offers the discounted tickets with the price P3, Q3 consumers will buy the tickets.

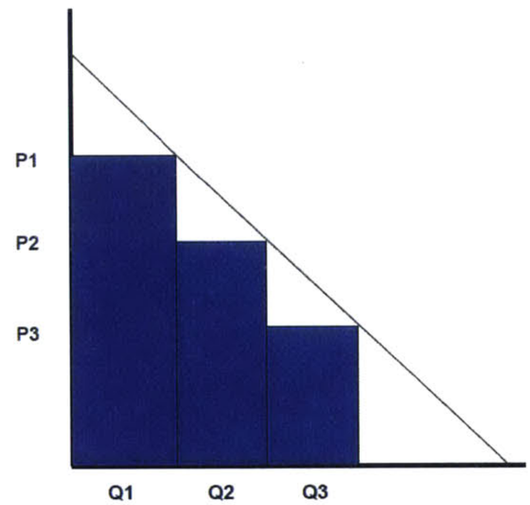


Figure 2-2: Differential Pricing model

Now, we assume that the firm can perfectly segment the market according to the consumers' WTP. In terms of the economic efficiency, both the firm and consumers are better off by differential pricing in this simple situation. If the firm cannot offer differentiated price, it would price the ticket at the price which maximizes the total revenue[22]. In this case, assume that the price which maximizes the total revenue is equal to P2. Clearly, the total revenue gained by the fixed price at P2 is less than that gained by the differential pricing as shown in the blue area in Figure 2-2. Therefore, the firm implementing differential pricing can be better off.

From consumers' point of view, they also get benefit from different pricing. If the firm offers a single price at P2, Q3 customers would not use the service since their willingness to pay P3 is less than P2 ("kicked out" from the market). While Q1 customers pay higher price (P1)

[22] In this simple demonstration, we ignore the cost of producing the transport service (zero marginal cost).

than what they would have paid if the firm offered a single price level (P2), it is also conceivable that high-fare customers end up with enjoying higher quality of service (e.g. larger frequency) than what it would have been. This is because the existence of low-fare customers would contribute the incremental revenue to the operating cost of the firm (Belobaba, Odoni, and Barnhart 2016).

This is the rationale of price discrimination supported by the economic theory. The theory explains that a firm tends to take the price discrimination strategy, if it has a certain market power under no price regulation. However, price discrimination brings another discussion regarding "fairness" among customers. Figure 2-3 illustrates an example of airline fare product for Boston-Detroit by Delta Airlines in September 2013. The highest fare for coach class (Y) is more than 4.5 times than the lowest fare for the same seat grade (V). This ratio can be as great as 8 times the lowest fare in some similar market (Belobaba, Odoni, and Barnhart 2016). Those who have to pay higher fare are usually business customers. We will discuss the argument in Chapter Chapter 5 as the argument around fairness and transparency.

Class	One Way Fare	Advance Purchase	Minimum Stay	Change Fee	Refunds	RT Required
Y	$936	None	None	None	Yes	No
B	$794	None	None	$200	No	No
M	$603	None	None	$200	No	No
H	$501	14 days	None	$200	No	No
K	$365	None	Sat Night	$200	No	Yes
T	$249	7 days	Sat Night	$200	No	Yes
X	$215	14 days	Sat Night	$200	No	Yes
V	$205	21 days	Sat Night	$200	No	Yes

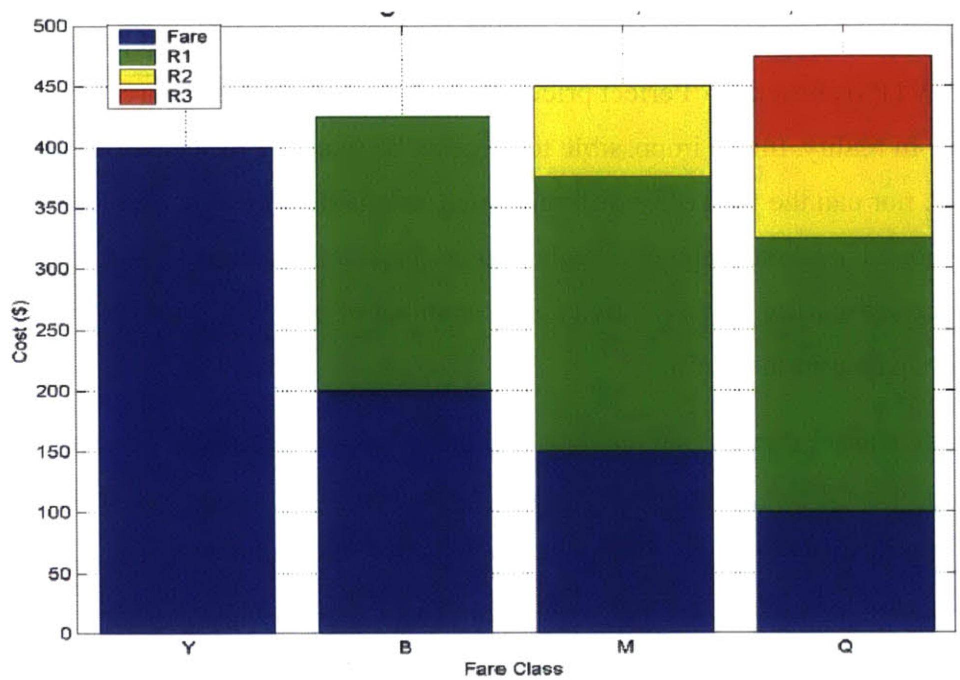
Source: (Belobaba, Odoni, and Barnhart 2016)

Figure 2-3: Example of airline fare product- Boston-Detroit fares by Delta, September 2013

- **Market segmentation**

Whether the price discrimination is successfully implemented or not largely depends on how the firm can segment the market according to the customers' willingness to pay (WTP). In theory, the total revenue for a firm is maximized when each customer pays a different price exactly equal to his/her WTP (referred as "Perfect price discrimination" or "First-degree price discrimination"). In reality, this is impossible to achieve, because the firm cannot know each customer's WTP, nor can the firm offer different prices available only to particular individuals. Instead, airlines identify market segments with similar characteristics among customers, such as trip purpose, price sensitivity, time sensitivity and a number of people in a group (referred as "Third-degree price discrimination").

In order to achieve demand segmentation in practice, airlines usually implement a combination of product differentiation and price discrimination. As for product differentiation, airlines can offer physically identifiable product such as first class and business class. The difference among time of flight departures, which is naturally dealt with the provision of multiple flights in a day, also can be regarded as a tool of product differentiation. The addition of attractive amenities and supplemental services such as the use of an airport lounge and the priority in early boarding can also be considered as techniques of product differentiation. On the other hand, setting restrictions on the advance purchase, the use of the ticket, and the refundability within the same economic cabin class is a way of price discrimination. These restrictions are designed to reduce the attractiveness of the tickets for business travelers, while keeping attractiveness for leisure customers. Figure 2-4 demonstrates the image of the actual fare and disutility cost imposed by the restriction on the affordable fare products. Blue color represents the actual fare for each fare class, while green, yellow, and red color represent disutility cost imposed by each type of restrictions. Even though actual fare of fare class Y is higher than any other fares, people who regard the restrictions on fare class B, M, and Q as sufficiently "undesirable", are expected to choose the fare class Y, which is intended for business travelers.



Source: MIT 16.71 unpublished lecture note (Belobaba 2015)

Figure 2-4: The representation of disutility cost in airline fare product

2.4 Airline Revenue Management

McGill's paper summarizes the history of the revenue management (RM) research (McGill 1999). Before 1972, most of the quantitative research in reservations control focused on how to effectively control overbooking for airlines. In the early 1970s, some airlines such as BOAC (current British Airways) started to offer restricted discount fare products for their flights, in which some passengers pay higher fare while others enjoy discounted fare with some restrictions in the same aircraft compartment[23]. This innovation provided the airlines the great opportunity to gain the additional revenue from the seats, which would otherwise flew empty. On the other hand, the launch of this operation imposed on the airlines a difficult question; to what extent should the discounted seats be offered (or to what extent should the high fare seats be protected), in order to avoid "spillover" of high-fare passengers into lower fares.

[23] BOAC's earlybird booking offered lower fare for people who book seats at least 21 days in advance of flight departure.

Since the effective control of the discount seats requires the development of information system capabilities, detailed demand estimation, and inventory control algorisms. Littlewood, who worked for BOAC, proposed the basic concept of seat inventory control in 1972, in which a discount fare booking should be accepted as long as the revenue from the discounted seat exceeded the expected revenue of future full fare bookings (Littlewood 1972). This simple, two-fare seat inventory control rule was the beginning of yield management and later, revenue management (RM). In North America, RM techniques started to be intensively developed after American Airlines launched Super Saver fares in April of 1977. The development of RM techniques has been intensified by the Airline Deregulation Act in 1978. The Act gave any airlines in the US complete freedom to enter or exit any US domestic market, also allowed them to determine the frequency of flights, the number of seats, and fares they charged.

Today, most airlines implement RM systems which calculate the booking limits on each fare class for all future flights. Typically, a RM system takes a set of fare classes, schedules, and capacities in a plane as given, and output the option capable of maximizing the potential revenue under the given condition[24]. The computerized RM system became necessary as the differential pricing of the firms got to include several number of fare classes for the same seat grade on a flight.

RM systems have evolved from the simple two-fare inventory control to single leg-base control though origin-destination control. Today, most airlines have a single leg-base inventory control system, typically called "third generation system" as explained later. Some of the world's major airlines have more advanced "O-D control" systems, which allow the airlines to further distinguish between the seats available to a single-leg and multiple-leg (connecting) passengers by fare products. We now see a brief summary of airline RM development and major function of it, according to Belobaba et al.'s book in the rest of this section (Belobaba, Odoni, and Barnhart 2016).

The first RM systems, developed in the early 1980s, generated historical booking pattern from the airline reservation systems and provided them for the RM analysts. However, the

[24] The explanation of the revenue management algorithm is beyond the scope of the thesis. If the reader is interested in the detail of the airline revenue management, see Belobaba et al. (2016).

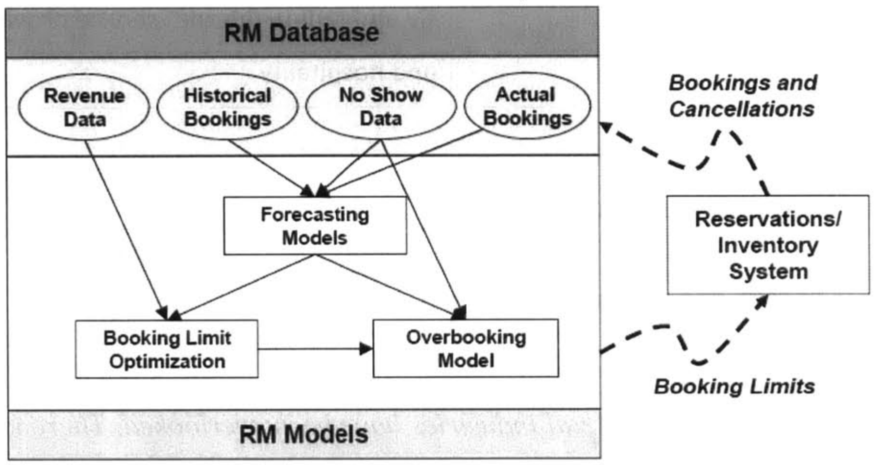
analysts still had to decide the appropriate booking limits for each fare class based on their experience, without any recommendation from the systems.

By the mid-1980s, several RM systems with additional monitoring capabilities were developed. These systems could compare the actual booking curves for future flights with the booking curves expected from the historical booking data, and provide the "exception report" for the analysts whenever the flight's booking deviated from the expected booking curves. These systems successfully identified the flights which required the analysts' attentions, but still could not provide the analysts with the recommended booking limits.

By the late 1980s, several large airlines and RM system venders began to develop RM systems which could forecast and optimize the booking limits for a future flight leg, as well as have the same database and booking monitoring systems as the airlines already had. The outcome of the development was a "third-generation" system. A typical third-generation system has following characteristics:

- Collect historical booking data by flight leg and fare class.
- Forecast future demand by flight leg and fare class.
- Make use of mathematical models to optimize expected flight revenues, by determining both the optimal overbooking levels by aircraft compartment (e.g. first, business, and economy) and the optimal booking class limits by booking class within each compartment.
- Provide RM analysts with interactive decision support, which allow them to review, accept, or reject the overbooking and booking limit recommendations.

The major components of a third-generation RM system, which are capable of performing the functions listed above, are illustrated in Figure 2-5. In short, the historical and the actual booking data are fed into a forecasting model, which generates a forecast of booking demand by each booking class. This forecast and revenue value of each booking class are then put into an optimization model, that calculates the recommended booking limits for each booking limit on the flight leg in question. At the same time, an overbooking model calculates an optimal overbooking level, by utilizing the demand forecast and historical information about passenger no-show rates. Both the booking class limits and the overbooking limits are calculated by the mathematical models and then given to the analysts as the recommendations. The analysts can approve or modify them to the airline's reservation system. All third-generation system revise their forecasts, booking limits, and overbooking limits at regular intervals, typically as often as on a daily basis (Belobaba, Odoni, and Barnhart 2016).



Source: (Belobaba, Odoni, and Barnhart 2016)

Figure 2-5: System illustration of typical third-generation revenue management system

Also according to Belobaba et al., it is now commonly accepted that the use of a third-generation RM system can increase airline revenue by 4-6%[25], based on a variety of empirical studies and simulation experiments (Belobaba, Odoni, and Barnhart 2016).

The success of RM development in the airline sector stimulated the applications in other transportation sectors, as well as other service businesses (Table 2-1). The most notable example of the application of RM may be seen in the hotel industry. Despite some similarities with the airline business, the application of airline RM for passenger rail business have not expanded widely, as we will see in following chapters.

[25] This is the increase in revenue, not profit. The revenue management system of course incurs initial investments on the system and training of analysts, so the increase in profit may be less than the increase in revenue. However, as one of the strongest points of revenue management in terms of business strategy, it may increase revenue without substantial increase in operating cost (Belobaba, Odoni, and Barnhart 2016).

Table 2-1: Revenue management application for various sectors

Transport related	Airlines, Passenger railways, Freight railways, automobile rental, cruise lines
Non-transport related	Broadcasting (e.g. advertising slot allocation on TV and radio), Internet service provision, Lodging and hospitality

2.5 Revenue Management in Rail

2.5.1 Differences in rail and air industry

> *"While the airline and hotel industries have received their fair share of attention, the passenger rail and freight rail industries have been overlooked. There is still little published research on these industries"* (Armstrong and Meissner 2010)

Despite the fact that both rail and air are categorized as mass transportation service with several similarities, as Armstrong and Meissner state, rail industry have not enjoyed the development of revenue management (RM) techniques, compared with airline. Some fundamental differences in the service characteristics between rail and air can be factors which inhibit the application of RM for rail industry. Also, the industrial characteristics in rail industry also hinder RM applications for rail. In addition, especially for the Japanese HSR, the difference in cost structure is considered to be one of the reasons for being reluctant to use RM. Since there exist some variations among HSRs in the, common characteristics are discussed below unless otherwise noted.

- **Fundamental differences in service nature**

Armstrong and Meissner illustrate six fundamental differences between air and rail (Armstrong and Meissner 2010):

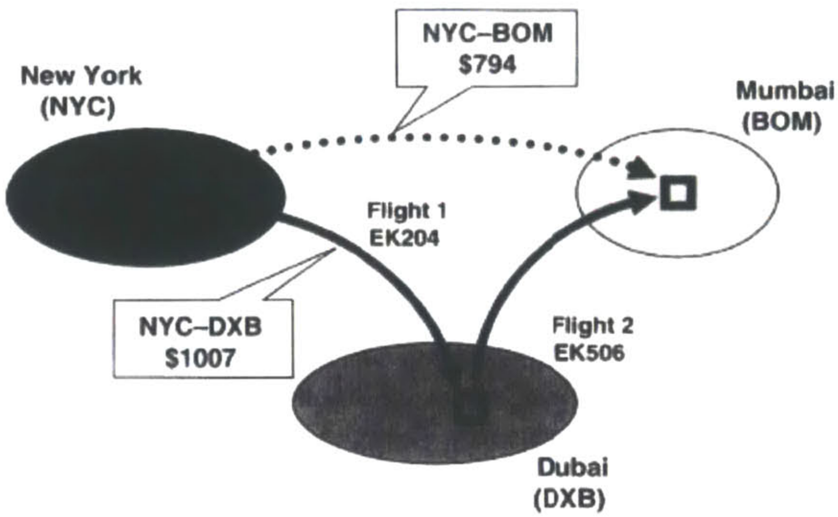
1. *"There is no check-in procedure on passenger rail services.*
2. *Open tickets generally allow passengers to travel on any rail service (without check-in or authorization to travel).*

3. *Walk up tickets are very common; a large number of passengers purchase their tickets on the day from the station.*
4. *A large number of services run at a load factor of less than 100%, thus the overbooking paradigm does not need to be considered.*
5. *Passengers are often allowed to stand during train journeys hence increasing capacity beyond the number of seats.*
6. *Legs cannot be considered independently as the majority of journeys are composed of multiple adjacent leg"*

While these points well emphasizes traditional characteristics in rail transport in general, some may not be true for HSRs. As for the second point, for example, TGV in France and Acela Express in the US don't adopt open tickets (non-reserve tickets), while the Tokaido Shinkansen has those. As for the third point, as we will see in Chapter Chapter 5, TGV offers largely discounted tickets in advance; thus many people seem to book the tickets prior to the departure.

The sixth point leads to two effects on rail RM as follows. First, most of O-D pairs in which HSRs dominant market shares usually have distance with the range of 300-500km (186-311miles). In this range, HSR has multiple intermediate stations between both terminals. For example, the Tokaido Shinkansen has 11 stations between Tokyo and Nagoya (342km or 213miles) and Acela has 6 stations between New York and Washington DC (362 km or 225 miles); thus the rail trip from Tokyo to Osaka comprises 12 legs and that from New York to Washington DC comprises 7 legs. On the other hand, airlines offer direct flights (a single leg) between the O-D pairs in this range of distance. The existence of larger number of legs makes differential pricing in rail more complicated than that of airlines.

Second, consider a simple string of stations in HSR, A, B, and C, respectively. A trip from A to C comprises two legs, a leg AB and a leg BC. In the rail fare structure, the fare between A and C should be higher than either the fare between A and B or the fare between B and C. Equivalently, if a firm increases the fare between A and B, then this increase usually brings a fare increase between A and C. This simple rule, a fare of an O-D pair is always higher than a fare of any subcomponent O-D pair, makes the fare structure consistent but inflexible. On the other hand, the fare structure of airlines is inconsistent but more flexible. Figure 2-6 illustrates an example of O-D market price in an airline. There are two distinct markets shown in the figure: from New York to Dubai and from New York to Mumbai (via Dubai). Distinct markets have different price elasticities. Airlines aggressively take advantage of the difference. In Figure 2-6, the lowest available one-way economy class fares in each O-D market in July 2014 are shown: $1007 is one-way travel on Emirates Airline from New York to Dubai, and $794 is one-way travel on the same airline from New York to Mumbai, with a connection of Dubai (Belobaba, Odoni, and Barnhart 2016). The fare between New York to Mumbai is much lower than the fare between New York to Dubai, despite New York to Dubai is the sub-component of New York to Mumbai. In rail fare, this is not the case because it adopts consistent relationship among adjacent legs.



Source: Belobaba et al. 2016

Figure 2-6: Example of O-D market price difference

- **Industrial differences**

Dorhout explains the characters which inhibit rail RM applications from the broader perspective, including institutional and practical issues (Dorhout 2014). Table 2-2 summarizes the points demonstrated in the paper.

Table 2-2: Characters inhibiting revenue management application to rail industry

Category	Characters in rail industry
Strategy	• Intramodal monopoly is usually allowed; thus price regulation still_exists. This constrains the abilities to optimize revenue. • Complexity exists in the operators' objective function. Many firms are state-own; thus sometimes their aim is not profit-maximization, but passenger-volume maximization.
Business Model	• Rail network structure requires extensive and sensitive segment optimization. • Commuters usually use non-reserved seats, jump-in, at the busiest time, even though their fare are often reduced by regulation.
Organization	• Rail revenue management teams were launched by inviting airline revenue management experts from air industry, but rail-specific characters were not usually taken into account. • Advanced revenue management systems became black-box and rail firms could not train experts. • Decisions made outside revenue management department can make impact on supply and demand. For example, train timetable is designed based on technical and operational standpoint.
Systems and Data	• Unlike airline industry, lack of global harmonization exists in rail industry: discrepancy in terminology, data, technical standard, and especially reservation and inventory system.

Source: Dorhout (Dorhout 2014), summarized by the author

Dorhout emphasizes in the paper that rail companies should realize they cannot just copy and paste the RM system from the air sector. He says that *"it is very optimistic to think that the full potential of RM can be realized without a deep and detailed understanding of the inner workings of the system"* (Dorhout 2014).

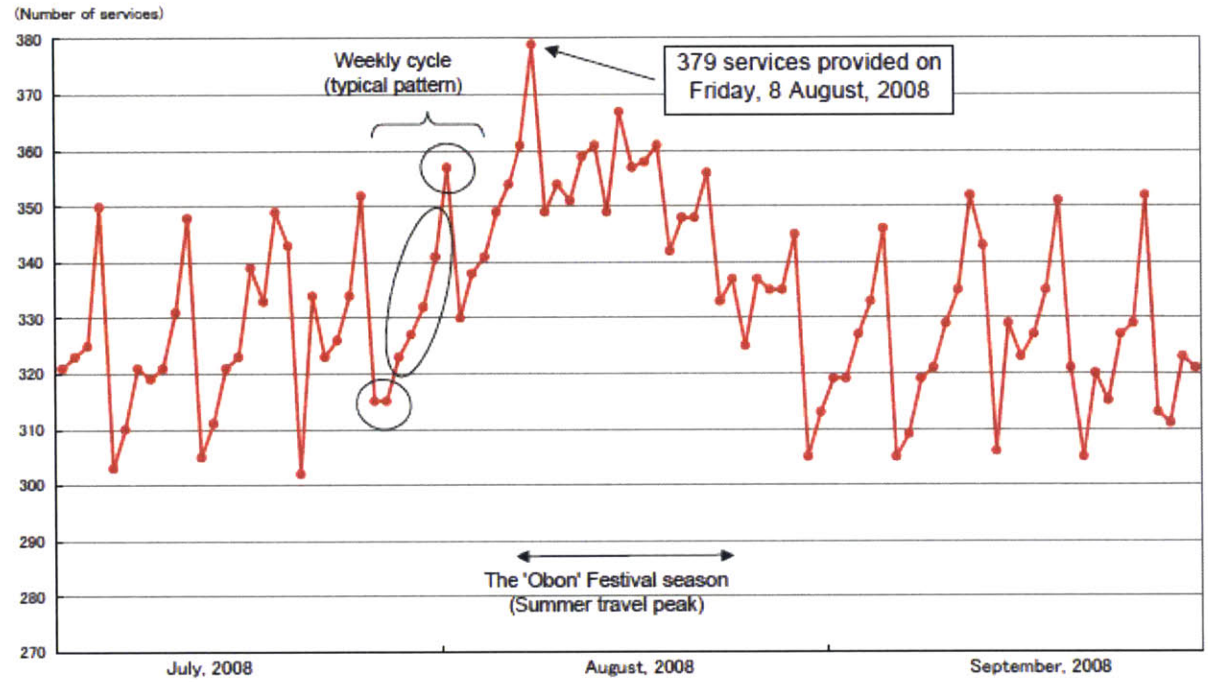
In addition, unlike airlines, the inventory systems, reservation systems, distribution systems, and also the information systems, which is the basis of those marketing systems in rail sector, are not standardized in the industry level. This explains the reason that even though some HSRs successfully implemented RM systems more than ten years ago, these systems or even the basic concept of the systems have not easily spread to other rail firms.

Also, the decision making in the "supply side" of a rail firm, such as a schedule planning department making a train timetable, is usually not well coordinated with the strategy built by the RM department. In airlines, a basic operating schedule, such as frequency, seat capacity, and basic time of departure, is fixed and rarely changed. On the other hand, a train schedule, which is usually decided and modified by a schedule planning department, is usually considered as more flexible especially in Japan. This is explained in the rest of this section with an economic rationale behind this.

- **Flexibility in supply – difference in cost structure**

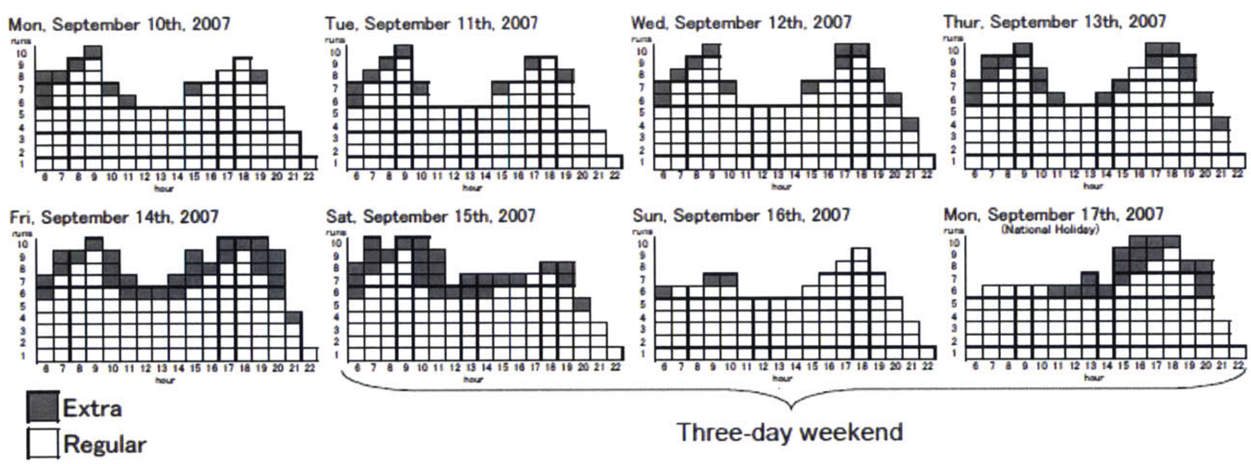
Although it is not true for all HSR operators in the world, basically the frequency of HSR is more flexible than that of an airline especially in Japan. As we can see in Figure 2-7, the number of trains in the Tokaido Shinkansen widely changes day-to-day basis. It basically has weekly cycle, as large number of trains on Friday and low number of trains on weekends. In a peak season, such as a week-long vacation in every August, the timetable is adjusted more dynamically in accordance with the demand fluctuation. Figure 2-8 demonstrates how the timetable is constructed and modified by a schedule planner for the Tokaido Shinkansen. A planner makes a "fixed", regular timetable once a year[26]. At that time, daily demand fluctuation for a coming year cannot be forecasted accurately, because of the lack of enough information. As departure day approaches, the planner adjusts the number of trains for every single operating hour, by adding extra trains in addition to regular services in order to satisfy the demand. Figure 2-8 illustrates the difference in the number of trains per hour, operated in eight consecutive days. The horizontal axis represents the hours of train departure at Tokyo Station. Each block shows a train service: White blocks are daily services and dark-shaded blocks are extra services. These figures illustrates that the number of trains changes significantly on a daily basis to accommodate fluctuating travel demands.

[26] A basic timetable renovation is usually implemented every March in Japan. But sometimes it is done in other seasons, for example October 1st in 2003, when Shinagawa Station opened. Also, no change is made in some years.



Source: (Ogawa et al. 2008)

Figure 2-7: The number of the Tokaido Shinkansen trains, changing day-to-day basis



Source: (Ogawa et al. 2008)

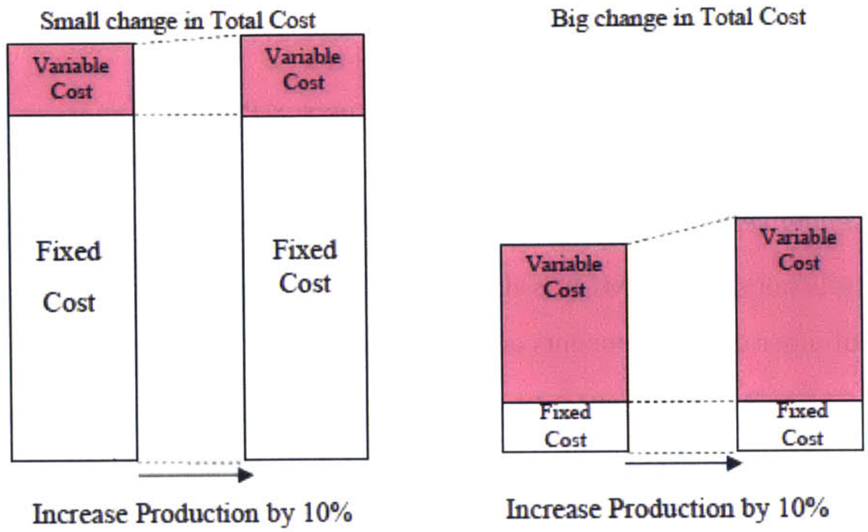
Figure 2-8: The number of hourly Nozomi and Hikari trains, departing Tokyo Station, in a week (9/10/2007-9/17/2007)

Frequency in HSR is a major supply factor, while fare is a major factor which can affect the demand. We now try to explain the tendency to change the supply side rather than the demand side in rail sector, comparing to airlines, from an accounting point of view.

Assuming that there are two firms which have different cost structures: One firm (Firm A) has a large fixed cost compared to a small variable cost, as shown in the left figure in Figure 2-9. The other has a large variable cost compared to a small fixed cost, as shown in the right (Firm B). If both Firm A and B increase their supply by 10%, while the total cost of Firm A changes slightly, the total cost of Firm B changes much more significantly than Firm A. Thinking of the number of trains as variable output, since railway companies have a large amount of fixed assets, such as structural infrastructure, station buildings, signal equipment, and rolling stock, they can be categorized as Firm-A type[27]. On the other hand, typical airline companies are classified as Firm-B type; since they don't own infrastructure and majority of their operating costs are related to the number of flights they offer.

In some literature, airlines are classified as fixed-cost intensive companies. In those cases, the number of flights are considered to be a fixed term, instead, the number of passengers is a variable term. Thinking in that way, since most operating expenses are related to the number of flights, the proportion of variable costs become much larger. Again, we assume that the frequency is a variable term in this discussion.

[27] Railway operators in a vertically separated industry, which don't have infrastructure, may not be the case. Japanese Railway industry is basically vertically integrated as we see in Chapter 1.



Source: Ogawa et al. 2008

Figure 2-9: The difference in cost structure between rail and air

Table 2-3 shows the annual operating cost on the railway operation of JR East, JR Central, and JR West, respectively[28]. All of three companies operates Shinkansens. Data is retrieved from the Railway Statistics Annual Report (Ministry of Land, Infrastructure, Transport and Tourism 2012a). Assuming that the train frequency is a variable term, some cost categories are clearly classified as either fixed costs or variable costs, such as depreciation (fixed cost), track/overhead trolley maintenance (fixed cost)[29], passenger services (fixed cost)[30], and clew and electricity (variable cost). On the other hand, other cost categories, such as traffic management, general and administrative, advertising, and facilities for the welfare of employees have both fixed and variable aspects. In order to allocate these costs (referred as other costs in the table) into either fixed or variable component, we follow a method used in the feasibility study of the

[28] This is the aggregated operating cost in HSR and conventional rail. It does not include the cost related to business other than railway, such as real estate business.

[29] It is possible to say that the track and overhead trolley maintenance cost are partly variable costs in a long-run, since the grade of the track or the overhead trolley are influenced by the required frequency of trains. However, periodical maintenance work is performed regardless of the number of trains; thus in a short-run, these are considered to be fixed costs.

[30] Passenger services costs are approximately in proportion to the number of passengers. Since we assume a variable term is the number of trains rather than the number of passengers, passenger services cost can be classified in fixed costs.

Hokuriku Shinkansen by MLIT (Ministry of Land, Infrastructure, Transport and Tourism 2012d). The equation in the cost allocation is shown below:

$$Fixed\ portion\ of\ other\ costs = Other\ costs\ \times P/(P + C) \quad (2\text{-}7)$$

$$Variable\ portion\ of\ other\ costs = Other\ costs\ \times C/(P + C) \quad (2\text{-}8)$$

P: Passenger services, C: Clew and electricity

Although it is not stated in MLIT's document, the assumption behind this equation seems that the majority of other cost components are related to either the number of passengers or the number of trains.

We can see that fixed cost dominates 68-76% of the total operating cost in these companies (Table 2-3). Especially for JR Central, depreciation cost accounts for a large proportion of the total cost.

Table 2-3: Annual operating cost of three JR companies in FY2012

¥120 = $1		JR East expence ($ million)	JR East % in total	JR Central expence ($ million)	JR Central % in total	JR West expence ($ million)	JR West % in total
Fixed costs	Track/Overhead trolley maintenance	**2,564**	**21%**	**1,463**	**22%**	**1,110**	**18%**
	Other asset maintenance	**345**	**3%**	**279**	**4%**	**183**	**3%**
	Depreciation	**2,252**	**18%**	**1,854**	**27%**	**1,102**	**18%**
	Passenger services	**2,330**	**19%**	**933**	**14%**	**1,184**	**19%**
	Other fixed costs	**1,375**	**11%**	**637**	**9%**	**581**	**9%**
	Sum of fixed costs	**8,866**	**72%**	**5,168**	**76%**	**4,160**	**68%**
Variable costs	Rolling stock maintenance	**852**	**7%**	**595**	**9%**	**604**	**10%**
	Clew and electricity	**1,664**	**13%**	**617**	**9%**	**932**	**15%**
	Other variable costs	**982**	**8%**	**421**	**6%**	**458**	**7%**
	Sum of variable costs	**3,498**	**28%**	**1,632**	**24%**	**1,994**	**32%**
Total costs		**12,364**	**-**	**6,800**	**-**	**6,153**	**-**

Source: Calculated by the author, based on Railway Statistics Annual Report FY2012 (Ministry of Land, Infrastructure, Transport and Tourism 2012a)

Table 2-4 shows the annual operating costs of American Airlines and Southwest Airlines. Since there is no available cost data regarding airlines in Japan, these two airlines are chosen as representatives of a typical legacy airline and a typical low-cost airline, respectively. Data are relieved from MIT Airline Data Project website (MIT Global Airline Industry Program 2014) and the Form 41 database (United States Department of Transportation 2014). We can see that variable cost dominates around 70% in these airlines, which is a marked contrast to the rail industry shown in Table 2-3. The largest cost component in airline operating cost is fuel cost, which occupies almost 30% of the total operating cost. This difference in cost structure between rail and airline industry leads to the tendency to change whether the supply side (train frequency) or the demand side (fare).

Table 2-4: Operating cost of American Airlines and Southwest Airlines in FY2014

		American Airlines		Southwest Airlines	
		expence ($ million)	% in total	expence ($ million)	% in total
Fixed costs	Aircraft depreciation	946	4%	359	2%
	Reservation and sales	1,340	6%	669	4%
	General and administrative	5,266	22%	1,582	10%
	Other fixed costs	589	2%	693	4%
	Sum of fixed costs	8,140	33%	3,303	21%
Variable costs	Pilots	1,863	8%	2,020	13%
	Fuel	7,000	29%	5,082	32%
	Aircraft maintenance	2,382	10%	1,472	9%
	Passenger service	1,910	8%	1,177	7%
	Aircraft service	1,178	5%	1,728	11%
	Traffic expense	1,848	8%	1,005	6%
	Sum of variable costs	16,181	67%	12,483	79%
Total costs		24,321	-	15,787	-

Source: Calculated by the author, based on MIT Airline Data Project (MIT Global Airline Industry Program 2014) and US DOT (United States Department of Transportation 2014, 41)

2.5.2 Revenue Management Application for HSR

As mentioned in Section 2.5.1, the rail industry has not enjoyed the development of RM techniques compared with the airline industry. On the other hand, several HSRs have already incorporated the RM system because of the relative similarities with airlines. To what extent they make use of the RM tactics for their business vary company to company and country to country.

Amtrak in the US is the first rail firm in the world to apply RM in the rail industry in 1991. In addition to Amtrak, Societe Nationale des Chemins de Fer Francais (SNCF) in France is one of a few companies, which are known to actively use RM techniques in the rail industry. About 20 years after the commencement of the RM applications in Amtrak and SNCF, JR East in Japan also implemented the RM system for its Tohoku Shinkansen. As for non-high-speed rail operators, VIA rail in Canada and rail operators in UK also actively implement RM. In this section, we present some RM applications for HSRs, mainly focusing on the system overview and the brief history of RM development in France, the US, and Japan.

- **United States**

Amtrak implemented the world-first railway RM system in July 1991 (Kraft, Srikar, and Phillips 2000). The RM system used by Amtrak was customized version of Sabre, which was developed by American Airlines. The system was integrated in the Amtrak's original reservation system ARROW.

ARROW is a simple leg-based reservation system, which is not capable of dealing with the O-D control algorithm explained in Section 2.4. Since the inception of the system, the primary focus of RM at Amtrak has been to prevent short-distance, low-revenue passengers from blocking long-distance, high-revenue passengers (Kraft, Srikar, and Phillips 2000). According to Kraft et al., Amtrak realizes an additional 3-5% incremental revenue from the application of its RM for long-distance trains.

Amtrak initially applied RM practice for long-distance trains, and implemented it for its Northeast regional (NER) trains in October 2005. After positive reactions from customers on the inception, Amtrak expanded the use of RM on its Acela Express and Metroliner trains in February 2006 (Associated Press 2006). The available fare of the Acela or Metroliner trains went up to 15% higher than the existing fare for the trains in peak hours, while the fare went down to 15% lower than the existing fare for the off-peak trains. This commencement of RM on NEC achieved about $15million incremental revenue increase in FY2006 (Abe 2007).

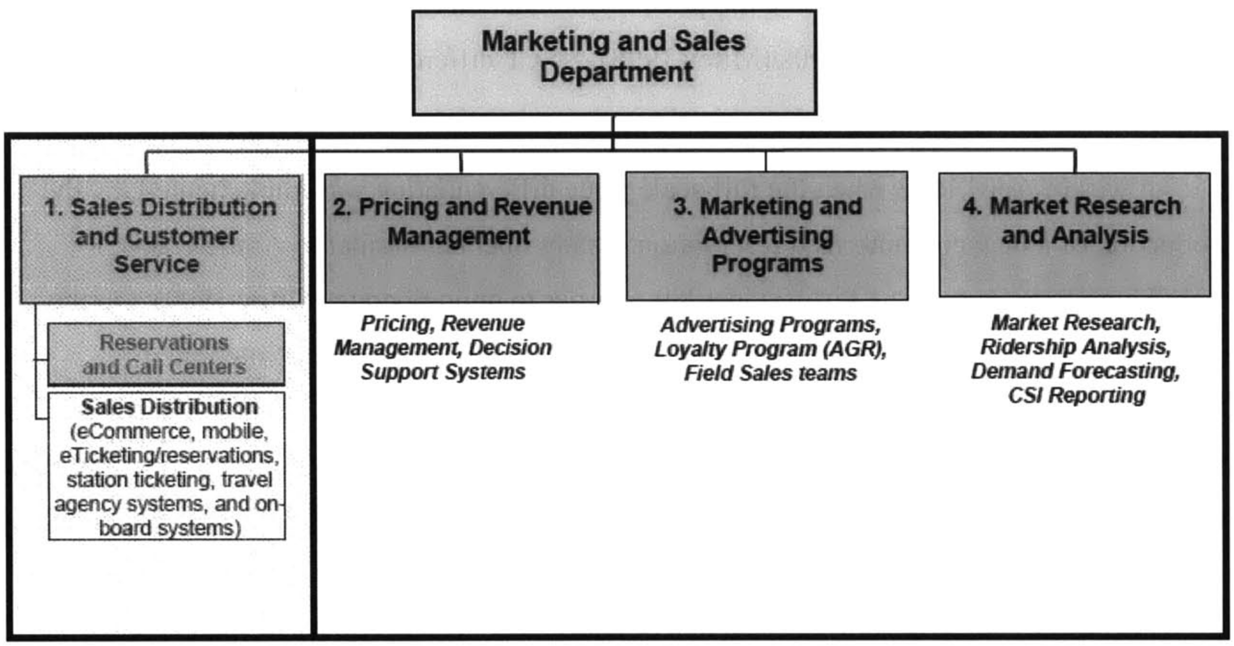
Figure 2-10 and Figure 2-11 demonstrate the organizational structure of Marketing and Sales Department, and its subgroup of Pricing and Revenue Management Section in Amtrak

(Hardison 2013; Richards 2013). RM teams are organized in accordance with distinctive business categories, such as Northeast Corridor (NEC), Auto trains, and long-distance routes.

Currently Amtrak plans to invest in an advanced forecasting module, which is capable of:

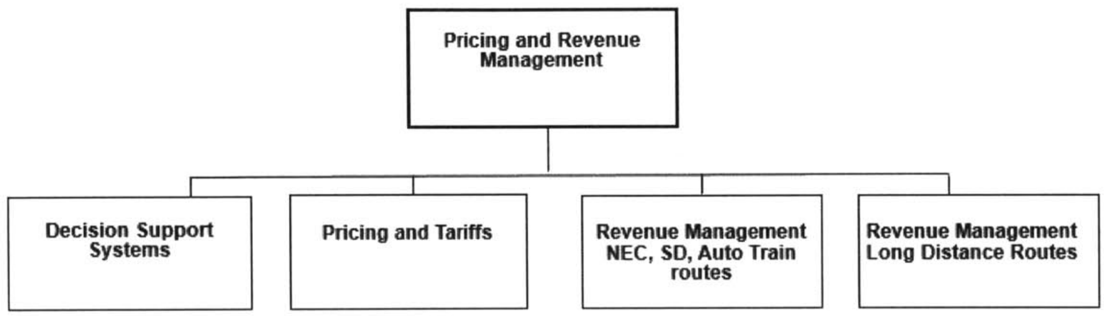
- Forecasting demand more accurately and optimizing revenue for each city pair and fare product
- Uploading optimized inventory in each fare product and authorizations to ARROW
- Achieving the incremental revenue increase by an estimated 3-5%

A similar system was installed in Eurostar in 2005. According to Eurostar management estimation, the investment made in its automated demand forecasting solution was recovered within the first 12 months of operation (Hardison 2013).



Source: (Hardison 2013)

Figure 2-10: Functional Organization of Marketing and Sales Department in Amtrak



Source: (Richards 2013)

Figure 2-11: Functional units in Pricing and Revenue Management in Amtrak

- **France**

SNCF started to implement differential pricing in the early 1980s, in the form of specific discounts (e.g. family cards, old people passes, and youth passes) for limited number of trains. As for HSR, SNCF first implemented the price differentiation in Paris-Lyon TGV in the 80s, then Paris-Bordeaux in the early 90s (Mitev 1998). SNCF differentiates the price in accordance with time of day.

It was in April 1993 when the full-scale price differentiation was implemented, by the introduction of a new computerized reservation system Socrate. Similar to Amtrak, SNCF bought Sabre from American Airlines in 1989 in order to build Socrate (Mitev 1999). On the development of Socrate, SNCF and its vendor Sabre Technology Solutions integrated multifunctional systems, such as a ticket reservation system, a distribution system, and a decision support system. A distinctive characteristic for Socrate is that the system not only functions as a price adjustment and inventory control tool, but also functions as a schedule development and capacity optimization tool (Ben-Khedher et al. 1998). This feature allows SNCF to adjust capacity according to demand. In fact, SNCF operates approximately 85% of the available TGV trainsets for a regular schedule period, and then uses the remaining 15% in peak travel season (Abe 2007).

As for the implementation of the new system Socrate in 1993, however, there were many technical troubles in ticketing, pricing, and selling policies due to the inadequate implementation process (Mitev 1998). Major implementation problems are demonstrated as follows:

- The project management did not give sufficient level of attention toward a design of database and user-interface of the system. For example, the representation of a basic unit in a ticketing database changed from each railway station to a relation between two stations (O-D pairs), like a leg in an airline. While there are usually modest number of O-D pairs in airline ticketing database, nation-wide SNCF network has a large amount of O-D pairs[31]. This feature lead to non-user-friendly interface.
- Staff training turned out to be inadequate. Bookings for non-existing trains happened while trains without no booking (empty trains) also happened, that lead to strikes by SNCF unions.
- Public relations failed to prepare the public for such a dramatic change.

One of the reasons for the inadequate implementation process attributed to rushed decisions by the SNCF management. In April 1993, the commencement of Paris-Lille TGV Nord was scheduled. The new line was strategically important for SNCF, since it lead to north Europe and UK through the Channel tunnel rail link, which was scheduled to be opened in 1994; thus the SNCF management wished to make use of Socrate to accumulate useful travel information from the very beginning of the commencement of TGV Nord. Hence, the implementation of Socrate was adjusted to coincide the date the commencement of Paris-Lille TGV Nord (Mitev 1999).

This is a good lesson for rail firms with a large intercity network, when they intend to make a big change in marketing system. First, the duplication of airline-based system will be problematic. Second, it takes a considerable length of time to prepare for the implementation of a new marketing system. Indeed, this encourages the motivation of the thesis, the examination of a new pricing strategy for JR Central, in accordance with the commencement of the Chuo Shinkansen Maglev.

- **Japan**

JR East started to use a customized RM system, JDA Rail Revenue Optimizer and JDA Reporting, both of which were developed by JDA software, Inc., in 2011. JDA is a world-wide RM system vendor and it also produced a pricing and RM systems for Eurostar in 2006 (JDA

[31] Sabre was programed for a maximum of 80 relations with few intermediate stops (e.g. New York-Denver-LA), SNCF realized that it had to cope with 22,000 relations in the whole French rail network (Mitev 1999).

Software Group, Inc. 2010) as well as large airline companies such as Delta. According to JDA's website, the capabilities of the system include:

- *Forecasting of demand for each market segment*
- *Maximization of revenue based on the management of price and product availability*
- *Inventory allocation so that seats for services for which sufficient demand exists are not sold out*
- *Reaction to competitive changes in the marketplace.* (JDA Software Group, Inc. 2012)

Expanding the use of the RM system, JR launched "JR East dynamic rail package" services on November 27 2015 (East Japan Railway Company 2015b). This is "a travel product that can be structured independently by customers over the internet by freely combining various package elements, such as trains and accommodations, according to price" (East Japan Railway Company 2012). The fare of HSR and the price of hotels are combined as a packaged travel product, which vary in accordance with season, day of booking, and time of departure. This is the first application of dynamic pricing for railway businesses in Japan (Sankei news 2015).

JR West is also enhancing the RM as the core strategy of Sanyo Shinkansen (West Japan Railway Company 2014). Since the competition with airlines in its major HSR market, namely between Osaka metropolitan area and Kyushu area, is getting fierce, JR West offers affordable tickets for those markets and enhance the frequent seat-allocation control for discounted tickets.

In sum, the application of RM for HSR in Japan is implemented with a slower pace than European HSR and the U.S. HSR, but it is getting enhanced recently.

2.6 Conclusion

In this chapter, we began with reviewing economic features of rail transport and basic pricing theory. Second, we reviewed price regulation in rail transport, especially focusing on the regulatory framework in Japanese rail industry. Then we reviewed the concept of differential pricing, which is used as a practical tool for increasing revenue in most airlines and several HSR operators. We illustrated airline RM tactics and development history in order to explain the basis of RM. Finally, we demonstrated the major differences between airlines and rail, which inhibits the simple duplication of airline revenue management for the rail industry, and introduced the HSR RM practices in France, the United States, and Japan.

We now move on to the literature review on the Chuo Shinkansen project and on the recent research work regarding pricing strategies for HSR.

Chapter 3 Literature Review

3.1 Literature Review on the Chuo Shinkansen Maglev Project

The plan of the Chuo Shinkansen Maglev project has been existed since more than three decades ago (Chapter 1). Because of the expected large economic and social impact on the area along the prospective route, most papers regarding the project focus on economic and social benefit analysis (Hino et al., 2015; Miyashita et al., 2009; Muto et al., 2012; Okuda, 2011; Sato, 2013; The Transport Policy Council, 2011; Yamaguchi and Yamazaki, 2009).

Sato simulates the time-series social impact such as the change in population distribution and economic benefit between Tokyo and Nagoya, by using a quasi-dynamic Spatial Computable General Equilibrium (SCGE) model (T. Sato 2013). Based on the result of the simulation for 40 year period, he suggests that the population of the Tokyo metropolitan area would decrease, while the population of the Nagoya metropolitan area and the Kofu area would increase by the commencement of the Chuo Shinkansen Maglev between Tokyo and Nagoya in 2027; thus the project has the potential to solve the overpopulation problem in the Tokyo metropolitan area. The result also demonstrates that the gross regional product for Tokyo, Kofu, and Nagoya will increase, especially Kofu and Tokyo will enjoy the greater economic benefit.

The two-stage scheme of the Chuo Shinkansen Maglev, in which the 1st stage Tokyo-Nagoya completion is scheduled in 2027 and the 2nd stage Tokyo-Osaka completion in 2045, also draws a large attention especially from Osaka metropolitan area, since the 18-year long interval between the 1st and 2nd stage completion might weaken the economy in this area. Hino et al. demonstrate that the opportunity cost of the 18-year interval is estimated as about ¥6trillion ($50billion) (Hino et al. 2015). Another research work by a council, which is promoting the early completion of the whole line of the Chuo Shinkansen[32], estimates the opportunity cost in the same period as ¥12trillion ($100billion) (Linear Chuo Shinkansen Simultaneous Whole-line Commencement Promoting Council 2015).

[32] The Linear Chuo Shinkansen Simultaneous Whole-line Commencement Promoting Council consists of major stake holders in Osaka metropolitan area such as the governor of Osaka and Kansai Economic Federation

While there are several papers focusing on economic and/or demographic impacts of the Chuo Shinkansen Maglev project as illustrated above, to the best of the author's knowledge, there is no academic study publicly available regarding the pricing strategy as a means for improving fiscal feasibility of the project. A part of the reason is that there had been few data publically available regarding the operating feature until recently.

At the third conference of Transport Policy Council Chuo Shinkansen Subcommittee (TPC-CSS) on May 22 2010, JR Central officially proposed the tentative fare plan of the Chuo Shinkansen Maglev for the first time (Table 3-1). In addition to the fact that fare of railway service usually draws public attention, the proposed fare drew a large public attention because it was perceived to be low, considering the current fare and service level of the Tokaido Shinkansen (Nikkei 2010).

Table 3-1: Proposed fare of the Chuo Shinkansen Maglev between Tokyo and Osaka

	Present: The Tokaido Shinkansen	The Chuo Shinkansen Maglev	
		Tokyo-Nagoya opened	Tokyo-Osaka opened
Fare	¥14,100* ($118)	¥14,900 ($124)	¥15,000 ($125)
Difference from present	-	+¥800 (+$6)	+¥900 (+$7)

* As of FY2011. The fare increased to 14,450 when sales tax increased in April 1 2014.

Source: (Transport Policy Council Chuo Shinkansen Subcommittee 2011)

Since the Chuo Shinkansen Maglev project is an innovative, a large-scale, and a long-term transportation project, the demand uncertainty is difficult to address. In addition, unlike conventional HSRs such as the Tokaido Shinkansen, each Maglev train requires a dedicated Power Conversion System (PCS) when it is in operation, which becomes a capacity constraint for Maglev line as described in Section 1.2.5. Ishii developes a hybrid real option model to evaluate the demand uncertainty and the risk and value of R&D for a development of a new PCS which enables flexible capacity adjustment for the Maglev system (Ishii 2007). In his conclusion, the investment for new PCS technologies, which could deal with multiple train operations by a single PCS, is recommended. However, such a technology has not been developed so far. Hence, the demand uncertainty and capacity constraint still exist, which further motivates this thesis.

3.2 Literature Review on Pricing Strategy on High-Speed Rail

There is not much research focusing on transport companies' pricing strategy, since it is usually difficult to collect relevant data in this industry (Perennes 2014). The US airline industry is probably a unique, notable exception for two reasons. First, in the U.S., the Civil Aeronautics Board (CAB) required airlines operating in the U.S. to provide data on fares, traffic, and costs. Then as one of the conditions of deregulation, the US Department of Transportation required the airlines to continue reporting these data. Second, unlike the rail industry, the information system regarding schedule and fare data are widely common among various airlines and integrated into some groups of the global distribution systems. However, as described in Section 2.5.1, the application of revenue management (RM) for the rail industry has been stagnant, which has discourage the research on pricing strategy in the rail industry.

In this section, first we review the limited literature regarding the theoretical approach for the RM in the rail industry. Then, we review some empirical studies about the pricing strategy of HSR in the context of inter-modal or intra-modal competition. Finally, we see the literature specifically working on the case studies of specific pricing strategies in the area of HSR.

- **Theoretical works on the rail revenue management**

Armstrong and Meissner argue that there is room to exploit RM developed in the airline industry to the rail industry (Armstrong and Meissner 2010). Their paper summarizes the models in the existing literature regarding RM in the passenger rail as well as freight rail. Six papers which focus on the passenger rail RM are reviewed in Armstrong and Meissner's paper. However, none of them deal with the fare variation for trains with identical service level, but their main focus are the optimal allocation of seats for each O-D pairs under given fare and capacity (Ciancimino et al. 1999; Hood 2000; Kraft, Srikar, and Phillips 2000; Peng-Sheng You 2008; Bharill and Rangaraj 2008; Sibdari, Lin, and Chellappan 2008).

Ciancimino et al. apply a model for a single-fare and multi-leg capacity allocation problem. The objective is to allocate a specific quantity of seats to each O-D pairs in order to maximize the revenue for a train (Ciancimino et al. 1999).

Kraft et al. discuss the advantage of a bid-price method over traditional airline-style, leg-based "EMSR" approaches[33] in order to deal with network-oriented characteristics in the rail RM. The main focus of their paper is also the optimal allocation of O-D pairs in a train.

Bharill and Rangaraj develop a RM strategy to increase the revenue of Rajdhani Express in Indian Railways (Bharill and Rangaraj 2008). The Rajdhani Express offers three differentiable seat classes and a single fare for each class. Their work examines how they can estimate the cross-elasticity of demand for three seat classes. Using the estimated value, they also develop a model to estimate demand in accordance with the fare change for each seat class and implementation of additional costs such as cancellation fees.

Sibdari et al. develop pricing policies which can improve the revenue of Amtrak Auto Train service (Sibdari, Lin, and Chellappan 2008). The fare of Amtrak Auto Train varies according to the choice of seat class for a passenger and the type of vehicle the passenger carries on a train. Sibdari et al. assumes a single leg and analyze the revenue improvement by the dynamic price modification in the booking horizon.

You extends a single-fare and multi-leg seat allocation model presented by Ciancimino et al. (1999) to a two-fare and multi-leg model (Peng-Sheng You 2008). The model assumes two fare classes, namely full-coach fare and discounted fare. The main focus of this work is to develop a heuristic, but not dynamic, efficient calculation method in rail network. The result shows that the invented algorism provides good solution and also improves calculation speed.

- **Pricing policy in the context of inter-modal competition**

There are substantial number of papers regarding the competition between HSR and air (Behrens and Pels 2012; Finger, Bert, and Kupfer 2014; Inoue et al. 2015; Pagliara, José Manuel, and Concepcion 2012; Yao and Morikawa 2005).

Sato and Sawaki present a dynamic pricing model for a HSR operator in a competitive market, in which customers are allowed to choose a preferable transportation mode among HSR and air (K. Sato and Sawaki 2012). The model takes into account that a HSR operator as well as an airline have multiple substitutable schedules. The model also incorporates cancellation of reservation, no-show, and overbooking. The objective of the model is to find an optimal pricing strategy in order to maximize the sum of revenues from multiple trains a HSR operator offers.

[33] If the reader is interested in EMSR approaches, see Belobaba et al. (2016).

The numerical result shows that the model outputs some intuitive results, such as the existence of a competitor leads to the reduction of fare in the market.

Yao et al. analyze the pricing strategy for HSR in Wuhan-Guangzhou in China with the aim to improve the seat occupancy rate, considering the competition between other transportation modes (Yao et al. 2013). Currently HSR in China does not incorporate price differentiation in terms of either time of departure, day of week, or day of booking. Partly because of this, the average load factor of Wuhan-Guangzhou HSR is as low as 20% except for the spring festival period (Yao et al. 2013). Yao et al. develop disaggregate choice model with nested structure based on stated preference data, and obtain the market share of HSR under a specific ticket fare. Yao et al. suggest that Wuhan-Guangzhou HSR can improve the profit by incorporating the price differentiation, and especially recommend the price differentiation among day of week, namely lower fare for weekdays and higher fare for weekends.

- **Pricing strategy in the context of intra-modal competition**

Hsu et al. study Taipei-Taichung-Kaohsiung corridor in Taiwan in the context of price competition between HSR and conventional railroad (Hsu, Lee, and Liao 2010). As their paper describes, the two-parallel structure in Taiwan is to some extent similar to the Chuo Shinkansen Maglev and the Tokaido Shinkansen, which is the subject of this thesis. The model used by Hsu et al. does not incorporate the price differentiation in a transport mode (HSR or a conventional rail), but takes the price level as the decision variable, in order to maximize each operator's profit. The model also assumes that there is no capacity problem; thus both HSR and conventional rail have sufficient capacity. The model considers a multiple-stage Bertrand game, in which both firms determine their price under Nash equilibrium. Using the real data from the firms, the paper estimates the firms' pricing behaviors and also conducts sensitivity analysis in terms of the relative difference in their operating costs, passengers' value of time, and the operating distance of HSR and the conventional rail. The result demonstrates intuitive and interesting behaviors of the firms, which produce parallel rail services with different prices and different service level. For example, if the operating cost of HSR increases compared to conventional rail (HSR operation becomes relatively inefficient), HSR sets higher fare in order to keep the profitability. Then, conventional rail gets higher market share and also increases its fare. If the passengers' value of time increase, HSR takes advantage of it and set higher fare. On the other hand, conventional rail lowers its fare in order to keep its market share. In our case of the Chuo Shinakansen Maglev and the Tokaido Shinkansen, both services will be provided by the same rail operator, JR Central; thus this game theoretical model cannot be directly applied. However, if the organizational structure of JR Central allows financially separated and independent management for two operating entities, the potential motivation of each operating entity might include the game theoretical characteristics. In this sense, the approach discussed in the paper might give us a meaningful insight.

In the context of the intra-modal competition among multiple rail operators on a shared track, several papers focus on Italian HSR, in which the open access led by European Commission brought a new entry of HSR operator for Rome-Milan in 2012 (Bergantino, Capozza, and Capurso 2015; Cascetta and Coppola 2014; Croccolo and Violi 2013; Finger, Bert, and Kupfer 2014; Mancuso 2014; Patuelli 2015). The Italian market is the first practice of the direct competition among HSR firms[34] which operate their services on a shared track. Also, Rome-Milan corridor is the most congested HSR corridor in Italy. While the entry of a new HSR operator NTV brought the significant increase in traffic demand in the whole Italian HSR (+52% in passengers and +79% in passenger-km), it also led to the significant price reduction (-31% on the average of single HSR ticket price) (Cascetta and Coppola 2014). So far, while it is clear that the on-track competition have brought positive effects for consumers in terms of price reduction at least from a short-term viewpoint, some doubt on the economic sustainability of the on-track competition is also reported, for example the financial performance of NTV is still far from economic equilibrium (Patuelli 2015).

- **Pricing strategy with specific case studies**

We review some literature which discuss the pricing strategy of HSR in France, the U.S. Northeast Corridor, and Japan, which are analyzed in our case study in Chapter 5, in the rest of this section. Perennes analyses SNCF's pricing behavior on most O-D pairs, in which SNCF operates HSR to/from Paris in order to clarify how SNCF's pricing strategy is affected by the intermodal competition with air and cars and the price regulation by French government (Perennes 2014). While the price regulation generally determines the specific fare for each O-D

[34] Nuovo Trasporto Viaggiatori (NTV) started to operate Itaro trains in April 2012, while the incumbent TranItalia operates Frecciarossa.

pair in accordance with the distance for conventional railroads in France, the "basic fare" for TGV[35] has 40% leeway from the basic fare (40% higher or 40% lower fare is allowed), depending on the conditions of speed and comfort as well as competitive situation. Empirical analysis demonstrates that the existence of the airline as a competitor in a corridor is a significant factor to reduce the basic fare level of TGV.

Several papers study SNCF's new low-cost HSR service "Ouigo", which provides high-speed rail service in the same corridor as regular TGV service with a very affordable fare. Ouigo was introduced in April 2013 and it connects Paris and southern French cities such as Lyon, Marseille, and Montpellier by aggressively cheaper fares. In September 2015, SNCF announced that it extends Ouigo service to northern and western France in the beginning of 2016 (Briginshaw 2015).

Delaplace and Dobruszkes analyze the fare strategy as well as the business model of Ouigo, such as production conditions, marketing and communication, booking, and network geography (Delaplace and Dobruszkes 2015). They conclude that Ouigo's business model is affected by the traditional railways constraints in SNCF and has a hybrid feature between low-cost airlines and traditional French HSR.

Chianbaretto and Fernandez also examine the business model of Ouigo by interviews and secondary data such as press articles and argue how rail operators successfully incorporate the low-cost airline strategies to their business model (Chiambaretto and Fernandez 2014). The characteristic features of the low-cost strategy include simplified fare policy, increased number of seats per train, use of secondary train stations, exclusive online distribution, e-ticketing, and development of ancillary revenues. Their analysis suggests that commercial features, such as pricing policy, may be adapted more easily than technical ones, such as network structure, which are more constrained by the industry characteristics.

Sauter-Servaes and Nash examine other examples of the application of low-cost airline strategies in the European rail industry (Sauter-Servaes and Nash 2006). They illustrate Deutsche Bahn's pricing reform, which is called PEP program, as a well-known failure in terms of customers' experience. Link also describes Deutsche Bahn's implementation failure in detail

[35] The fare of TGV varies depending on time of departure and day of booking. "Basic fare" refers to the highest fare in the O-D pair, which is determined by the specific kilometer reference and 40% leeway. SNCF has freedom to offer discounted fare, based on the basic fare.

(Link 2004). On the other hand, the introduction of independent subsidiaries is illustrated as a success, such as "iDTGV" by SNCF and "TrenOK" by Trenitalia (both were launched in 2004). Sauter-Servaes and Nash's paper emphasizes that successful introduction of the low-cost airline pricing strategies to the railroad business is not a simple task, but necessary as inter-modal and intra-modal competition continue to increase in the European rail industry.

Pternea et al. study the optimal pricing strategy for HSR in Boston-Washington DC corridor from the rail operator's perspective, by applying RM technics and considering the inter-modal competition specifically with airlines (Pternea, Haghani, and Zhang 2016). The model developed by Pternea et al. is aimed to maximize the revenue of HSR by determining the optimal price for each O-D pair and each trip purpose (business or leisure). Their simulation result shows that HSR sets higher fare for the O-D pair which has larger demand, and the highest fare is observed in Baltimore-New York segment. Also, their result shows that HSR increases its fare when the competitor's fare in the same O-D pair increases.

Taura statistically analyzes the air fare in the domestic flights in Japan after the deregulation of air fare in Japan in 2000 (Taura 2005). His research suggests that not only the competition between airlines, but also the competition between an airline and Shinkansen leads the reduction of unit fare (¥/km). Especially, the unit fare of the flights which compete with the Tokaido-Sanyo Shinkansen (Tokyo-Osaka-Hakata) are lower than the flights which compete with other Shikansens such as Tohoku Shikansnen, because airlines competing with Tokaido-Sanyo Shinkansen offer more aggressive discounts for these flights than other flights.

3.3 Conclusion

In this chapter, we reviewed the existing literature regarding the Chuo Shinkansen Maglev project and the pricing strategy on HSR.

As for the Chuo Shinkansen Maglev project, since the plan of the project has existed since more than three decades ago, and also the project has the potential large economic and social impact on the area along the prospective route, there are several papers focusing on economic and social benefit analysis. However, the study focusing on the pricing strategy for the Chuo Shinkansen Maglev in order to strengthen the financial feasibility has not been seen so far.

As for the pricing strategy of HSR, first we reviewed a few studies regarding the theoretical approach for the RM in the rail industry. Next, we reviewed some empirical studies about the pricing strategy of HSR in the context of inter-modal and intra-modal competition. Finally, we see some research work conducting case studies of specific pricing strategies in HSR.

In the next chapter, we now move in to the discussion regarding appropriate fare level of the Chuo Shinkansen Maglev.

Chapter 4 Analysis of the Fare level of the Chuo Shinkansen Maglev

4.1 Framework of the analysis

In this chapter, we will analyze the appropriate fare level of the Chuo Shinkansen Maglev. As we see in Section 1.2.5, there has been no situation in the world, such that multiple HSRs are operated **in a same corridor** and **by a single firm**. To the best of the author's knowledge, there is no literature which can deal with the discussion on the appropriate fare level determination for a HSR (i.e. Chuo Shinkansen Maglev), which will be introduced on the existing rail corridor (i.e. Tokyo-Nagoya-Osaka). Therefore, the thesis proposes a new framework to analyze the fare level in this situation. Then, the framework is applied to the Chuo Shinkansen Maglev case.

As we saw in the Chapter 2, the upper fare of Shinkansen is constrained by the price regulation in Japan, which is based on the full-cost principle and the yard-stick formula. Therefore, first of all, we begin with the analysis of the upper fare set by the price regulation scheme as the starting point of the fare level discussion. Next, we estimate the additional willingness to pay for the travel time saving of the new line, in comparison to the existing line in the same corridor. This is a theoretical approach to find an appropriate fare level. Then, in order to validate this theoretical estimation by the real situation, a reference case of the fare determination in the past, if any, should be applied. In our following case study, we examine how JR Central determine the fare of Nozomi Super-Express introduced in March 1992, which cut the travel time between Tokyo and Osaka by 19 minutes from 169 minutes to 150 minutes. Figure 4-1 shows this 3-step framework proposed in this thesis.

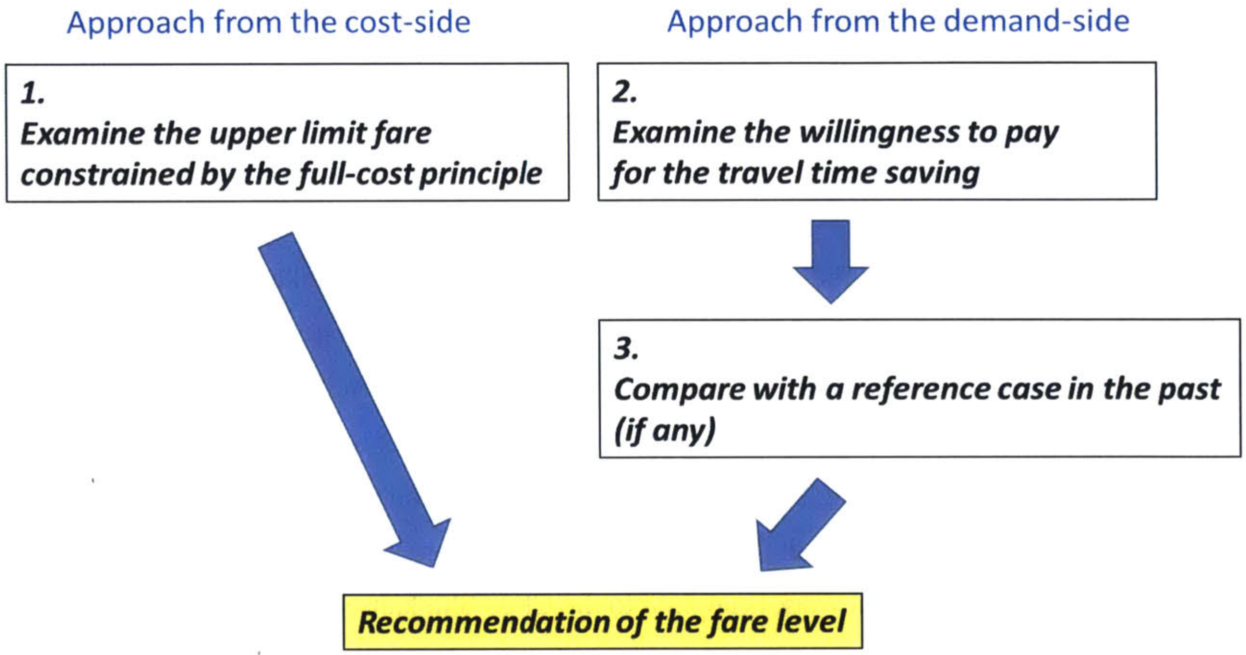


Figure 4-1: Framework of the fare level analysis of the Chuo Shinkansen Maglev

In the case study of the Chuo Shinkansen Maglev, the thesis considers the situation under the first-stage of the Chuo Shinkansen Maglev operation, in which the new Maglev line connects Tokyo and Nagoya, because of the following reasons:

1. Our primary motivation is to shrink the 18-year long interval between the first-stage commencement (Tokyo-Nagoya) and the second-stage (Tokyo-Osaka).
2. Also, the price level on the first-stage operation of the Chuo Shinkansen Maglev seems more challenging than that in the second (final) stage, because the major flux of passengers between Tokyo and Osaka will have to transfer from Maglev to Tokaido or vice versa at Nagoya.

Also, this thesis focuses on the new fare of Tokyo-Nagoya O-D and Tokyo-Osaka O-D segments since this is the largest O-D pairs in the Tokyo-Nagoya-Osaka corridor.

The brief explanation of each step in the Chuo Shinkansen Maglev case, based on Figure 4-1, is as following.

1. ***Examine the upper limit fare constrained by the full-cost principle.***

   In this step, in accordance with the procedure in the full-cost principle, we see the operating cost and revenue estimation of the Chuo Shinkansen Maglev. As reference cases of the application of the full-cost principle, we review the actual data on recently opened Shinkansens, namely the Hokuriku Shinkansen and the Hokkaido Shinkansen. As an output of the step, we estimate the specific scope of the upper fare for the Chuo Shinkansen Maglev.

2. ***Examine the willingness to pay for the travel time saving in comparison to the Tokaido Shinkansen.***

   In this step, we approach the appropriate fare level of the Chuo Shinkansen Maglav from the demand-side. The goal of this step is to estimate the value of travel time (VOTT) saving of the Chuo Shinkansen Maglev. In order to do this, we estimate the VOTT between Tokyo and Osaka, by using the intercity trip data collected in 2010 by MLIT. As described above, we focus on the first-stage operation, in which passengers traveling Tokyo-Osaka will have to transfer trains at Nagoya; thus we take into account the disutility of transfer for the willingness to pay analysis.

3. ***Compare with the reference case in the past: Introduction of Nozomi Super-Express***

   The purpose of this step is to examine the validity of the step 2. In reality, the determination of the fare level may be influenced by operator's policy/philosophy as well as other factors such as the competition from other modes. Therefore, it is useful to consider how JR Central set the fare when it shrunk the travel time between Tokyo and Osaka on the Tokaido Shinkansen. We see the introduction of Nozomi super-express in March 1992 as a reference case.

4. ***Recommendation of the fare level***

   Considering the result of the step 1-3, we present a recommendation for the fare level of the Chuo Shinkansen Maglev.

In the next section, we will briefly review the current fare structure of the HSR in Japan. Then, we will move in to the analysis in Section 4.3.

4.2 Fare Structure of Shinkansen

4.2.1 Current fare structure of Shinkansen

Table 4-1 shows some ticket type of the Tokaido Shinkansen and brief explanation for each of them. Although some of other Shinkansens have certain variations from Table 4-1[36], those are beyond the scope of the thesis.

"Basic fare" is based on the distance traveled. The unit price of the basic fare (per km) is almost the same among any trains in any JR companies, although three-island JRs (JR Hokkaido, JR Shikoku, and JR Kyushu) apply slightly higher unit fare than Honshu JRs (JR East, JR Central, and JR West). If one uses a commuter train in a conventional line of any JR companies, only the basic fare is charged.

When one uses Shinkansen, express surcharge is required in addition to the basic fare[37]. There are two types of express surcharges in Shinkansen: limited express reserved seat ticket and limited express non-reserved seat ticket. The grade of in-car accommodation for those type of seats are identical and referred to as "ordinary class". The only difference between two is whether the seat is reserved or not. The price of limited express reserved seat ticket is based on each O-D pair; thus also varies among companies. Also, the price of the limited reserved seat class slightly varies according to season in a year as shown in Table 4-1.

If one uses first class instead of ordinary class in Shinkansen, first class car fare is required in addition to basic fare and limited express non-researved seat fare[38]. The price of the first class fare varies in accordance with the distance traveled. Table 4-2 shows the number of each grade of seats in a train in the Tokaido Shinkansen.

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[36] For example, the E5 series train sets used in the Tohoku Shinkansen have a higher grade "Gran class" in addition to the ordinary class and the first class. The fare for the Gran class seat is higher than the first class.

[37] There are also express trains in conventional lines. If one uses this conventional express train, a limited express reserved or non-reserved seat ticket is required. The price of the limited express reserved or non-reserved seat ticket for conventional express trains are cheaper than Shinkansen. If one uses first class car in a conventional express, first class car ticket is required similarly to Shinkansen.

[38] Precisely saying, the limited express non-reserved seat fare for first class use is calculated as the fare of limited reserved seat fare in regular season minus ¥520.

Table 4-3 illustrates some examples of required fares for a typical Tokaido Shinkansen ride.

Table 4-1: Ticket type of Shinkansen

Fare type	Explanation
Basic fare	This basic fare is based on **the distance traveled**, required regardless of the type of trains that are used. Hence, for example, conventional trains require the same price of basic fare as Shinkansen, for the same distance traveled.
Limited express reserved seat fare ("ordinary class")	This is required when one uses a researved seat in ordinary or first class car of Shinkansen. The price of the limited express reserved seat ticket differs according to **origin-destination pair**. The price also varies according to **season in a year**, such as peak season (+¥200), regular season (±0), and off-peak season (Δ¥200).
Limited express non-reserved seat fare ("ordinary class")	This is required when one uses a non-researved seat in ordinary car of Shinkansen (first class car does not have non-reserved seat). The price of the limited express non-reserved seat ticket differs according to **origin-destination pair**. There is no difference in season in a year.
First class car ticket fare ("Green class")	This is required when one uses first class car of Shinkansen, in addition to limited express reserved seat ticket. The price of the first class car fare differs according to **the distance traveled**. There is no difference in season in a year.

Source: Tariff information on JR Jikokuhyo (JR timetable)

Table 4-2: Seat capacities for each seat grade in a train in the Tokaido Shinkansen as of 2015

Type of trains	*First class*	*Reserved ordinary class*	*Non-reserved ordinary class*	*Total*
Nozomi	200	873	250	1,323
Hikari	200	683	440	1,323
Kodama	200	238	885	1,323

Source: JR Jikokuhyo (JR timetable)

Table 4-3: Example of required ticket type and fare for Tokyo-Osaka Shinkansen ride by a Nozomi train (as of December 2015)

	Example	Required ticket type and one-way fare
Nozomi	- Ordinary class reserved seat - Regular season	**Total (¥14,450):** Basic fare (¥8,750) Limited express reserved seat fare (¥5,700)
	- Ordinary class non-reserved seat	**Total (¥13,620):** Basic fare (¥8,750) Limited express non-reserved seat fare(¥4,870)
	- First class	**Total (¥19,230):** Basic fare (¥8,750) Limited express non- reserved seat fare (¥5,180) First class car fare (¥5,300)
Hikari or Kodama	- Ordinary class reserved seat - Regular season	**Total (¥14,140):** Basic fare (¥8,750) Limited express reserved seat fare (¥5,390)
	- Ordinary class non-reserved seat	**Total (¥13,620):** Basic fare (¥8,750) Limited express non-reserved seat fare (¥4,870)
	- First class	**Total (¥18,920):** Basic fare (¥8,750) Limited express non-reserved seat fare (¥4,870) First class car fare (¥5,300)

Source: JR Jikokuhyo (JR timetable)

4.2.2 Price regulation for Shinkansen

We already reviewed three types of price regulation schemes in Section 2.2. The price regulation in Japan applies the combination of the full cost principle and the yard stick formula, and also give rail operators some leeway for fare setting. The article 16 of Railway Business Act stipulates the fare setting of passenger rails.

> *"The Railway Transportation Business Operator shall set forth the upper limits of the fares or the passengers and the charges for the passengers prescribed an ordinance of the Ministry (hereafter referred to as "Passenger Fares") and obtain an approval of the Minister of Land, Infrastructure, Transport and Tourism. The same shall apply if he/she intends to change them.*
>
> *(2) When the Minister of Land, Infrastructure, Transport and Tourism intends to give the approval of the preceding paragraph, he/she shall examine whether the upper limits of the Passenger Fares, etc. do not exceed the amount of the appropriate costs under efficient management plus the appropriate profit, before giving the approval.*
>
> *(3) The Railway Transportation Business Operator shall set forth the Passenger Fares, etc. within the upper limits of Passenger Fares, etc. for which the approval of paragraph 1 was obtained and shall notify the Minister of Land, Infrastructure, Transport and Tourism to that effect in advance. The same shall apply if he/she intends to change them.*
>
> *(5) When the Minister of Land, Infrastructure, Transport and Tourism finds that the Passenger Fares, etc. in paragraph 3 or the charges for passengers in the preceding paragraph fall under any of the following items, he/she may order the said Railway Transportation Business Operator to change the said Passenger Fares, etc. or the charge for passengers by setting the due date.*
>
> > *(i) When they are unjustifiably discriminating against certain passengers*
> > *(ii) When there is a risk that they may cause unjust competition with other Railway Transportation Business Operators"*
>
> (Railway Bureau at the Ministry of Land, Infrastructure, Transport and Tourism 1986)

As we see in the paragraph 3 above, rail operators are allowed to set any price of fare within the upper limit approved by the government, unless the submitted fare is *"unjustifiably* *discriminating against certain passengers"* or causing *"unjust competition with other Railway Transportation Business Operators"*. Figure 4-2 illustrates the procedure of a new upper fare approval. The proposal of a new upper limit fare is submitted by rail operators to MLIT. The fare is discussed and inspected by MLIT and Transportation Committee, whether it reflects the proper operating cost, and whether it is fair for passengers.

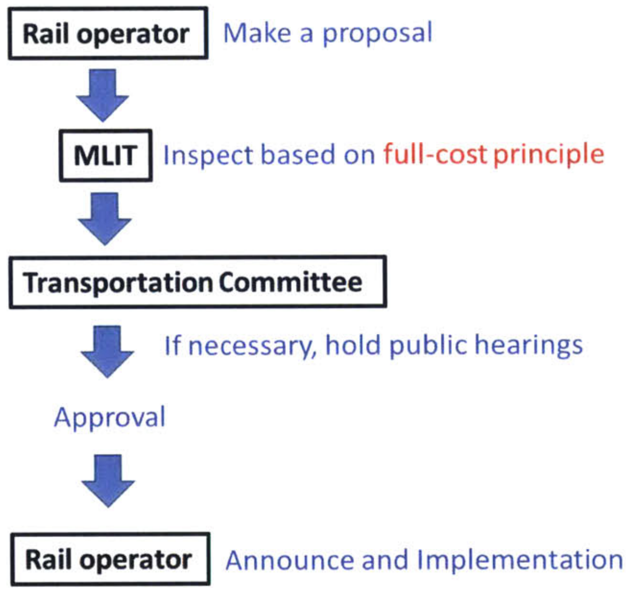


Figure 4-2: The procedure of a new upper limit fare approval

Rail operators in Japan usually use the approved upper limit fare as the regular fare, and offer discounted fare to limited extent. For example, JR Central offers some discounted fare for the Tokaido Shinkansen, such as a book of coupons with six one-way tickets. If one uses a book of coupons for a Tokyo-ShinOsaka Nozomi train, he/she gets about 5% discounts per ride[39].

4.3 Examination of the upper fare constrained by the full-cost principle

4.3.1 The Hokuriku and Hokkaido Shinkansen case

We have reviewed the concept of full-cost principle (Figure 2-1). Now we apply this concept for the Chuo Shinkansen Maglev, and estimate its potential upper limit fare. In order to calculate each cost and revenue term, we refer to the Hokuriku Shinkansen (Nagano-Kanazawa segment,

[39] The price of a book of coupon for six Tokyo-ShinOsaka Nozomi one-way rides is ¥82,140; thus ¥13,690 per ticket. The discount rate is about 5% compared to the regular price.

opened in March 2015) and the Hokkaido Shinkansen (ShinAomori-ShinHakodateHokuto segment, opened in March 2016) as reference cases. The reason of using these cases is that these are the latest cases of the upper limit fare approval, and the detailed cost accounting procedure provided by MLIT is publicly available (Ministry of Land, Infrastructure, Transport and Tourism 2014; Ministry of Land, Infrastructure, Transport and Tourism 2015).

Table 4-4 shows the result of the full-cost accounting, in which the total revenue expected by the new fare and the total cost is compared, for the Hokuriku and the Hokkaido Shinkansen.

Table 4-4: Full-cost accounting of Hokuriku and Hokkaido Shinkansen

number's in ¥millions ($millions) per year		Shinkansen	Hokuriku		Hokkaido
		Operator	JR East	JR West	JR Hokkaido
		Operating segment	Nagano-JoetsuMyoko	JoetsuMyoko-Kanazawa	ShinAomori-ShinHakodateHokuto
Revenues	Ticket revenue		¥20,400 ($170.0)	¥28,372 ($236.4)	¥10,795 ($90.0)
	Transportation incidentials		998 ($8.3)	¥482 ($4.0)	¥343 ($2.9)
	Total revenue (a)		**¥21,398 ($178.3)**	**¥28,854 ($240.5)**	**¥11,138 ($92.8)**
Expenses	Operating costs, etc.	Personnel cost	¥2,039 ($17.0)	¥4,546 ($37.9)	¥3,576 ($29.8)
		Other expenses	¥2,858 ($23.8)	¥8,724 ($72.7)	¥7,865 ($65.5)
		Total operating cost	**¥4,897 ($40.8)**	**¥13,270 ($110.6)**	**¥11,441 ($95.3)**
		Infrastructure charges	¥17,464 ($145.5)	¥12,613 ($105.1)	¥909 ($7.6)
		Depreciation	¥1,745 ($14.5)	¥9,588 ($79.9)	¥3,266 ($27.2)
		Taxes	¥97 ($0.8)	¥450 ($3.8)	¥95 ($0.8)
	Operational return (interest expense, dividends, etc.)		¥311 ($2.6)	¥1,386 ($11.6)	¥265 ($2.2)
	Total cost (b)		**¥24,514 ($204.3)**	**¥37,307 ($310.9)**	**¥15,976 ($133.1)**
Profit or loss (a-b)			-¥3,116 -($26.0)	-¥8,453 -($70.4)	-¥4,838 -($40.3)
Cost coverage ratio (a/b)			**87.3%**	**77.3%**	**69.7%**

Source: MLIT 2014, MLIT 2015

Ticket revenue (95-98% of total revenue)

The ticket revenue appearing in Table 4-4 is the revenue on the new segment[40]. It comprises the basic fare and the express charges. It is estimated by the estimated demand times the new fare for each O-D segment with respect to the new operating segment.

Transportation incidentals (2-5% of total revenue)

Transportation incidentals are the side revenue which comes from the new HSR operation. It typically comprises tenant revenue and advertising revenue. It is calculated by the proportion of the transportation incidental revenue to the total revenue in the reference line operated by the same operator[41].

Operating costs

Operating costs consist of personal cost and other operating expenses. The cost estimation is provided by each operator, and checked by MLIT based on the yard-stick formula (Section 2.2.2).

Infrastructure charges

Infrastructure charges are paid to JRTT, the main constructor of these lines. JRTT uses this revenue source for the repayment of the loans, which required for the construction of the lines as well as the construction of the future Shinkansen. For the case of the Chuo Shinkansen, the construction cost is expected to be fully funded by JR Central; thus there is no infrastructure charge after the operation.

Depreciation

Although the majority of the infrastructure in the Hokuriku and the Hokkaido Shinkansen, such as tunnels, stations, and signals, are owned by JRTT and leased to each operator, each operator

[40] For example, if one travels from a station outside the new segment to a station on the new segment, the revenue on the new segment is calculated by the total revenue from the trip multiplied by the proportion of the operating km to the total operating km. The revenue from a trip entirely outside the new segment is not included.

[41] For the estimation of transportation incidentals in the Hokuriku Shinkansen of JR East's segment, the proportion of the transportation incidentals to the total revenue in the existing Hokuriku Shinkansen (Tokyo-Nagano section) was used (4.89%). For JR West's segment, the proportion of the transportation incidentals to the total revenue in Sanyo Shinkansen was used (1.7%). For the Hokkaido Shinkansen, since JR Hokkaido had not had Shinkansen before, the conventional line between Sapporo and Hakodate was referred to.

has to have some fixed assets, such as rolling stock and maintenance facilities, for the operation of the new line. Depreciation is estimated in accordance with the book value of the fixed assets.

Taxes

Required annual property tax for the fixed assets, which are obtained by each operator, is estimated. 1.4% is used for the property tax ratio.

Operational return

Operational return consists of interest expense and dividends. Operational return is calculated by the product of "rate base" and "rate level", as seen in Equation (2-1) in Chapter 2.

The rate base is calculated based on Equation (2-2). The fixed assets for the operation is the same as in the calculation of depreciation and taxes. Construction in progress and deferred assets are assumed to be zero. The amount of working capital is estimated as 4% of the sum of the yearly operating cost and the infrastructure charges (Ministry of Land, Infrastructure, Transport and Tourism 2014).

The rate level is calculated based on Equation (2-3). Rate of return on equity for either JR East or JR West is calculated as 5.45%, by following the average of three index: yield to subscribers for public and corporate bonds (1.22%), overall-industry average of return on equity (4.14%), and dividend on equity ratio (11%). Real average rate of liabilities is 1.91% for JR East, 2.04% for JR West, and 1.20% for JR Hokkaido. Equity ratio is 30% for JR East and JR West, and 0% for JR Hokkaido, since JR Hokkaido's stock is not listed. Hence, borrowed capital ratio is 70% for JR East and JR West, and 100% for JR Hokkaido. As a result, the rate level for JR East, JR West, and JR Hokkaido are 2.97%, 3.06%, and 1.20%, respectively.

Cost coverage ratio

Based on full-cost principle, cost coverage ratio should not exceed 100%; if so, the proposed fare is considered to be too high. The cost coverage ratio of the Hokuriku Shinkansen and the Hokkaido Shinkansen range from 69.7% to 87.3%. Therefore, at this stage of the upper fare evaluation, some losses always appear in the accounting sheets for any cases.

According to final reports produced by the Transportation Committee, these losses are considered to be dealt with by the managerial efforts of the operators (Ministry of Land, Infrastructure, Transport and Tourism 2014). For example, the traffic demand in the existing lines, which connect to the new Shinkansen line, might increase by the operators' marketing effort. This potential revenue is not included in the revenue in Table 4-4; thus it may improve the cost coverage ratio. Also, based on the current scheme governed by MLIT, operators are allowed to withdraw the operation of the unprofitable conventional lines parallel to the new Shinkansen after the commencement of Shinkansen[42]. This may also improve the cost coverage ratio.

Some Shinkansen projects took higher cost coverage ratio. For example, the cost coverage ratio of the Kyushu Shinkansen (from Shin-Yatsushiro to Kagoshima-Chuo, opened in March 2011) is estimated as 99.2%, for the approval of the upper limit fare of the new segment (Ministry of Land, Infrastructure, Transport and Tourism 2015).

4.3.2 The Chuo Shinkansen Maglev case

- **Revenue estimation**

Ticket revenue

Ticket revenue on the Tokyo-Nagoya segment of the Chuo Shinkansen Maglev is calculated as the estimated traffic demand (in passenger-km) multiplied by the unit fare (in ¥/km).

As for the annual traffic demand of the Chuo Shinkansen Maglev, it is estimated as 16.7 billion passenger-km after the commencement of the Tokyo-Nagoya segment (Table 1-4). We use this for the revenue estimation.

As for the unit fare of the Chuo Shinkansen Maglev, we calculate it based on the current unit fare of the Tokaido Shinkansen 23.14 (¥/km), the five-year average (FY2010-2014) of the Tokaido Shinkansen[43] (Central Japan Railway Company 2015b). We use this unit fare of the Tokaido Shinkansen as a reference. As we see in Table 4-5, we prepare five examples of the upper limit fare in Tokyo-Nagoya for the Chuo Shinkansen Maglev, from ¥11,590 (+¥500) to ¥13,590 (+¥2500) [B]. Comparing them with ¥11,090 as the current upper limit fare in Tokyo-Nagoya for the Tokaido Shinkansen, we obtain the rate of increase [B/A]. We assume the unit fare of the Chuo Shinkansen Maglev is the product of the unit fare of the Tokaido Shinkansen

[42] After JRs withdraw the operation of these conventional lines, these lines are owned and operated by public entities subsidized by the local governments.
[43] Excluding revenue and passenger-km from the commuter pass use.

(¥23.14/km in [C]) and the rate of increase [B/A]. We obtain the ticket revenue of the Chuo Shinkansen Maglev by the product of the annual traffic demand (16.7 billion passenger-km) and the unit fare (the very right column in Table 4-5).

Table 4-5: Upper limit fare and unit fare of the Chuo Shinkansen Maglev

	Upper fare (Tokyo-Nagoya)		Comparison		Unit fare	
	Tokaido (Nozomi) [A]	Chuo [B]	[A-B]	Chuo/Tokaido [B/A]	Tokaido (Nozomi) [C]*	Chuo [C x B/A]
Ex. 1	¥11,090	¥11,590	¥500	1.045	¥23.14	¥24.18
Ex. 2		¥11,890	¥800	1.072		¥24.81
Ex. 3		¥12,590	¥1,500	1.135		¥26.27
Ex. 4		¥13,090	¥2,000	1.180		¥27.31
Ex. 5		¥13,590	¥2,500	1.225		¥28.36

* Calculated by five-year average of the ticket revenue and the passenger-km of the Tokaido Shinkansen (FY2010-2014) (Central Japan Railway Company, 2015)

The important assumption we made in this analysis is that the traffic demand is not affected by the change in the fare of the Chuo Shinkansen Maglev, in other words, we assume the price elasticity is equal to zero. In the original demand estimation model built by MLIT, the fare difference of the Chuo Shinkansen Maglev compared to the Tokaido Shinkansen is assumed to be ¥800 (Ministry of Land, Infrastructure, Transport and Tourism 2010c). The thesis does not aim to find the exact upper limit fare of the Chuo Shinkansen Maglev, but to examine whether the fare level of the Maglev estimated from the step 2 and 3 in our framework (Figure 4-1) is below the upper limit. Therefore, we have to keep in mind that if the upper limit fare suggested from the analysis in this section is far from the assumption for the demand estimation (+¥800 for Tokyo-Nagoya), the result might not be accurate. In this case, we need to recalculate the demand estimation, which is not the scope of this thesis.

Transportation incidentals

As we see in Table 4-4, transportation incidentals will account for 1.7-4.7% of the total revenue. Since the number of the stations in the Chuo Shinkansen Maglev is relatively small, we use the lowest number of 1.7% for the calculation of the transportation incidentals in the Chuo Shinkansen Maglev.

- **Cost estimation**

Operating costs

The annual operating cost of the Chuo Shinkansen Maglev between Tokyo and Nagoya is estimated ¥162 billion ($1,350 million) per year (Table 1-5).

Depreciation

The depreciation cost of the fixed assets regarding the Chuo Shinkansen Tokyo-Nagoya section is estimated ¥110 billion ($917 million) from Table 1-10. The deprecation before the commencement of the Chuo Shinkansen Maglev (FY2010-2027 on average) is ¥200 billion ($1,667 million), which can mainly consist of the deprecation of the assets in the Tokaido Shinkansen and the conventional lines. This is expected to increase to ¥310 billion ($2,583 million) in FY2010-2027 on average. Hence, we assume that this increase of ¥110 billion ($917 million) can be the approximation of the depreciation of the assets in the Chuo Shinkansen Maglev.

Taxes

Taxes are estimated as ¥62 billion ($518 million), which is calculated as follows: The fixed assets regarding the Chuo Shinkansen Maglev (Tokyo-Nagoya) is estimated as ¥4,440 billion ($37 billion). This is the difference of the amount of the fixed assets between the end of FY2027 and the end of FY2009 (Table 1-11). Property tax ratio is 1.4%, which is the same as the ratio used in the Hokuriku Shinkansen and Hokkaido Shinkansen case (Table 4-4). Hence, we obtain ¥62 billion ($518 million) by multiplying the property tax ratio 1.4% to ¥4,440 billion ($37 billion) as the amount of the fixed assets of the Chuo Shinkansen Maglev.

Operational return

The operational return (the sum of interest expense and dividends) is calculated by the product of "rate base" and "rate level" based on Equation (2-1), (2-2), and (2-3), as seen in the Hokuriku and the Hokkaido Shinkansen case. The operational return for the Chuo Shinkansen Maglev is estimated as ¥138 billion ($1,150 million).

Based on Equation (2-2), the rate base is estimated as follows: we assume that fixed assets for the Chuo Shinkansen Maglev operation as ¥4,440 billion ($37 billion), as we seen in the calculation of taxes. Construction in progress and deferred assets are assumed to be zero. The amount of working capital is estimated as 4% of the amount of the yearly operating cost, which is ¥6.5 billion ($54 million)[44]. Therefore, the rate base is estimated as ¥4,446 billion ($37.05 billion). The rate level is set as 3%, which is approximately same as that used in Hokuriku Shinkansen case[45]. Hence, the operational return is calculated as ¥133.4 billion ($1,112 million) by the product of the rate base and the rate level.

- **Result**

Table 4-6 shows the result of the analysis of the upper limit fare of the Chuo Shinkansen Maglev (Tokyo-Nagoya), based on full-cost principle. Five examples of the upper fare, which are consistent with Table 4-5, are demonstrated in Table 4-6.

Table 4-6: Examination of upper limit fare of the Chuo Shinkansen Maglev based on full-cost principle

	Shinkansen	Chuo Shinkansen Maglev (Tokyo-Nagoya)				
	example	1	2	3	4	5
	Tokyo-Nagoya upper fare (difference from Tokaido)	¥11,590 (+¥500)	¥11,890 (+¥800)	¥12,590 (+¥1,500)	¥13,090 (+¥2,000)	¥13,590 (+¥2,500)
	Unit fare (¥/km)	¥24.18	¥24.81	¥26.27	¥27.31	¥28.36
Revenues	Ticket revenue	403.9	414.3	438.7	456.1	473.6
in ¥billions	Transportation incidentials	7.0	7.2	7.6	7.9	8.2
	Total revenue (a)	**410.8**	**421.5**	**446.3**	**464.0**	**481.7**
Expenses	Total operating cost	162.0	162.0	162.0	162.0	162.0
in ¥billions	Depreciation	110.0	110.0	110.0	110.0	110.0
	Taxes	62.2	62.2	62.2	62.2	62.2
	Operational return (interest expense, dividends, etc.)	133.4	133.4	133.4	133.4	133.4
	Total cost (b)	**468**	**468**	**468**	**468**	**468**
Profit or loss (a-b)		-57	-46	-21	-4	14
Cost coverage ratio (a/b)		**88%**	**90%**	**95%**	**99%**	**103%**

Source: Author's calculation

[44] Since all fixed assets of the Chuo Shinkansen Maglev will be owned by JR Central, there will be no infrastructure charge. Therefore, unlike the Hokuriku Shinkansen case, working capital does not contain the infrastructure charge.
[45] As we saw in the calculation of the Hokkaido Shinkansen case, since JR Hokkaido is partly owned by the government, the rate level only reflect the cost of the borrowed capital.

First of all, we see the example 2 (+¥800) is a base case, since the demand estimation of the Chuo Shinkansen Maglev (16.7 billion passenger-km) is based on that fare. For this case, the cost coverage ratio is 90%, which is smaller than 100% and similar to the cost coverage ratio for the Hokuriku Shinkansen of JR East segment (Table 4-4).

Since we assume zero price elasticity for the demand estimation in this analysis, the relationship between the upper limit fare (in the value of difference to the fare of the Tokaido Shinkansen) and the cost coverage ratio becomes linear (Figure 4-3). The value of the upper limit fare which makes cost coverage ratio 100% is ¥13,190 (+¥2,100). However, in reality, the fare increase leads to the decrease in traffic demand; thus the shape of the red line above 800 yen in the horizontal axis in Figure 4-3 will be concave instead of linear. Hence, the cost coverage ratio at the upper fare of ¥13,190(+¥2,100) may be less than 100%.

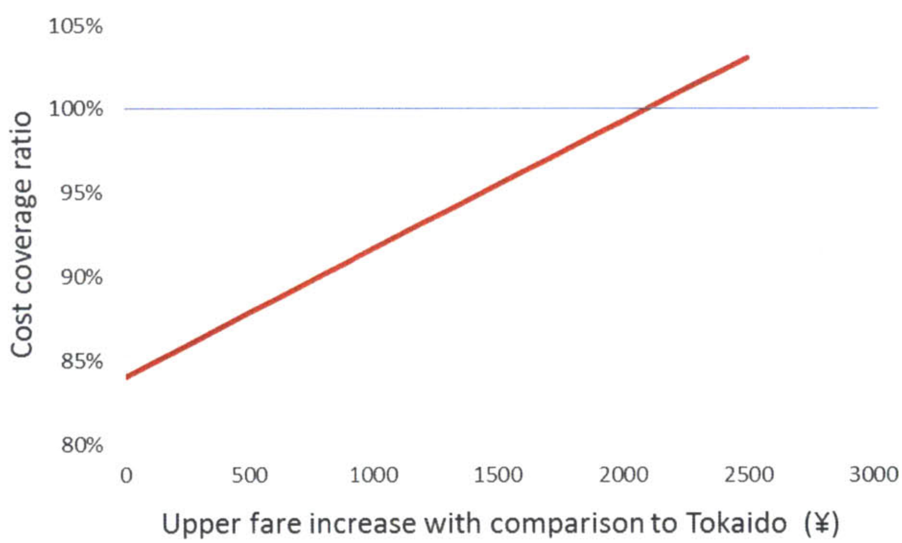


Figure 4-3: Upper limit fare vs. cost coverage ratio (Chuo Shinkansen Maglev, Tokyo-Nagoya)

4.4 Examination of the willingness to pay for the travel time saving

This is the second step of the fare level analysis of the Chuo Shinkansen Maglev (Figure 4-1). From the demand side, we can discuss the appropriate price level by considering the potential users' willingness to pay for the travel time saving, which will be brought by the introduction of the Chuo Shinkansen Maglev.

As we mentioned before, this analysis focuses on the passengers who will travel between Tokyo and Osaka as an O-D pair, after the Tokyo-Nagoya segment of the Chuo Shinkansen Maglev is completed. We already know the estimated travel time saving brought by the Chuo Shinkansen Maglev (Table 1-3). However, the Chuo Shinkansen Maglev will require the passengers to transfer from/to the Tokaido Shinkansen at Nagoya station. Hence, the major work in this step is to estimate value of travel time (VOTT) as well as the disutility of transfer, for the potential users of the Chuo Shinkansen Maglev.

4.4.1 Methodology

- ***Value of travel time (VOTT)***

VOTT varies in accordance with socio-demographic characteristics (income, age, gender, etc.) as well as target region. There are two common ways to calculate VOTT (Ministry of Land, Infrastructure, Transport and Tourism 2012c).

1. **Choice experiment approach**
   This method obtains VOTT by estimating coefficients of travel time and travel cost in demand choice model, based on surveyed trip data. For the demand choice model, either aggregate logit or discrete choice model applied. VOTT is estimated by the following equations (4-1) and (4-2).

$$V_k = \beta_{time} T_k + \beta_{cost} C_k \qquad (4\text{-}1)$$

$$VOTT = \frac{\frac{\partial V_k}{\partial T_k}}{\frac{\partial V_k}{\partial C_k}} = \frac{\beta_{time}}{\beta_{cost}} \qquad (4\text{-}2)$$

Here,

V_k: systematic utility for a transport mode k

T_k: travel time for a mode k (minute)

C_k: travel cost for a mode k (yen)

VOTT: value of travel time (yen/minute)

2. **Income approach**

   This method is based on the idea that one can utilize the saved time for the opportunity to work and get income. In other words, the willingness to pay for the travel time saving is treated as the opportunity cost for the additional income. Thus the income approach obtains VOTT by calculating unit wage of potential users, usually represented by income per hour. Since this approach does not focus on the travel behavior, it is recommended only when the choice preference approach cannot work (Ministry of Land, Infrastructure, Transport and Tourism 2012c). For the calculation of the unit wage, usually the real wage rate, the average yearly income divided by yearly real working time, may be applied. Table 4-13 shows the VOTT calculated for three metropolitan areas, using the monthly labour survey in 2014 (Ministry of Health, Labor and Welfare 2014).

Table 4-7: VOTT for three metropolitan areas, estimated by income approach

	National average	**Tokyo**	**Nagoya**	**Osaka**
VOTT (¥/min)	36.36	42.22	36.81	37.77

- Use data for offices with five workers or more in 2014
- Calculate VOTT by each pref., and weight them with respect to the number of labor in each pref.
- Tokyo metropolitan area: Tokyo, Saitama, Chiba, Kanagawa; Nagoya metropolitan area: Aichi, Gifu, Mie; Osaka metropolitan area: Osaka, Kyoto, Hyogo, Nara

Source: Ministry of Health, Labor and Welfare (2014)

If it is possible to obtain trip data and estimate appropriate coefficients from the model, choice preference approach is recommended (Ministry of Land, Infrastructure, Transport and Tourism 2012c), since VOTT obtained from the choice experiment approach directly linked to the travel behavior; thus more appropriate to be used for travel-behavior analysis. In this thesis, we basically use choice experiment approach, but also show the VOTT obtained from income approach as a reference.

- ***Disutility of transfer***

In order to evaluate the travel time saving for passengers who will travel Tokyo-Osaka with the Chuo Shinkansen Maglev in the first-phase operation, we need to evaluate the disutility of transfer at Nagoya station. According to MLIT (Ministry of Land, Infrastructure, Transport and Tourism 2012c), a number of empirical studies show that it is reasonable to divide the disutility of transfer into two components: one is disutility related to the increase in time (minutes) required by transfers ($DU_{transfer\_time}$), and the other is disutility not related to time but related to the number of transfers ($DU_{transfer\_number}$). Therefore, the disutility of transfer ($DU_{transfer}$) is calculated by the sum of two components above.

$$DU_{transfer} = DU_{transfer\_time} + DU_{transfer\_number} \tag{4-3}$$

As for the disutility of transfer related to the increase in time ($DU_{transfer\_time}$), existing empirical works shows that the monetary value of time during a transfer at a station is worth twice the VOTT in the vehicle. Hence, $DU_{transfer\_time}$ is calculated as follows:

$$DU_{transfer\_time} = T_{transfer} \times VOT_{transfer} \tag{4-4}$$

$$VOT_{transfer} = 2 \cdot VOT_{in\ Vehicle} \tag{4-5}$$

Here,

$VOT_{transfer}$: $Value\ of\ time\ during\ a\ transfer\ (yen/min)$

$VOT_{in\ Vehicle}$: $Value\ of\ time\ in\ a\ vehicle\ (yen/min)$

$T_{transfer}$: $Time\ required\ in\ a\ transfer\ (min)$

As for the disutility of transfer not related to time but the number of transfer ($DU_{transfer\_number}$), the existing empirical works shows that one transfer at a station yields disutility equivalent to 10-minute increase in vehicle time. Hence, $DU_{transfer\_number}$ is calculated as follows:

$$DU_{transfer\_number} = VOT_{inVehicle} \times 10N_{transfer} \tag{4-6}$$

Here,

$N_{transfer}$: $The\ number\ of\ transfer\ required\ in\ a\ trip$

From Equation (4-3) to (4-6), we obtain Equation (4-7).

$$DU_{transfer} = DU_{transfer\_time} + DU_{transfer\_number}$$
$$= 2T_{transfer} \times VOT_{inVehicle} + VOT_{inVehicle} \times 10N_{transfer}$$
$$= (2T_{transfer} + 10N_{transfer}) \times VOT_{inVehicle} \qquad (4\text{-}7)$$

If we assume $T_{transfer}$ = 15min, $N_{transfer}$ = 1, then

$$DU_{transfer} = 40\ VOT_{inVehicle} \qquad (4\text{-}8)$$

Equation (4-8) means that a transfer at Nagoya Station will cancel out the travel time saving of the Chuo Shinkansen Maglev as 40 minutes.

4.4.2 Data

- ***The 2010 Inter-Regional Travel Survey in Japan (MLIT)***

We use the 2010 Inter-Regional Travel Survey in Japan, which is conducted and released by MLIT. This survey is aimed to create a database for inter-regional passenger travels[46]. The sample survey was conducted on passengers using five inter-regional transportation mode (air, rail, sea, bus, and car) and the data is collected on each travel mode. The Inter-Regional Travel Survey in Japan was first conducted in 1990, and then conducted every five years. The data is collected on a typical weekday and a typical holiday in winter. The total sample size of the survey in 2010 is 810,000 (Table 4-8) (Ministry of Land, Infrastructure, Transport and Tourism 2010a).

Table 4-8: Sample size of the 2010 Inter-Reginal Travel Survey in Japan

(Thousands)

	Weekday	Holiday	Total
Air	127	186	313
Rail	57	72	129
Sea	3	5	8
Bus	17	31	48
Car	606	1,333	1,939
Total	810	1,628	2,438

46 Travels beyond a border of prefectures are targeted for the survey. Daily commuting travels are also excluded.

Trip data

This trip data for the 2010 Inter-Regional Travel Survey in Japan was collected by the surveys on a typical weekday (Wednesday, Dec.1.2010) and a typical holiday (Sunday, Nov. 28.2010). We use a weekday data for the estimation of VOTT. Each individual data includes travel-related data such as departure and destination zone (O-D), trip purpose, route and ticket type, as well as socio-economic data such as gender, age, occupation and income. As for the origin and destination zone, the whole area of Japan divided into 207 zones basically according to the city size.

Level of Service (LOS) data

LOS data is representative travel time (min), travel cost (yen) for each transportation mode between the centers of the 207 zones as of March 2010, based on NITAS (National Integrated Transport Analysis System) offered by MLIT. Since the travel costs shown in NITAS reflect the regular fare (one-way, no discount), we make the following assumption regarding real fares.

Figure 4-4: Example of LOS data (travel time) for each O-D

LOS for each O-D

Travel time for 207 O-D zones

Mode: Rail

(unit: minute)

		Destination	253	261	262	263	264	265	271	272	273	274	281	282	283	284
		pref.	滋賀	Kyoto	Kyoto	Kyoto	Kyoto	Kyoto	Osaka	Osaka	Osaka	Osaka	Hyogo	Hyogo	Hyogo	Hyogo
Origin	pref.	city	中部	Kyoto	Uji	Nothern region	Kameoka	Southern region	Osaka	Sakai	Higashi-Osaka	Toyonak a	Kobe	Amagasa ki	Harima	Tajima
111	Saitama	Urawa	252	209	224	322	235	279	235	255	260	244	238	237	263	359
112	Saitama	Kawagoe	282	239	254	352	265	309	265	285	290	274	268	267	293	389
113	Saitama	Kodama/Ozato	270	227	242	340	253	297	253	273	278	262	256	255	281	377
114	Saitama	Chichibu	342	299	314	412	325	369	325	345	350	334	328	327	353	449
121	Chiba	Chiba	272	229	244	342	255	299	255	275	280	264	258	257	283	379
122	Chiba	Funabashi	255	212	227	325	238	282	238	258	263	247	241	240	266	362
123	Chiba	Awa/Kimizu	301	258	273	371	284	328	284	304	309	293	287	286	312	408
124	Chiba	Narita	295	252	267	365	278	322	278	298	303	287	281	280	306	402
131	Tokyo	23wards	243	200	215	313	226	270	226	246	251	235	229	228	254	350
132	Tokyo	Tama	250	207	222	320	233	277	233	253	258	242	236	235	261	357

Discount fare for air and rail

Because of the deregulation of air fare in Japan since 1996, airlines offer a variety of discounted fares. Currently, a majority of air passengers use some kind of discounted fare instead of non-discounted one-way fare. According to Tansei (2010), the data in 2007 shows that only 20.1% of business passengers and 6.1% of leisure passengers take flights with non-discounted one-way tickets (Tansei 2010).

Tansei (2010) also calculates the average discount rates for all domestic flights in Japan using the data in 2007. According to his paper, the average discount rate of a flight between Tokyo International airport (Haneda, HND) and Osaka International airport (Itami, ITM) is 28.7% (Tansei 2010). Therefore, we apply this rate to the calculation of the air fare in the binary choice model.

Also, we obtained the actual price of the discounted tickets which were offered by Japan Airlines on the survey date (Dec.1.2010) (Japan Airlines 2010). The average discount rate of the actual discounted tickets ("Tokubin" and "Sakitoku" discount) is 47.3%. Therefore, we use this number for the travel cost of individuals, who actually used the discounted ticket for the travel.

As for rail fare, there is limited discount as we already discussed above. The unit fare of the Tokaido Shinkansen in FY2010 is ¥23.20/km. Using this unit fare and the distance between Tokyo and Osaka (552.6km), we calculate the average fare in Tokyo-Osaka as ¥12,822. On the other hand, the regular fare of Tokyo-Osaka (Nozomi) in 2010 was ¥14,050. Therefore, the average discount rate is calculated as 8.7%. We apply this rate to the calculation of the rail fare in the binary choice model.

4.4.3 Binary choice model

We construct a binary choice model with equations from (4-9) to (4-12).

Table 4-9 demonstrates the notation and variables in the equations.

$$V_{nij}^{Air} = \alpha + \beta_{time} TT_{ij}^{Air} + \beta_{cost} RTC_{ij}^{Air} \tag{4-9}$$

$$V_{nij}^{Rail} = \beta_{time} TT_{ij}^{Rrail} + \beta_{cost} RTC_{ij}^{Rail} + \beta_{purpose} Purpose \tag{4-10}$$

$$RTC_{ij}^{Air} = (0.713 - 0.186 Dum_{discount}) TC_{ij}^{Air} \tag{4-11}$$

$$RTC_{ij}^{Rail} = 0.912 TC_{ij}^{Rail} \tag{4-12}$$

Table 4-9: Notation and variables in the discrete choice model

Notation/Variable	Explanation
n	Individual
i	Origin
j	Destination
Purpose	Trip purpose (business or leisure)
V_{nij}^{k}	Systematic utility for an individual "n" traveling between origin "i" and destination "j" with mode "k"
TT_{ij}^{k}	Travel time (min) between origin "i" and destination "j" with mode "k" (Air or Rail) , obtained by NITAS
TC_{ij}^{k}	Travel cost (¥) between origin "i" and destination "j" with mode "k" (Air or Rail), obtained by NITAS
RTC_{ij}^{k}	Real travel cost (¥), in which we take into account the use of discounted tickets
$Dum_{discount}$	Dummy variable for the use of discounted tickets (only for air alternative) 1: if the individual "n" used a discounted ticket, 0: otherwise

4.4.4 Result

Coefficients in binary logit model are estimated by Biogeme 2.2.

Table 4-10 shows the estimated results. Adjusted R-squared value is 0.294. Signs of all coefficients are reasonable, and t-values show they are significant.

Table 4-10: Estimation result

Name	Value	t-test
α	-0.866	-16.19
β_{cost}	-0.000531	-59.93
β_{time}	-0.0279	-49.27
$\beta_{purpose}$	0.382	16.04
Sample number	24738	-
Final log-likelihood	-12104.176	-
$\overline{\rho^2}$	0.294	-

From estimated β_{cost} and β_{time}, we calculate VOTT by Equation (4-2).

$$VOTT = \frac{\beta_{time}}{\beta_{cost}} = \frac{-0.0279}{-0.000531} = 52.54\ (¥/min) \tag{4-13}$$

In order to validate the result of estimation,

Table 4-11 compares our result with VOTT estimation in literature regarding the areas in Japan. As the table shows, the value of VOTT varies from 25 to 155 (¥/min). Also, according to the post-construction evaluation about recent Shinkansen extention projects (Tohoku, Hokuriku, and Kyushu) in JRTT's website (http://www.jrtt.go.jp/01Organization/org/org-hyoka27.html), it regards 50-100 (¥/min) as the reasonable value for the VOTT obtained by discrete choice model (JRTT 2016).

Our proposed approach for the determination of the appropriate price level of a new HSR largely depends on the evaluation of VOTT. As

Table 4-11 demonstrates, the estimation of VOTT can be affected by choice model. Although our result by the disaggregated binary logit model exists within the recommended range of JRTT, it is clear that further research is needed for more accurate estimation of VOTT. Also, since the travel time (including access and egress), the travel cost (especially the variety of the discounted tickets are increasing), as well as people's preference toward transportation modes varies year by year, the estimation of VOTT should be implemented with the latest data.

Table 4-11: Comparison of VOTT with other sources

Method	Source	VOTT (yen/min)	Note
Choice experiment approach	Author's calculation	52.54	- Disaggregated binary logit - Focus on Tokyo-Osaka
	Asami 2004	55.00	- Disaggregated binary logit - Whole area in Japan
	Muto 2001	155.8	- Disaggregated Mixed logit - Focus on between Tokyo metropolitan area and 16 competitive O-D areas (air vs. rail) such as Osaka, Hiroshima, Fukuoka
	JRTT 2016	Business: 78.57 Leisure: 73.22 Other: 62.32	- Discrete choice model - focus on Hachinohe-ShinAomori, Hakata-ShinYatsushiro
	Yai 1993 (1)	Business: 147.77 Leisure: 72.90	- Disaggregated Multi-nominal logit - Focus on kanto area (including Tokyo) to other whole areas in Japan
	Yai 1993 (2)	Business: 93.02 Leisure: 80.07	- Disaggregated Multi-nominal logit - Focus on Kinki area(including Osaka) to other whole areas in Japan
	Inoue 2015	Business: 36.18 Leisure: 25.45	- Disaggregated Mixed logit - Focus on Tokyo-Osaka, Tokyo-Fukuoka, Tokyo-Hokkaido, Osaka-Fukuoka, Osaka-Hokkaido
Income approach	Author's calculation	36-42	- See Table 4-7

Source: (Asami 2004; Inoue et al. 2015; JRTT 2016; M. Muto and Uchiyama 2001; Yai and Iwakura 1993)

Using our result of VOTT estimation (¥52.54/min), we now estimate the willingness to pay (WTP) for the travel time saving by the Chuo Shinkansen Maglev. The result is shown in Table 4-12.

Table 4-12: The estimated result of the willingness to pay for the travel time saving in Tokyo-Nagoya/Osaka

	Valid travel time saving (considering disutility of transfer)	WTP for the valid travel time saving (VOTT as ¥52.54/min)	WTP for the Chuo Shinkansen Maglev
Tokyo-Nagoya	60 min	¥3,152 ($26.37)	¥14,242 ($118.69)
Tokyo-Osaka	20 min	¥1,051 ($8.76)	¥15,501 ($129.17)

The reason for the difference in WTP for travel time saving for Tokyo-Nagoya and that for Tokyo-Osaka is that we focus on the first-phase operation, in which the Chuo Shinkansen Maglev is operated between Tokyo and Nagoya. Since WTP for the travel time saving for Tokyo-Osaka is smaller than that for its partial portion (Tokyo-Nagoya), the practical implementation of the fare system should be considered. We will discuss this issue in Section 4.6. Here, we now argue WTP for the travel time saving either for Tokyo-Nagoya or Tokyo-Osaka individually.

The result suggests that the WTP for the travel time saving for Tokyo-Nagoya (¥3,152) might exceed the upper-limit fare constrained by the full-cost principle in Section 4.3. Even though the precise determination of the upper limit for Tokyo-Nagoya fare is out of scope of this thesis, it is a useful insight that the fare for Tokyo-Nagoya will be constrained by the upper-limit fare constrained by the full-cost principle.

As for Tokyo-Osaka, WTP for the travel time saving (¥1,051) will be below the upper limit fare constrained by the full-cost principle. This suggests that it is rational to set the fare level according to WTP for the travel time saving rather than the full-cost principle. If JR Central sets the fare level led by the full-cost principle, for example ¥2,000 higher than the Tokaido Shinkanen for Tokyo-Osaka, our analysis suggests that passengers will not choose the Chuo Shinkansen Maglev, but choose the Tokaido Shinkansen or airlines. It will lead to insufficient use of the Chuo Shinkansen Maglev capacities, which will result in the smaller revenue than expected.

However, since WTP for the travel time saving of the Chuo Shinkansen for Tokyo-Osaka users largely depends on the disutility of transfer at Nagoya Station. We used Equation (4-8) for the estimation of the disutility of transfer. It suggests that the actual transfer time (estimated as 15 minutes in our model) as well as the design of Nagoya Station (e.g. transfer route between the Chuo Shinkansen Maglev and the Tokaido Shinkansen) will have a large impact on WTP for the Chuo Shinkansen Maglev. If we use our model of the disutility of transfer and assume that the transfer time is shrunk to 10min from 15min, WTP for travel time saving for Tokyo-Osaka users will increase as much as ¥520, which might have significant impact on the revenue from the Chuo Shinkansen. Therefore, it is strongly recommended to reduce the transfer time in Nagoya Station.

4.5 Case study: the introduction of Nozomi Super-Express

4.5.1 Background and purpose

- **Background**

Before JR Central introduced "Nozomi" Super-Express in March 1992, the fastest type of HSR service in the Tokaido Shinkansen had been "Hikari". The maximum speed of Hikari was 220km/h (137mile/h), with Series 100 rolling stock (left in Figure 4-5).

Source: SCMAGLEV and Railway Park (http://museum.jr-central.co.jp/en/)

Figure 4-5: Series 100 (left) used for "Hikari" and Series 300 (right) used for "Nozomi"

The introduction of new-type rolling stock (series 300, right in Figure 4-5) enabled the Tokaido Shinkansen to set the maximum operating speed at 270 km/h (137mile/h) for the first time. At the same time of the introduction of the new rolling stock series 300, JR Central commenced the new HSR service "Nozomi" with series 300, with shorter travel time between Tokyo and Osaka, than the existing "Hikari" and "Kodama".

JR Central set the fare of Nozomi between Tokyo and Osaka as ¥950 higher than Hikari and Kodama. This is the only experience for JR Central to raise the fare of the Tokaido Shinkansen since JR Central's commencement in 1987, except when 3% sales tax was introduced in 1989 and it was raised to 5% in 1997 and to 8% in 2014.

The fare difference of ¥950 became ¥970 after the sales tax increase in 1997, but except that, the fare difference between Nozomi and Hikari had not changed before the fare and schedule renovation in Oct. 2003. In Oct. 2003, JR Central opened Shinagawa Station with service between Tokyo and Shin-Yokohama. Since Shinagawa Station was already a large transportation hub in terms of conventional railways and buses in the Tokyo metropolitan area similar to Tokyo Station, and also its location was closer to Tokyo International Airport (also known as Haneda Airport) than Tokyo Station, a large number of passengers were expected to use Shinagawa Station. At the same time as the commencement of Shinagawa Station, the big schedule change was implemented for the Tokaido Shinkansen, and also the fare of Nozomi was changed simultaneously. The fare of Nozomi was reduced by ¥670 and set just ¥300 higher than the fare of Hikari.

- **Purpose of the case study**

We use the Nozomi introduction as the case study for the determination of the fare level of the Chuo Shinkansen Maglev because of the reasons as follows:

1. The difference in fare between the introduced faster train (Nozomi) and the existing slower train (Hikari) may reflect willingness to pay (WTP) for the travel time saving of a faster train, rather than the difference in the costs to JR Central between two train-types. Whether the electricity (power) cost of Nozomi might be higher or smaller than Hikari is unclear, because while Nozomi's maximum speed is higher than Hikari, the number of intermediate stops in Nozomi is smaller than Hikari, which means less acceleration and

deceleration are required. Also, the proportion of the electricity (power) cost in the total operating cost is small as we have seen in Table 2-3. Therefore, the difference in the fare may not come from the cost-side, but from other reasons including demand-side (e.g. WTP). It is hard in general to find a case such that the fare is determined by the WTP, with little cost-related argument; thus this case presented an opportunity for this research.

2. Even though the cost is not a major determinant of the fare, there may be other concerns (e.g. equity/equality) as we have seen in Chapter 2. Rail operators' stance toward these concerns depend on their funding sources, philosophy and backgrounds. The Nozomi introduction case involves the same company and the same corridor as the Chuo Shinkansen Maglev case; we argue that their stance toward those external concern would be similar; thus, WTP for travel time saving may be the most important determinant in the Nozomi introduction case.

4.5.2 The fare of Nozomi at its introduction in 1992

Table 4-13 summarizes the fare and the travel time between Tokyo and Osaka, when Nozomi was introduced in March 1992. Not only the maximum speed, but also the intermediate stops for Nozomi and Hikari between Tokyo and Osaka were different from each other. Although only Nozomi users could enjoy new rolling stock, the basic accommodation and on-train experience was almost identical; thus the major differences between them were the travel time and the fare.

Table 4-13: The specification of Nozomi and Hikari between Tokyo and Osaka in 1992

	Hikari	Nozomi	Difference
Fare*	¥13,480	¥14,430	¥950
Travel time	172 min	150 min	22 min

*The fare shows the sum of the basic fare and the limited-express charge for reserved seat.

Source: JR timetable

Calculating the difference in the fare ($\Delta fare$) divided by the difference in the travel time ($\Delta time$), we obtain ¥43.18/min.

$$\frac{\Delta fare}{\Delta time} = \frac{¥950}{22min} = 43.18\ (¥/min) \tag{4-14}$$

If we assume that VOTT in 2010, calculated in Section 4.4, have not changed since 1992, VOTT between Tokyo and Osaka in 1992 can be estimated as ¥52/min. The fare increase for Nozomi compared to Hikari (¥43.18/min) is lower than the VOTT as ¥52/min. From our standpoint, in which the fare increase for the faster train is determined based on the WTP for the travel time saving (i.e. VOTT), the result of this case study seems reasonable, because the actual fare increase (¥43.18/min) < the WTP for the travel time saving (¥52/min).

4.5.3 The fare of Nozomi after the fare reduction in 2003

Table 4-14 summarizes the specification of Nozomi and Hikari between Tokyo-Osaka O-D before/after the 2003 schedule and fare change. At the same time of the change, Series 100 rolling stock was retired, and all rolling stock used in the Tokaido Shinkansen began to run at maximum 270km/h. Although the travel time of Hikari remained still longer than Nozomi because of the larger number intermediate stops, the difference in the travel time shrunk as seen in Table 4-14. Also, the majority of the trains turned to Nozomi from Hikari.

Table 4-14: The specification of Nozomi and Hikari between Tokyo and Osaka before and after the 2003 schedule and fare change

		Hikari	Nozomi	Difference
Before 2003 schedule and fare change	Travel time	170-183 min	150-153 min	17-33 min
	Max speed	220km/h	270km/h	50km/h
	Rolling stock used	Series 700, 300, **100**	Series 700, 500, 300	Old Series 100 was used for Hikari
	Frequency (per hr each way)	6	3	-
	Fare*	¥13,750	¥14,720	¥970
After 2003 schedule and fare change	Travel time	173-180 min	154-157 min	16-26 min
	Max speed	270km/h	270km/h	0 km/h
	Rolling stock used	Series 700, 300	Series 700, 500, 300	All trains can run at Max 270km/h
	Frequency (per hr each way)	2	7	-
	Fare	¥13,750	¥14,050	¥300

*The fare shows the sum of the basic fare and the limited-express charge for reserved seat. Also, the fare before the 2003 renovation shown in the table is different from that in Table 4-13. This is because the fare was raised when the sales tax was raised to 5% from 3% in 1997.

Source: (Ministry of Land, Infrastructure, Transport and Tourism 2003)

As for the travel time and the fare after the 2003 change, the difference in the fare ($\Delta fare$) divided by the difference in the travel time ($\Delta time$) is calculated as ¥18.75/min.

$$\frac{\Delta fare}{\Delta time} = \frac{¥300}{16min} = 18.75\ (¥/min) \tag{4-15}$$

The value of ¥18.75/min is still lower than ¥52/min as the WTP for the travel time saving; thus this result is also consistent with our view. However, the difference in the fare between Nozomi and Hikari became much lower than before by the 2003 schedule and fare renovation. The reason of this may be considered as follows:

1. **The service level of Nozomi and Hikari became more similar.**
   By the retirement of the old 100 series rolling stock, the maximum speed as well as the rolling stock used (except a limited number of series 500 rolling stock) became identical for both Nozomi and Hikari.
2. **JR Central aimed to stop the "dilution" of its market share by reducing fares.**
   As Figure 4-6 demonstrates, the market share of the Tokaido Shinkansen for Tokyo-Osaka O-D has decreased since 1990 (except small increase in 2010), while the share of airlines has increased. The major driver of this trend is the reduction of air fare led by the deregulation of the airline industry in Japan.

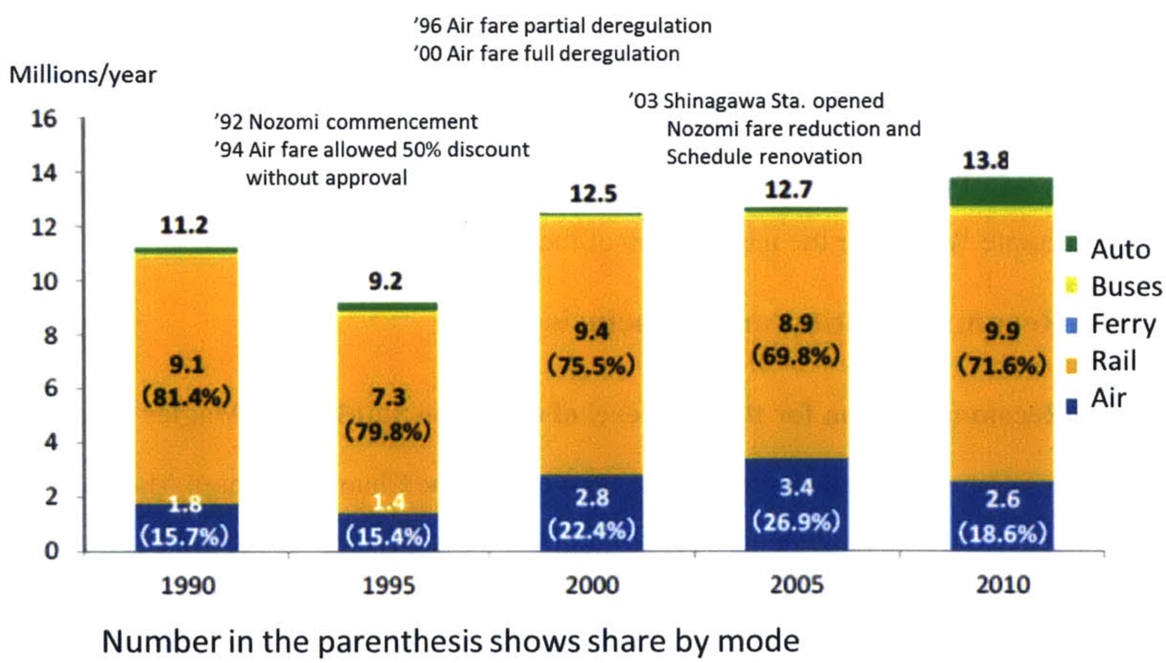


Figure 4-6: Passengers traveled between Tokyo Metropolis and Osaka Prefecture

4.5.4 Possibility of overlooking impacts led by an unprecedented transport system

This thesis's approach for the Chuo Shinkansen Maglev is focused on the incremental improvement on the travel time saving from the current situation. More specifically, VOTT is expected unchanged. However, there are a lot of examples such that people's preference on the travel behavior (including VOTT) has radically changed by the introduction of the unprecedented transportation systems. Looking into the past, like the Brooklyn Bridge in New York City built in 1883, and the Panama Canal in 1914, there is no doubt that all of these unprecedented transportation system has dramatically changed business as well as lifestyle.

As for the drastic change in travel behavior, the introduction of the Tokaido Shinkansen in 1964 seems to be the most closely related example to the Chuo Shinkansen Maglev. The travel time between Tokyo and Osaka before the introduction of the Tokaido Shinkansen was about seven hours, which was shrunk to four hour in 1964 and soon became three hours in 1965. This made significant impact on the business and lifestyle along the operating area of the Tokaido Shinkansen. For example, before the commencement of the Tokaido Shinkansen, the round-trip between Tokyo and Osaka must have included at least one night stay at the destination, which is no longer necessarily the case after the commencement of the Tokaido Shinkansen.

There are several papers regarding the effect of the Tokaido Shinkansen on the national/regional economy and land use (Usami and Okuda 2013). However, the effect on the travel behavior (e.g. VOTT) is not clear mainly because of the lack of the sufficient data before the commencement. The consideration of the discontinuous change in the travel-behavioral factors is out of the scope of this thesis; however, further research is needed in order to estimate more accurate WTP after the introduction of the Chuo Shinkansen Maglev.

4.6 Recommendation and Conclusion

4.6.1 Recommendation for the fare level of the Chuo Shinkansen Maglev

In Chapter 4, we analyzed an appropriate fare level of the Chuo Shinkansen Maglev from the two perspective: 1) the regulatory upper-limit fare constrained by the full-cost principle, and 2) the WTP for the travel time saving of the Chuo Shinkansen Maglev in comparison to the Tokaido Shinkansen. Based on the results of this work, in this section, we propose two plans as viable implementations for the fare of the Chuo Shinkansen Maglev. Also we analyze merits/demerits of the two plans and give suggestions, and conclude this chapter.

As the first step of the framework (Figure 4-1), the examination of the upper fare constrained by the full-cost principle, we obtained that the upper-limit fare of the Chuo Shinkansen Maglev would be at least ¥13,090, which is ¥2,000 larger than the Tokaido Shinkansen. As mentioned in Section 4.3, the thesis does not give a precise value of the upper limit; thus we assume that ¥13,090 (+¥2,000) is the upper-limit fare for Tokyo-Nagoya, which is consistent with the full-cost principle, in the following analysis.

As the second step, the examination of the WTP for the travel time saving in comparison to the Tokaido Shinkansen, we estimated that the WTP for the travel time saving is ¥52/min. Based on this estimation, we calculated that WTP for Tokyo-Nagoya with the Chuo Shinkansen Maglev is ¥14,242 (¥3,152 larger than the current Tokaido Shinkansen) and WTP for Tokyo-Osaka with the Chuo Shinkansen Maglev (Tokyo-Nagoya) and the Tokaido Shinkansen (Nagoya-Osaka) is ¥15,501(¥1,051 larger than the current Tokaido Shinkansen) (Table 4-12).

In order to attract customers, the fare should be sufficiently lower than the WTP for the service. As for Tokyo-Osaka fare, we assume that the incremental fare for Tokyo-Osaka with the Chuo Shinkansen Maglev (Tokyo-Nagoya) and the Tokaido Shinkansen (Nagoya-Osaka), with respect to the Tokaido Shinkansen (Tokyo-Nagoya-Osaka), would be set at +¥800, which is about 75% of the WTP for the travel time saving for Tokyo-Osaka (¥1,051).

Then, as for Tokyo-Nagoya fare, we can consider two plans: the incremental fare for Tokyo-Nagoya Chuo Shinkansen Maglev can be set as ¥800 with respect to the Tokaido Shinkansen; thus the incremental fare for Tokyo-Osaka users, who use both the Chuo Shinkansen Maglev (Tokyo-Nagoya) and the Tokaido Shinkansen (Nagoya-Osaka), also becomes ¥800 (**Plan A** in Figure 4-7). On the other hand, the incremental fare for Tokyo-Nagoya can be set as ¥2,000, which is the upper-limit fare for the Chuo Shinkansen Maglev Tokyo-Nagoya (**Plan B** in Figure 4-7). As for Plan B, in order to ensure the fare increase in Tokyo-Nagoya is higher than that in Tokyo-Osaka, it requires ¥1,200 discount for the Tokaido Shinkansen Nagoya-Osaka, which is only applied if the users take the Chuo Shinkansen Maglev in Tokyo-Nagoya.

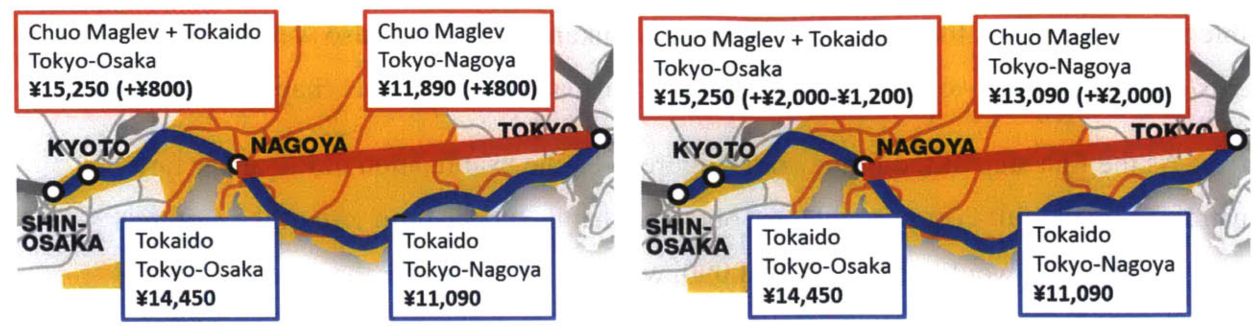


Figure 4-7: Plan A (left) and Plan B (right)

In order to discuss merits and demerits for Plan A and Plan B, we propose three perspectives, consumer surplus, producer surplus, and simplicity.

Consumer surplus (CS)

CS is the benefit captured by consumers (in our case, the Chuo Shinkansen Maglev users) rather than a producer (JR Central) and can be calculated by the sum of the WTP less the fare. If we assume the total users of Plan A are the same for simplicity, the consumer surplus per user can be calculated in Table 4-15.

Table 4-15: Comparison of the consumer surplus per user brought by Plan A and Plan B

O-D	Plan A			Plan B		
	WTP	Fare	CS	WTP	Fare	CS
Tokyo-Nagoya	¥14,242	¥11,890	**¥2,352**	¥14,242	¥13,090	**¥1,152**
Tokyo-Osaka	¥15,501	¥15,250	**¥251**	¥15,501	¥15,250	**¥251**

Clearly, Plan A may produce the larger total CS than Plan B. However, the larger CS will not be distributed geographically evenly. In Plan A, the difference in CS between a Tokyo-Nagoya user and a Tokyo-Osaka user is greater than Plan B. Large CS captured by the travelers within the Tokyo-Nagoya segment—the majority of them might belong to Tokyo metropolitan area and Nagoya metropolitan area—may transfer to the regional economic benefit for the region.

As mentioned in Section 3.1, there are a large concerns from the western area of Japan regarding the two-phase project scheme with 18-year long interval between each phase. While

Plan A will certainly enhance economic development for Tokyo and Nagoya metropolitan areas, the Osaka metropolitan areas and other areas west of Nagoya might not enjoy the same benefit.

Producer surplus (PS)

Since the total CS produced by Plan B may be smaller than Plan A, if we assume the total benefit is the same for both plans (the same number of users), Plan B will produce the larger PS for JR Central. The large PS may relieve the financial risk of JR Central, and also have the possibility of shrinking 18-year interval between phase 1 and phase 2.

The risk in setting higher fare is the loss of users, and in our case, it is that the Chuo Shinkansen Maglev could not attract a large number of passengers in Tokyo-Nagoya, who may continue to use the Tokaido Shinkansen. Hence, JR Central should be careful about WTP for the travel time saving for Tokyo-Nagoya users, and set the fare sufficiently lower than the WTP. However, as we have seen in Section 4.4, the large uncertainty in the WTP for the Chuo Shinkansen Maglev might come from the disutility of transfer at Nagoya Station, which will not affect Tokyo-Nagoya users. Therefore, setting the higher fare for the Tokyo-Nagoya segment seems more reasonable and safer approach for JR Central.

The other concern on the larger PS for JR Central by setting higher fare may be the issue of price gouging, since the market share of JR Central in Tokyo-Nagoya inter-city passenger travel is already almost 100%. If the fare for Tokyo-Nagoya segment becomes the upper-limit fare constrained by the full-cost principle as our estimation in Section 4.4 suggests, JR Central may be required to be transparent on the cost data and also be cost-efficient. On the other hand, higher PS of Plan B might be justifiable in this situation (after the commencement of Tokyo-Nagoya operation), since JR Central should yield sufficient profit in order for the investment on the construction of Nagoya-Osaka segment in the phase 2.

Simplicity

Simplicity in fare structure is an important issue in a public transportation service. Unfortunately, the fare system in JR companies is much more complex than the other nationwide rail companies in the world (e.g. SNCF in France, Amtrak in the U.S.).

In our case, Plan A is simpler than Plan B, since there will not be no discount applied on specific occasions. This specific discount in Plan B might encourage cheating with the discounted ticket. For example, the travelers from Osaka to Nagoya (Nagoya as a final destination) by the Tokaido Shinkansen might be attracted by the discounted ticket, which is not available for them but to the travelers who will use the Chuo Shinkansen after the journey to Nagoya by the Tokaido Shinkansen. Therefore, a sophisticated customer segmentation by O-D pairs will be required for the implementation of Plan B than Plan A.

However, the customer segmentation in terms of O-D pairs is already in common even in the rail sector[47]. For example, "Transfer discount" is available in JR Companies between Shinkansen and conventional express; e.g. if a customer travels from Tokyo to Nagoya by the Tokaido Shinkansen and travels from Nagoya to Takayama (a popular sight-seeing spot in Gifu prefecture) by Hida Limited-Express in Takayama line as a combined trip, the express surcharge for Hida Limited-Express will be discounted for 50% of the regular price. There is no information publicly available regarding the fare evasion on this discount, to the best of the author's knowledge, Transfer discount does not lead to a problematic situation. The similar system would be required for the implementation of Plan B.

4.6.2 Conclusion

In this chapter, we analyzed an appropriate price level of the Chuo Shinkansen Maglev, focusing on the project's first-phase operation in which the Chuo Shinkansen Maglev Tokyo-Nagoya segment is under operation (during 2027-2045, as projected by JR Central). We propose 3-step procedure for the fare-level analysis (Figure 4-1): 1) Examine the upper fare constrained by the full-cost principle, 2) Examine the WTP for the travel time saving in comparison to the Tokaido Shinkansen, 3) Compare with the reference case in the past: introduction of Nozomi Super-Express. Based on the results of these steps, recommendation of the fare level is given.

As the first step, we reviewed the actual calculation and evaluation of the full-cost principle in the recent HSR projects, the Hokuriku Shinkansen and the Hokkaido Shinkansen. Then we estimated the total revenue on the Chuo Shinkansen Maglev (Tokyo-Nagoya) and the total cost, based on the information by Transport Policy Council Chuo Shinkansen Subcomittee

[47] In the airline industry, the large discrimination in the fare regarding O-D pairs is more common and more aggressively used than the rail, as we have seen in Figure 2-6.

(TPC-CSS) (Transport Policy Council Chuo Shinkansen Subcommittee 2011). As a result, we calculated that the upper-limit fare of the Chuo Shinkansen Maglev would be at least ¥13,090, which is ¥2,000 larger than the Tokaido Shinkansen. Although the precise estimation of the upper-limit fare is out of the scope of this thesis, and should be implemented with latest demand and cost data, the result demonstrates the meaningful insight for the scope of the approvable fare level of the Chuo Shinkansen Maglev.

As the second step, we built the model to estimate the WTP for the travel time saving of the Chuo Shinkansen Maglev, considering VOTT and the disutility of transfer at Nagoya Station. Then we estimated VOTT by the disaggregated binary logit model with 2010 Inter-Regional Travel Survey data. As a result, we obtained VOTT for Tokyo-Osaka users as ¥52/min. Based on this estimation, we calculated that WTP for Tokyo-Nagoya with the Chuo Shinkansen Maglev is ¥14,242 (¥3,152 larger than the current Tokaido Shinkansen) and WTP for Tokyo-Osaka with the Chuo Shinkansen Maglev (Tokyo-Nagoya) and the Tokaido Shinkansen (Nagoya-Osaka) is ¥15,501(¥1,051 larger than the current Tokaido Shinkansen) (Table 4-12). This result and the result of the step 1 suggest that the fare of Tokyo-Nagoya segment of the Chuo Shinkansen Maglev might be constrained by the full-cost principle (i.e. WTP > upper fare limit).

As the third step, in order to validate WTP approach with a real case, the thesis analyzed the fare setting of Nozomi Super-Express in the Tokaido Shinkansen as a reference case. The incremental fare of Nozomi at its introduction in 1992 with respect to the fare of the second fastest train Hikari was ¥43.18/min, while that difference between Nozomi and Hikari became ¥18.75/min, when the fare of Nozomi was reduced in 2003. The result suggests that our approach may be reasonable because the incremental fare is lower than WTP. However, in this step, there may be a possibility of overlooking impacts on travel behavior, led by an unprecedented transport system, as we have seen in Section 4.5.4.

As a recommendation of the appropriate fare-level determination, we suggested two practical plans for the fare of the Chuo Shinkansen Maglev. As for the merits/demerits of both plans, we compared two plans from three perspectives: customer surplus, producer surplus, and simplicity, respectively.

In the next chapter, we now move in to another perspective of pricing strategy, namely the application of the dynamic pricing for the Chuo Shinkansen Maglev.

Chapter 5 Application of dynamic pricing to HSR

5.1 Purpose of the analysis

As we have seen in Section 2.5, while the introduction of the price differentiation (i.e. dynamic pricing) for HSR may increase the revenue without the substantial increase in the operating cost, the simple copy-and-paste of the airline dynamic pricing has usually been problematic. The system should be appropriately customized suitable to the specific network structure of the HSR line. Also, operators who are responsible for pricing and seat allocation should operate the system consistently the company's pricing policy as well as the market characteristics.

In this chapter, we will examine the pricing strategy of SNCF in France on TGV Paris-Lyon and Amtrak in the U.S. on Acela in the Northeast Corridor (NEC, i.e. Boston-New York-Washington DC) from the customers' perspective. From the pricing behaviors observed by the actual fare data, we discuss the implications regarding the application of dynamic pricing to the Chuo Shinkansen Maglev.

Table 5-1 summarizes the basic operating specification of TGV Paris-Lyon and Amtrak NEC, with the comparison to the Tokaido Shinkansen Tokyo-Osaka. The reasons to choose TGV Paris-Lyon and Acela NEC as reference cases for the Chuo Shinkansen Maglev in this analysis are as follows:

- TGV Paris-Lyon and Acela in NEC have implemented dynamic pricing since 1980s and 2006, respectively; thus those two have relatively long histories and experiences on the application of the dynamic pricing. Both of them started to incorporate the basic system from that of American Airlines, but their systems have been customized in order to adjust to their circumstances, as we have seen in Section 2.5. Therefore, focusing on the difference between these two gives us useful insight on the application of dynamic pricing.
- TGV Paris-Lyon is the second profitable HSR in the world, following the Tokaido Shinkansen Tokyo-Osaka, and only those two lines are considered to be profitable if we take into account the depreciation cost of the infrastructure (Albalate and Bel 2013). Also, Acela in NEC is considered to be profitable if we only consider the operating cost (Archila 2013).

- Both SNCF and Amtrak are funded by each government; thus their managerial policy should be influenced by public policy (e.g. equity issues). However, the profitability in TGV Paris-Lyon for SNCF as well as the profitability in Acela for Amtrak should be one of the central concerns in the pricing strategy for those lines, since they have to internally subsidize their unprofitable lines. In this sense, the situation for the future Chuo Shinkansen Maglev will have some similarities with TGV Paris-Lyon and Acela NEC.

Since the information regarding the pricing strategy, such as fare class, demand estimation, and seat allocation policy for specific fare classes, are treated as confidential by each operator, the analysis in this thesis basically uses the fare data, which can be collected from each company's website.

Table 5-1: Operating specification about Amtrak NEC, SNCF Paris-Lyon, and the Tokaido Shinkansen Tokyo-Osaka

Company	Amtrak				SNCF		JR Central
Segment	NY – DC		BOS – NY		Paris-Lyon		Tokyo-Osaka
Distance	225 mile		231 mile		264 mile		320 mile
Number of stations	12		14		5		17
Train type	Acela	NER	Acela	NER	TGV	Ouigo	Tokaido Shinkansen Nozomi
Travel time (hour:min)	2:53	3:28	3:33	4:10	1:59	1:45	2:28
Number of stops	7-8	10-11	6-8	11-14	2-4	2	6
Daily frequency (each way)	16	20	10	8	22	4	114

5.2 Methodology

The purpose of the survey is to understand the dynamic pricing behavior of TGV Paris-Lyon and Amtrak in NEC from the customers' point of view, and to consider which specification would be suitable for the potential pricing strategy for the Chuo Shinkansen Maglev. In order to analyze the dynamic pricing behavior, two approaches are proposed in the thesis:

- **Price variation regarding time of departure**

Unlike the Tokaido Shinkansen, TGV and Acela differentiate fare in accordance with the difference in time of departure on a day. The rationale behind this is that under the limited capacity, peak time trains deserve higher fare than off-peak trains because of customers' higher willingness to pay (WTP) for peak time trains.

- **Price variation regarding day of booking**

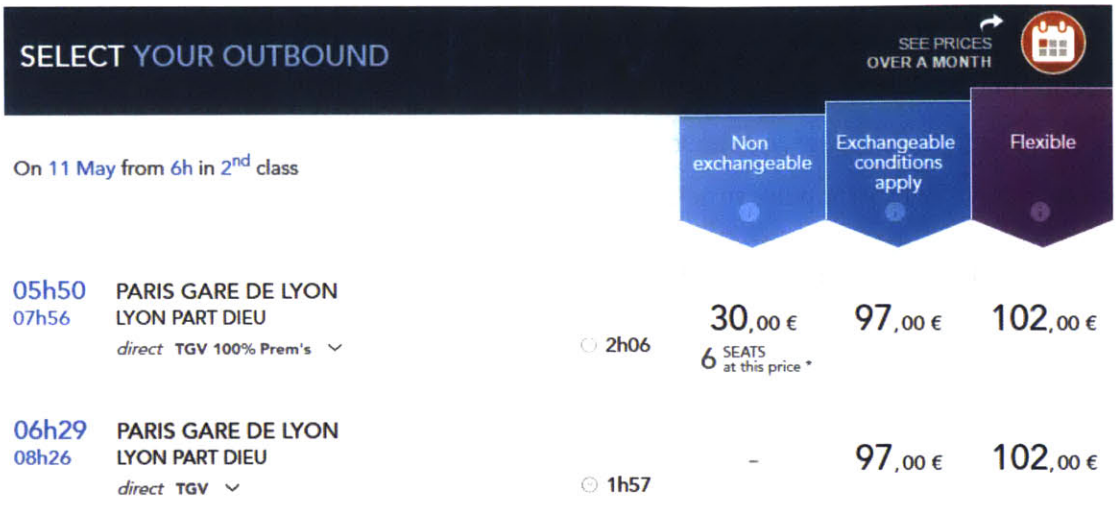
TGV and Acela also differentiate fare in accordance with advance purchase. The rationale behind this is that keeping empty seats without reservation requires larger cost (risk for spoilage) for a supplier; thus seats booked in advance deserve cheaper fare for customers. For suppliers, the price differentiation regarding advance purchase makes sense also because it can differentiate more price sensitive customers (leisure) from less price sensitive customers (business travelers) by using customers' behavioral characteristics. This is based on the assumption that business travelers are less likely to fix their schedule in advance; thus the proportion of less price-sensitive customers increases as the day of departure approaches.

5.3 Data collection

5.3.1 Current fare structure

- SNCF: TGV Paris-Lyon

Figure 5-1 shows the ticket-booking website for TGV Paris-Lyon, which includes the fare products available for second class seats in each TGV train. SNCF offers three fare classes for an identical seat, Non-exchangeable "100% Prem's" (the left column in Figure 5-1), conditionally exchangeable "TGV Leisure" (the middle column in Figure 5-1), and flexible "TGV PRO" (the right column in Figure 5-1), respectively. As Figure 5-1 shows, the availability of the most affordable "100% Prem's" fare is limited based on the remaining seats in the train. The price of "100% Prem's" and "TGV Leisure" change in accordance with the time of departure and the day of booking, while the price of "TGV PRO" only varies in accordance with the time of departure, but does not change as the day of departure approaches.

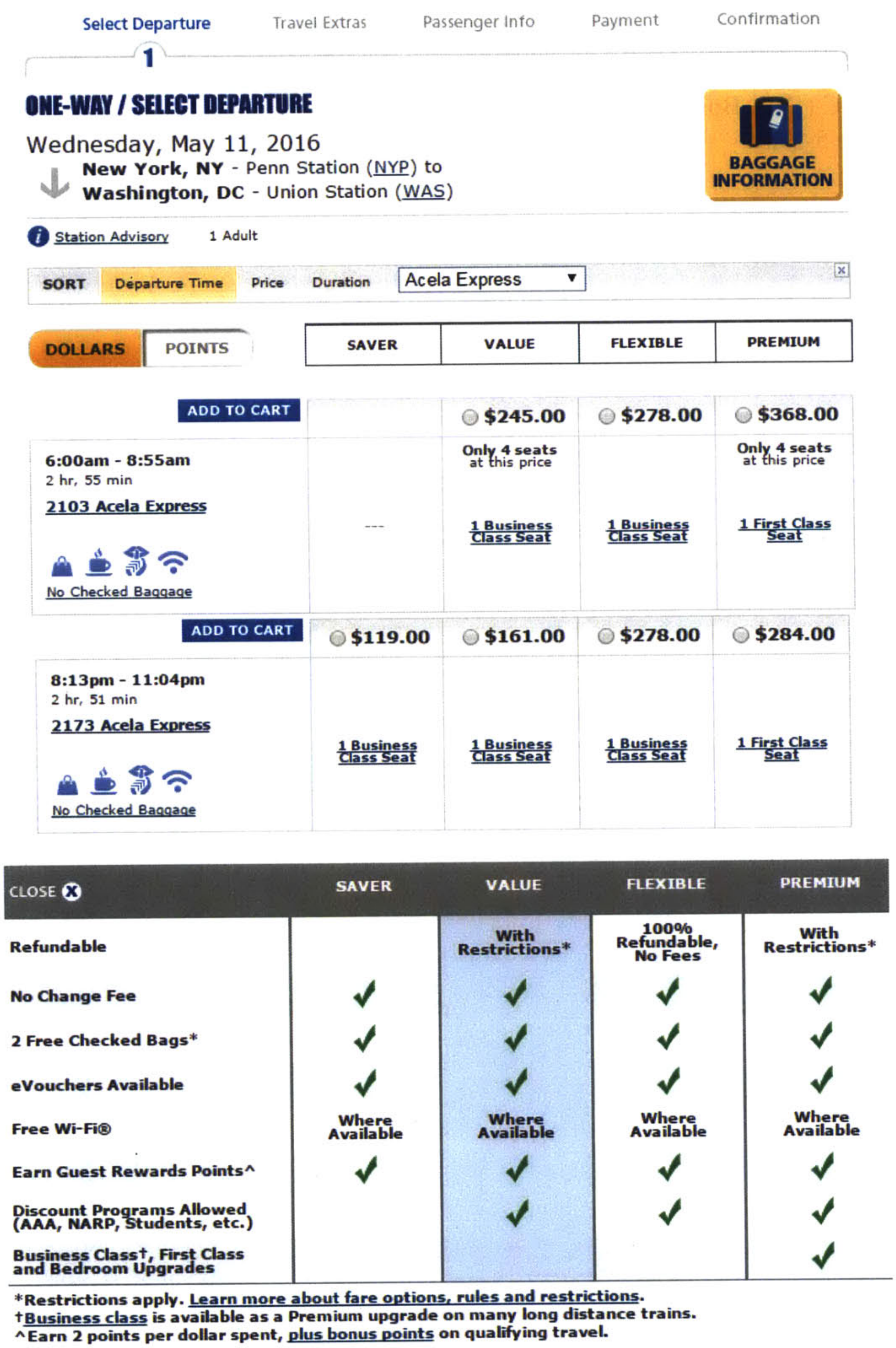


Source: SNCF (http://www.sncf.com/en/trains/tgv)

Figure 5-1: The booking website for TGV Paris-Lyon

- Amtrak: Acela/NER BOS-NY-DC

Figure 5-2 shows the ticket-booking website of Amtrak for Acela in New York – Washington DC. Amtrak offers three types of fare classes for the business class seats (comparable to the second class in TGV), "Saver", "Value", and "Flexible", respectively. The conditions applied to each fare class is also shown at the bottom of Figure 5-2. The price of "Saver" and "Value" change in accordance with the time of departure as well as the day of booking, while the price of "Flexible" is identical for any Acela trains whenever it is booked.



Source: Amtrak (https://www.amtrak.com/acela-express-train)

Figure 5-2: The booking website for Acela NY-DC

5.3.2 Data collection

In this survey, we collected fare data of HSRs in the three corridor, Paris-Lyon, New York (NY)-Washington DC (DC), Boston (BOS)-NY and flights in the same corridor from each operator's website (Table 5-2 and

Table 5-3).

In either NY-DC or BOS-NY, three legacy carriers, American Airlines (AA), Delta, and United, and a low-cost carrier JetBlue (JB) offer flights. The pricing strategies of the legacy carriers observed turned out to be similar to each other in terms of fare level as well as fare structure; thus only the fare data of AA was collected. As for airports, there are some airports in each metropolitan area. In this survey, Logan International Airport (BOS) is taken into account as a representative of O-D in Boston, LaGuardia Airport (LGA), John F. Kennedy International Airport (JFK) as representatives of O-D in NY, and Ronald Reagan Washington National Airport (DCA) and Washington Dulles International Airport (IAD) as representatives of O-D in DC.

The day of departure is targeted as January 21 2016, Thursday, which is chosen as a nominal weekday. We collected the fare data from 59 days prior to the departure, to one day prior to two days prior to departure. The fare data was collected every week.

Table 5-2: HSRs surveyed in the analysis

Corridor	Train type	Departure station	Arrival station	# of trains per day
NY-DC	Acela	NY Penn Station	DC Union Station	16
	NER	NY Penn Station	DC Union Station	22
BOS-NY	Acela	Boston South Station	NY Penn Station	10
	NER	Boston South Station	NY Penn Station	8
Paris-Lyon	TGV	Paris Gare de Lyon	Lyon Part Dieu	22
	Ouigo	Paris Marne-La-Vallée-Chessy	Aéroport Lyon St Exupéry or Lyon Part Dieu	4

Table 5-3: Flights surveyed in the analysis

Corridor	Airlines	Departure airport	Arrival airport	# of flights per day
NY-DC	AA	LGA or JFK	DCA	22
	JB	JFK	IAD	3
BOS-NY	AA	BOS	LGA or JFK	19
	JB	BOS	JFK	13
Paris-Lyon	AF	CDG or ORY	LYS	8

AA: American Airlines, JB: JetBlue, AF: AirFrance

As we have seen in Section 5.3.1, each firm always offers more than one fare for a train or flight. We use the lowest available fare for the train or flight throughout the analysis. The fare of regular-class seats in each train is analyzed as follows: for Acela, it is the fare of Business class seats, and for TGV, it is the fare of the second class seats.

5.4 Approach 1: time of departure

Figure 5-3, Figure 5-4, and Figure 5-5 show the lowest available fare as a function of various departure time for each Acela in NY-DC (Figure 5-3) and BOS-NY (Figure 5-4), and TGV in Paris-Lyon (Figure 5-5), respectively. In each diagram, the fare checked on the various days prior to departure (from 59 to two days in advance) is shown as different series. A broken line connects the average of the lowest available fares for each train throughout the survey period, which is intended to show the trend line regarding the difference in fares among various time of departure.

From the trend line (broken line in each diagram), we can see that relatively high fare is set for peak time such as morning and evening, while low fare is set for off-peak time such as very early morning, daytime, and night.

However, for a difference observed between Acela and TGV, Acela sometimes offers the same low fare even for peak-time trains as that of off-peak time trains. For example, looking at the fares on five days prior to departure (highlighted as red solid line) in Figure 5-3, we can see that the fares for the morning peak time (7-9am) are identical to the fares in off-peak time. Similarly, in Figure 5-4, the fares observed on two days prior to departure (highlighted as red solid line) are the same as the fares in off-peak time. On the other hand, as for TGV (Figure 5-5), the fares in peak time is usually higher than those in off-peak time in any day surveyed. The fares 59 days in advance and two days in advance are highlighted as blue and red line in Figure 5-5, respectively. We can see that the both red and blue lines in Figure 5-5 are consistent with the trend line (black broken line). Figure 5-6 compares the difference in the standard deviation of each train as a function of departure time. As Figure 5-6 demonstrates, while the standard deviation of the TGV fare does not vary significantly with respect to the trains with different departure time, the standard deviation of the Acela fare varies with respect to departure time, especially for the morning peak time and afternoon-evening.

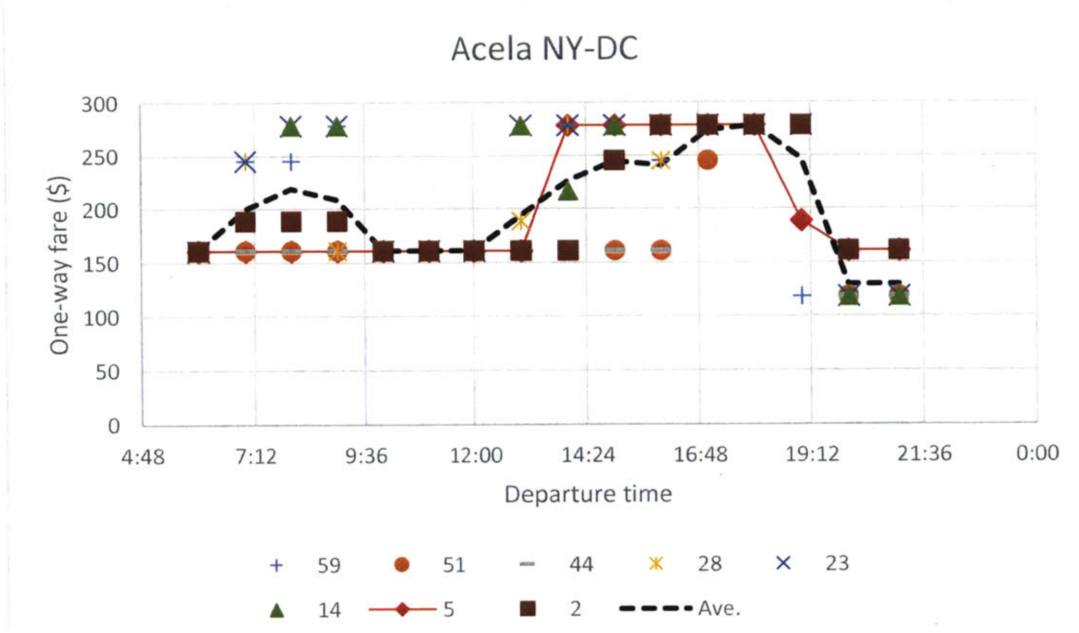


Figure 5-3: The lowest available fare for each Acela (NY-DC) as a function of time of departure

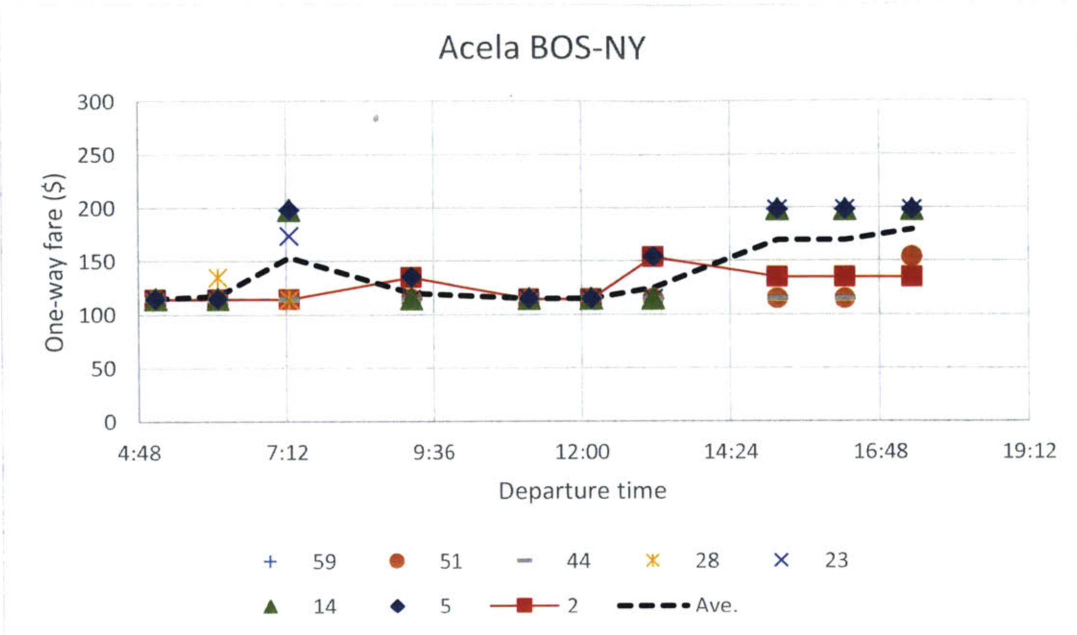


Figure 5-4: The lowest available fare for each Acela (BOS-NY) as a function of time of departure

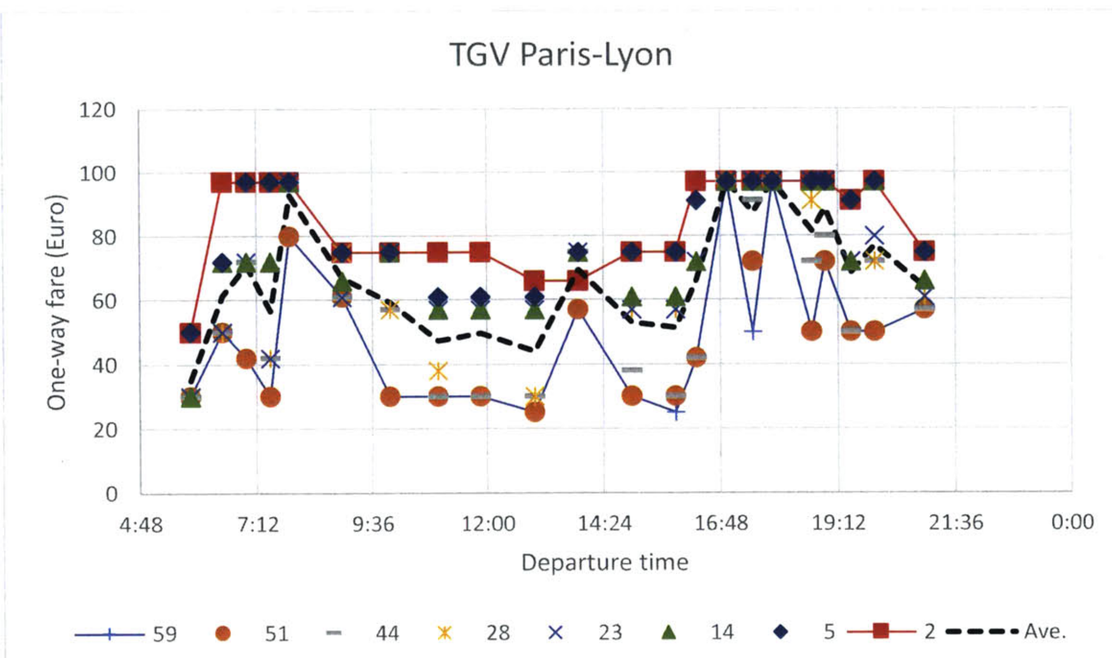


Figure 5-5: The lowest available fare for each TGV (Paris-Lyon) as a function of time of departure

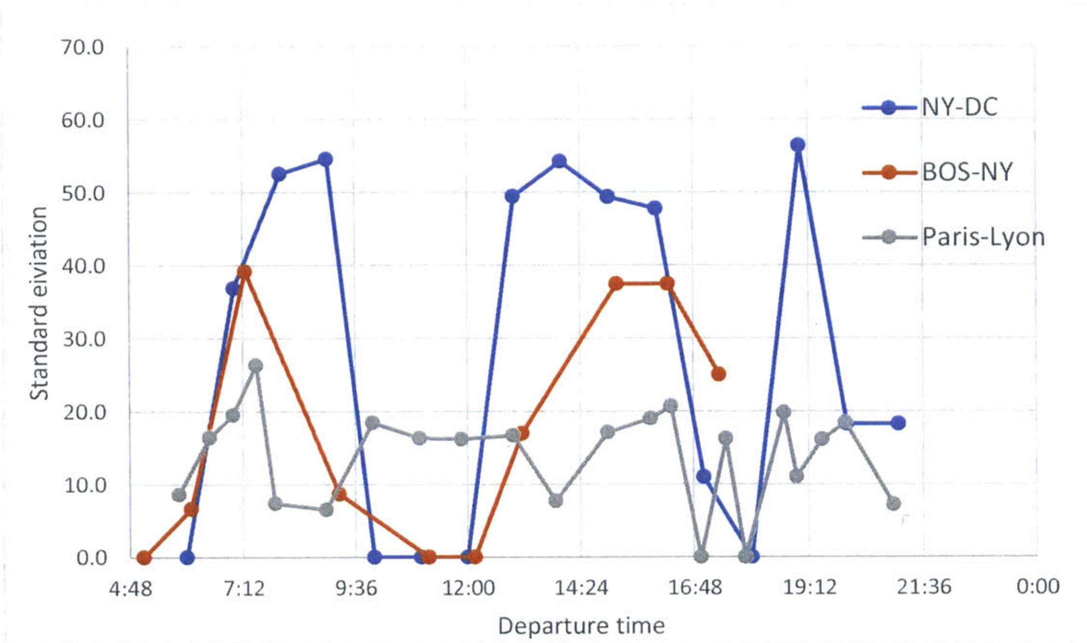


Figure 5-6: Standard deviation of the fare as a function of departure time

- **Comparison of the degree of fare variation**

The other interesting discussion regarding price difference is the degree of fare variation. Table 5-4 shows the maximum and minimum fare observed in this survey period in regular-class seats in each train. Again, we only observed the lowest available fare for a train on a day we checked the website; thus "Maximum" fare shown in the Table 5-4 means the maximum of the lowest available fares observed in the survey. We define the degree of fare variation as the maximum fare divided by the minimum fare. In order to compare the fare level, the unit fare is also shown in Table 5-4. We assume that 1 euro is 1.2 dollars.

Table 5-4: The fare variation (the difference between Max and min) in each train

	Maximum		Minimum		Max/min
	Fare	$/mile	Fare	$/mile	
Acela NY-DC	$278	$1.24	$119	$0.53	2.34
Acela BOS-NY	$198	$0.86	$115	$0.50	1.72
TGV Paris-Lyon	$122	$0.46	$30	$0.11	4.08

Major findings from Table 5-4 are as follows:

- First of all, if we compare the unit fare (fare/mile) of TGV and Acela, the maximum fare for TGV is less than Acela.
- The degree of fare variation observed is Acela BOS-NY (1.72) < Acela NY-DC (2.34) < TGV Paris-Lyon (4.08). As we have seen in Figure 5-6, even though the standard deviation of the fare in TGV is relatively modest compared to Acela, the degree of fare variation is larger than Acela's.
- Since the degree of fare variation for TGV is significantly larger than Acela, the relative difference in the minimum fares between TGV and Acela is more significant than that in the maximum fares. Indeed, the minimum fare of TGV is quite affordable compared to Acela.
- If we compare NY-DC and BOS-NY in Acela, while the minimum fare for Acela NY-DC is almost the same as that for BOS-NY, the maximum fare for NY-DC was higher than that for BOS-NY.

Although the actual data is not available, the difference in operating costs between Acela and TGV seems not so significant compared with the difference in fares observed in Table 5-4. Therefore, we analyze the causes of the findings above from the following three perspectives: price regulation, competition with other modes, and company policy.

- **Price regulation**

The price regulation imposed by the government seems to influence the difference in the maximum fares between TGV and Acela observed in this survey. In the U.S., Amtrak has a freedom in the pricing, and is not influenced by any price regulation by the government (OECD 2005). On the other hand, in France, the price for the second class seats in any kinds of trains including TGV is constrained by the state's price regulation[48] (Perennes 2014). Under the current regulatory scheme, the "basic fare" of TGV should be determined by each O-D pair and be approved by the French Secretary of Transportation. After the basic fare for each O-D is approved, SNCF has a 40% leeway to set the fare; i.e. the acceptable maximum fare is 1.4 times the basic fare. This difference in the regulatory scheme between the U.S. and France might influence the difference in the maximum fares observed in this survey. As we reviewed in

[48] The fare for the first class seats has not been affected by the regulation since 1980s.

Section 2.2 and 4.2, there is price regulation on the upper fare of the current Shinkansen in Japan, similar to France. Also, there will be the same price regulation on the upper fare of the Chuo Shinkansen Maglev.

- **Competition with other modes**

Table 5-5 shows the market share in terms of different transportation modes, rail, air, or road (bus or private car), respectively, for surveyed corridors as well as Tokyo-Osaka for comparison. While road dominates transportation in NY-DC and BOS-NY, rail captures the majority in Paris-Lyon as well as Tokyo-Osaka. If we focus on the competition between rail and air, the rail share is larger in Paris-Lyon and NY-DC, than BOS-NY and Tokyo-Osaka.

The difference in the dominance in market share regarding rail-air market between NY-DC and BOS-NY might lead to the difference in the maximum fare between Acela NY-DC and BOS-NY (Table 5-4). Since Amtrak has dominant market share in NY-DC (regarding rail/air market), it may able to set higher maximum fare than for BOS-NY. Also, the fact that road is the most popular transportation mode in NY-DC (Table 5-5) allows Amtrak to increase the maximum fare of Acela NY-DC relatively easily, because the government and general public (the source of subsidy for Amtrak) becomes less sensitive to social equity or price gouging. Although TGV has dominant share (92%) in Paris-Lyon with respect to rail/air market, SNCF is not allowed to set higher fare beyond the upper fare constrained by price regulation.

Table 5-5: Intermodal market share of each mode

	INTERMODAL SHARE			**RAIL VS. AIR**	
	Rail	Air	Road (bus + auto)	Rail	Air
NY-DC (2015)	27%	6%	67%	82%	18%
BOS-NY (2015)	15%	8%	77%	65%	35%
PARIS-LYON (1997)	73%	6%	21%	92%	8%
TOKYO-OSAKA (2005)	69%	26%	5%	73%	27%

Source: (Central Japan Railway Company 2015b; Northeast Corridor Commission 2015; des Rus 2009)

As for the competition with other modes, it is also noteworthy that beginning in August 2015, the intercity bus service is deregulated for the first time in France. In the case in Germany, the deregulation of intercity bus service caused the reduction in intercity rail ridership and encouraged price war between bus and rail. Based on the data, roughly one third of long-distance passenger bus customers have switched from intercity rail(Barrow 2014). Partly because of the fear from the bus industry, SNCF offers the low fare for TGV service as well as the launch of Ouigo service in Paris-Lyon (SNCF MOBILITÉS 2015). This would be a part of the motivation for the low minimum fare of TGV (Table 5-4)

- **Company policy**

Another reason for TGV's quite affordable fare would be that SNCF as a public entity might care about social benefit more than profit. SNCF should have the motivation to increase profit by setting high fare for TGV Paris-Lyon, because it has to internally subsidize a lot of non-profitable routes such as regional rail and intercity (not high-speed) rail from the profit of the profitable Paris-Lyon route. However, partly because SNCF is subsidized by the French government, the priority of being profitable in its finance might be less than the maximization of ridership and social benefit.

5.5 Approach 2: day of booking

Figure 5-7, Figure 5-8, and Figure 5-9 show the transition of the lowest available fares as a function of day of booking. The black broken line connects the average of the fares of all trains (from morning to midnight) on the day of the survey, which is intended to represent the trend line of how the fare changes as it approaches the departure day.

In theory, as mentioned in Section 5.2, a firm implementing dynamic pricing intends to increase the fare as the day approaches the departure. As for TGV Paris-Lyon (Figure 5-9), the trend line (black broken line) monotonically increases as it approaches the day of departure. If we look at the fare of each train, it seldom decreases as it approaches the day of departure; for example, the fare for either the train with 5:50am departure (red solid line), 7:53am departure (blue solid line), or 19:58pm departure (red solid line) monotonically increases as the departure day approaches.

On the other hand, this is not necessarily the case for Acela, as we can see the trend line (broken line) in Figure 5-7 and Figure 5-8. For example, Figure 5-7 shows the fare for the train with 9:00am departure (red solid line) went up and down such as $278 on 59 days prior to departure, $161 on 51-28 days prior to departure, $278 on 23-14 days prior to departure, $161 on 5 days prior to departure, and finally $189 on 2 days prior to departure. Similarly, in Figure 5-8, the fare of the train with 7:15am departure also went up and down.

The mechanism of this fare change in Amtrak is as follows: Amtrak closes the seats assigned for an affordable fare when the number of booking for the seats reaches the limit, which is calculated based on the demand forecast. However, when Amtrak recalculates the demand and considers the number of the low fare seats booked becomes below the limit, Amtrak reopens the fare class. This case would occur when new bookings were fewer than expected, or the seats once booked were canceled. As a result, the lowest available fare goes up and down as the day of departure approaches.

This difference in the pricing behavior between Acela and TGV described above is interesting. The possibility in the future fare reduction ("last minute deals") might give Amtrak the flexibility; thus it might make it easier to increase its load factor. In this sense, this is economically reasonable for a supplier. However, it might lead to the feeling of unfairness for customers.

From the customers' point of view, we propose two perspectives to consider the price variation with respect to day of booking: transparency in fare setting and price change in a short time period.

- **Transparency in fare setting**

According to Kannan and Kopalle, the transparency in fare setting is an important factor for high customer satisfaction when a firm implements dynamic pricing (Kannan and Kopalle 2001). When customers face unstable fare, which goes up and down on a day-to-day basis, they feel uncertainty in price. Intuitively, customers who already booked a seat in advance feel uncomfortable to see the future fare decrease. In this sense, the pricing policy of SNCF is more conservative for customer's perspective, and more acceptable than Amtrak.

Interestingly, although SNCF may seldom take the option to reduce fare as the day of departure approaches, the load factor of TGV Paris-Lyon is higher than that of Acela. Table 5-6 shows the load factor of Amtrak Acela and NER in NEC (NY-DC and BOS-NY combined) and

SNCF TGV and Ouigo in Paris-Lyon. The primary reason that the load factor of TGV Paris-Lyon is higher than Amtrak NEC might be the difference in pricing system. Amtrak's pricing system adopts fare bucket system and it allows the fare of the Acela train to take only limited number of options. In our survey, the lowest available fare of Acela NY-DC only took the value of $119, $161, $189, $245, and $278. Unlike Amtrak, SNCF does not adopt limited-number price bucket system. In order to have a larger number of fare class, SNCF might have a more sophisticated demand forecasting system than Amtrak. Also, since the number of stops of a TGV train in Paris Lyon (2-4) is smaller than that of Acela (6-8), the number of O-Ds in TGV Paris-Lyon is smaller than Acela; thus the calculation in the revenue management system for TGV can be simpler than Acela. Because of these difference, the degree of the day-to-day change in the fare is more modest. We now discuss this point in the following paragraph.

Table 5-6: Load factor of Amtrak NEC, SNCF Paris-Lyon

	Amtrak NEC (BOS-NY-DC)		**SNCF Paris-Lyon**	
	Acela	NER	TGV 2014	Ouigo 2014
Load factor	64%	52%	75%	85%

Source: (Archila 2013; Hagiwara 2014)

- **Price change in a short time period**

From customers' view point, the larger price change in a short time period leads to larger negative consumer satisfaction (Haws and Bearden 2006). Figure 5-7, Figure 5-8, and Figure 5-9 suggest that the fare change in Amtrak NEC is more drastic than TGV. For example, the fare of Acela NY-DC often changed from $278 to $161 (i.e. 42% decrease) and $161 to $278 (i.e. 73% increase). Even though the fare was checked once in a week in our survey, the large fare change in Amtrak may probably have happened over night. On the other hand, the price change in TGV Paris-Lyon is relatively modest, especially when the fare gets high. For example, the fare of the train with 19:58pm departure (red line in Figure 5-9) changed gradually from €50, €72, €80, to €97.

The difference in the fare change between TGV and Acela would be partly because the difference in the pricing system as explained in the previous part. The pricing system in SNCF might allow finer change than Amtrak, which applies a limited number of fare buckets. Another reason might be the company policy and the competitive situation in the corridors. Since TGV Paris-Lyon has a dominant share in Paris-Lyon intercity travel market (Table 5-5), the drastic change in the price may have significant impact on the customers' perception, even though the demand for TGV actually fluctuates. This would be a helpful insight for the JR Central's pricing in Tokyo-Nagoya-Osaka corridor, because the projected market situation is similar to Paris-Lyon.

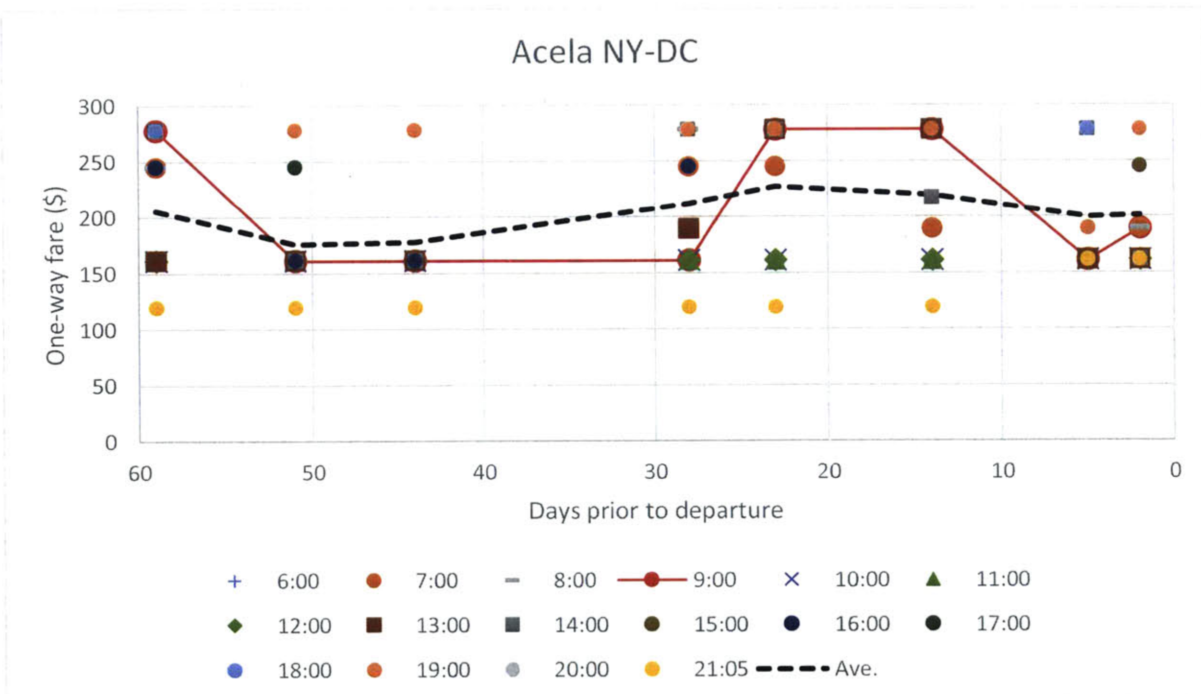


Figure 5-7: The fare of Acela (NY-DC) as a function of day of booking

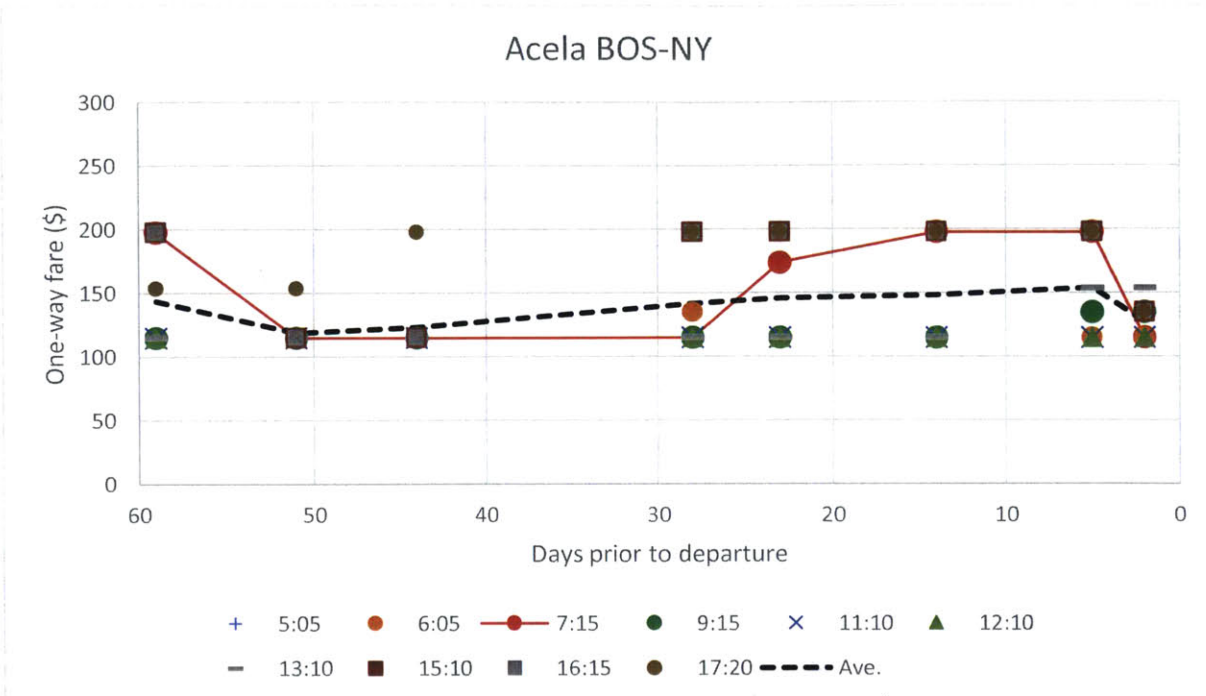


Figure 5-8: The fare of Acela (BOS-NY) as a function of day of booking

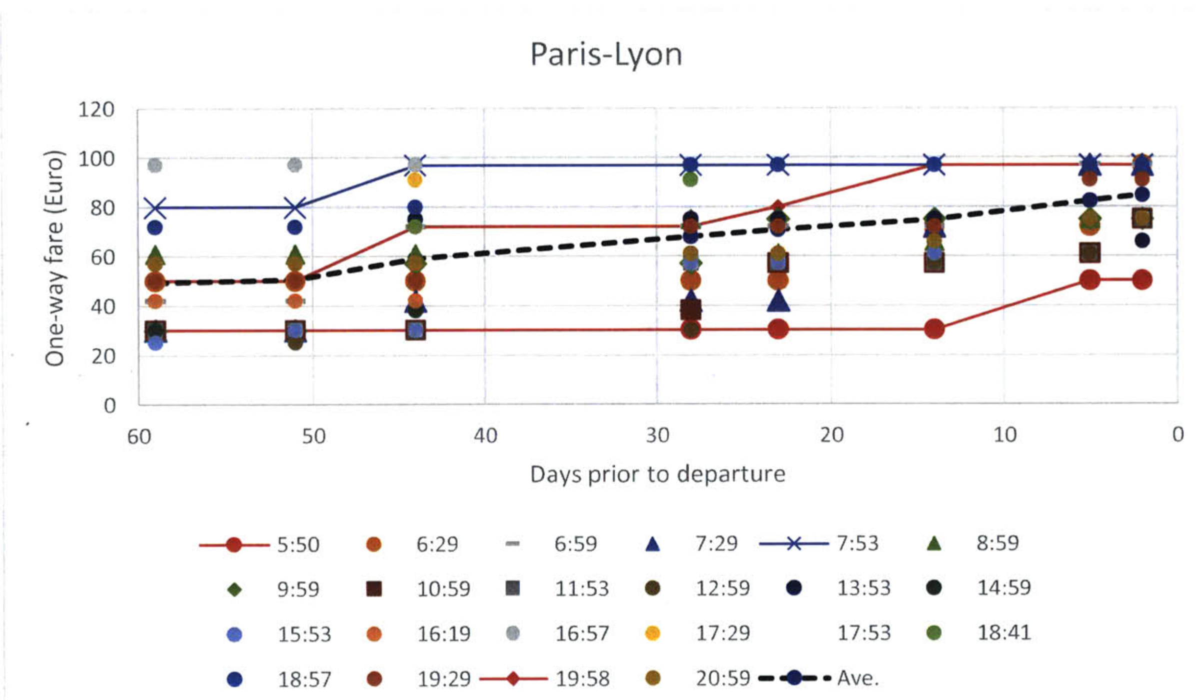


Figure 5-9: The fare of TGV (Paris-Lyon) as a function of day of booking

5.6 Comparison with airfare

This section supplements the observation of the pricing behavior of SNCF and Amtrak, by comparing them with airlines.

According to our observation, airlines both in NY-DC and in BOS-NY rarely differentiates price regarding difference in departure time; thus whether the flight is in peak time or off-peak time has basically nothing to do with the fare difference. On the other hand, airlines tend to differentiate the price depending on departure/arrival airports, especially for the airports in New York. American Airlines (AA) offers flights from/to LGA and JFK in New York, while JetBlue (JB) offers flights only from/to JFK. AA, as well as other major legacy carriers, offer the business shuttle service from/to LGA both in NY-DC and in BOS-NY (https://www.aa.com/i18n/urls/shuttle.jsp). The fare for the business shuttle is fixed and set as higher than the standard service. Also, the fare for the business shuttle does not change in accordance with time of departure as well as day of booking, until it approaches less than 14 days in advance. For example, the one-way fare for all flights from LGA to DCA is fixed as $256 when 14 days in advance, and becomes $511 after that. Similarly, the fare of all flights from BOS to LGA is $248 with 14 days in advance, and $439 after that. The fare of the flights from/to JFK changes over time as the day approaches to departure, and also it varies slightly in accordance with time of departure. As for Paris-Lyon, the price difference regarding airports was not seen in the survey. The difference regarding time of departure exists, and the fares for the flights at 9:30 AM and 13:30 AM (both from Paris) are higher than others.

In Figure 5-10, Figure 5-11, and Figure 5-12, the transition of the average of the lowest available fares for all trains/flights with different departure time in January 21 2016 is shown. Each line in Figure 5-10 represents the transition of the average fare of Acela, Northeast Regional (NER), American Airlines (AA), and JetBlue (JB) in NY-DC. Figure 5-11 shows the same comparison in BOS-DC. Figure 5-12 shows the comparison among TGV, Ouigo, and Air France (AF) in Paris-Lyon.

If we compare Figure 5-10 with Figure 5-11, we can see that the fare of Acela in NY-DC (about $200) is higher than that in BOS-NY (about $150), while the fares of AA, JB, and even Amtrak's NER are almost identical between the two regions. This result complements our analysis in the previous section; Acela in NY-DC utilizes the market power with respect to airlines.

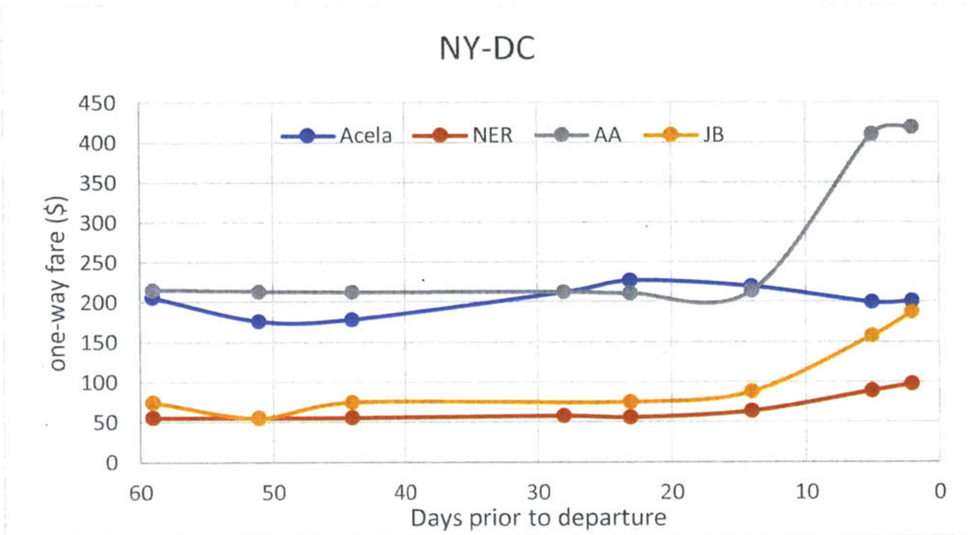
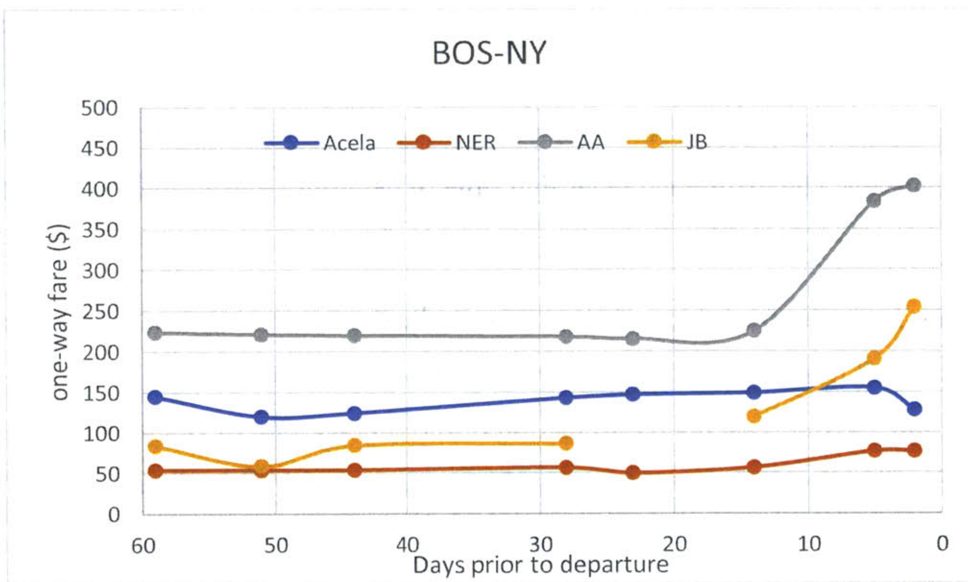


Figure 5-10: The average of the lowest available fares for each train/flight on each booking day (NY-DC)



The data of the ticket price for JB flights, which was checked on 23 days prior to departure, was not available because no seat was available for any flights.

Figure 5-11: The average of the lowest available fares for each train/flight on each booking day (BOS-NY)

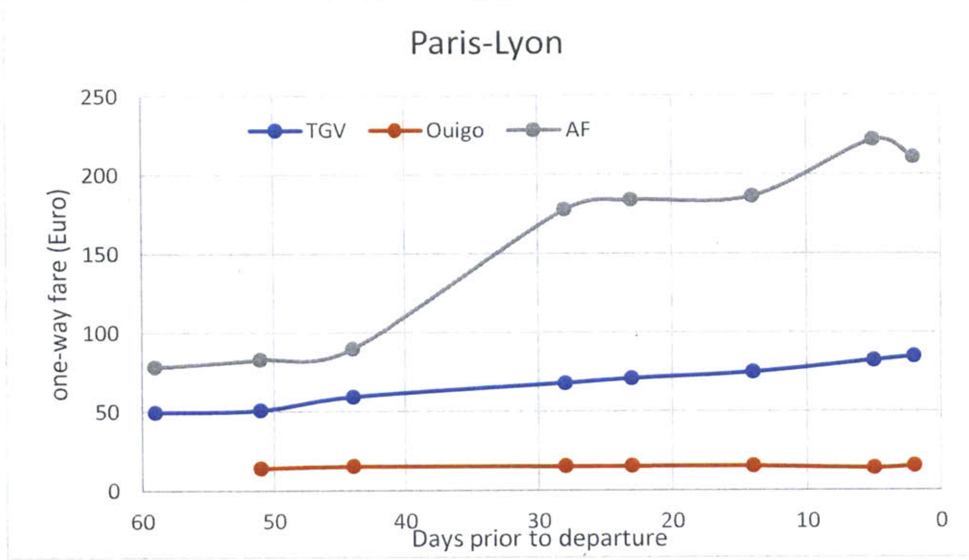


Figure 5-12: The average of the lowest available fares for each train/flight on each booking day (Paris-Lyon)

5.7 Implications for the Chuo Shinkansen Maglev

5.7.1 Projection on the specification of the Chuo Shinkansen Maglev

We have seen the pricing behavior of TGV Paris-Lyon and Acela BOS-NY-DC in the previous section. In this section, we now review what specification will be applied to the Chuo Shinkansen Maglev, and discuss how the specification will affect the applicability of dynamic pricing, based on the comparison with the specification of TGV, Acela, and the Tokaido Shinkansen Nozomi as a reference. Table 5-7 summarizes the comparison of the specification of the Chuo Shinkansen with the Tokaido Shinkansen Nozomi, TGV, and Acela.

Table 5-7: Comparison of the specification regarding the applicability of the dynamic pricing

HSR (Segment)	Tokaido Nozomi (Tokyo-Osaka)	TGV (Paris-Lyon)	Acela (NY-DC)	Chuo Maglev (Tokyo-Osaka)
Flexibility in frequency design	Large	Little	None	Little
Standees	Many	None	None	None
# of stops	6	2-4	7-8	3*

* Based on the author's assumption

Small Flexibility in frequency design

As we have seen in Section 1.2.5, the schedule planning of the Chuo Shinkansen Maglev is inflexible compared to the Tokaido Shinkansen, since an initial plan of the spatial allocation for Power Conversion Systems (PCSs) along the entire track between Tokyo and Osaka will fix the maximum number of trains operated simultaneously in the Chuo Shinkansen. Therefore, the price variation will be more important for the Chuo Shinkansen Maglev than the Tokaido Shinkansen, which basically fixes the fare and changes the frequency quite flexibly.

As for TGV in Paris-Lyon, SNCF slightly modifies the daily frequency based on the demand. 85% of train sets is used for regular service and 15% is used for adding capacity for high-demand season (Abe 2009). For example, SNCF offers 22 TGV trains on a typical weekday per each direction, while it offers 24 TGV trains on Friday March 25, the day before the Easter holiday. Amtrak doesn't change the frequency in the Northeast Corridor.

No standee allowed on a train

According to JR Central, there will not be any standee on a Maglev train in the Chuo Shinkansen Maglev for safety reasons; thus every passenger on a Maglev train will be required to book a seat prior to departure (Akasaka 2013). As we have seen in Section 2.5.1, the existence of the standees as well as the walk-in passengers who do not reserve a seat in advance make dynamic pricing difficult for a rail company. Comparing with the Tokaido Shinkansen Nozomi, in which the non-reserved seats occupy 19% of the total seats (Table 4-2), the new specification of the Chuo Shinkansen Maglev may be more suitable for dynamic pricing. TGV as well as Acela require ticket reservation prior to departure[49].

The small number of stops (simpler network)

The number of stops in the Chuo Shinkansen Maglev will be smaller than the Tokaido Shinkansen. The plan of the type of trains in the Chuo Shinkansen Maglev has not been decided yet, so the number of stops for the fastest type in the Chuo Shinkansen Maglev is unclear.

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[49] In precise, Acela does not offer specific seat reservation and all seats are served based on the first-come and first-service. However, the total bookings of the seats in a train is controlled by Amtrak reservation system, and the users basically have to book a train in advance.

However, since the total number of stations in the Chuo Shinkansen Maglev (6 in Tokyo-Nagoya and 9 in Tokyo-Osaka) is much smaller than the Tokaido Shinkansen (13 in Tokyo-Nagoya and 17 in Tokyo-Osaka), the number of O-Ds in the Chuo Shinkansen Maglev is expected to be smaller than the Tokaido Shinkansen.

As we have seen in the previous section, the smaller number of stops in TGV Paris-Lyon than Acela may be considered as one of the reasons that enable the finer price discrimination in TGV Paris-Lyon.

5.7.2 Market projection of Tokyo-Osaka corridor

- **Current competitive situation with airlines**

Table 5-8 shows the daily frequency of airlines, which offer flights between Tokyo and Osaka. As of April 25, 2016, five airlines offer 59 flights per day, in which 48 flights are from Tokyo International Airport (HND) and 11 flights are from Narita International Airport (NRT). As Table 5-9 shows, the access for NRT from Tokyo Station (assumed as the city center of Tokyo metropolitan area) is worse than HND, in terms of both travel time and cost. As for airports in Osaka metropolitan area, Osaka International Airport (ITM) is better than Kansai International Airport (KIX), but the difference in the distance and the travel cost between ITM and KIX is smaller than that between HND and NRT. Because of the low accessibility of NRT due to the distance to Tokyo, the majority of the flights currently depart/arrive at HND instead of NRT.

However, HND is operated at full capacity and has no room to accommodate a large number of additional flights; thus there is no LCC currently operating from/to HND (Ministry of Land, Infrastructure, Transport and Tourism 2012b). The allocation of HND's capacity is implemented by MLIT. Since the revision of Civil Aeronautics Acts in 2000, the number of arrival/departure slots for non-major carriers (e.g. Star Flyer, SKYMARK, Peach Aviation, and Jetstar) has been increasing. Also, the total capacity of HND has increased gradually from 316 flights per days in 1997 to 440 flights per day in 2011, mainly by the runway expansion, operational change, and regulatory changes. However, currently there is no practical plan to extend the capacity from the current level, so it is difficult to expect a large increase in the capacity of HND.

Table 5-8: Daily frequency of Tokyo (HND/NRT) – Osaka (ITM/KIX) flights, as of Apr.25.2016

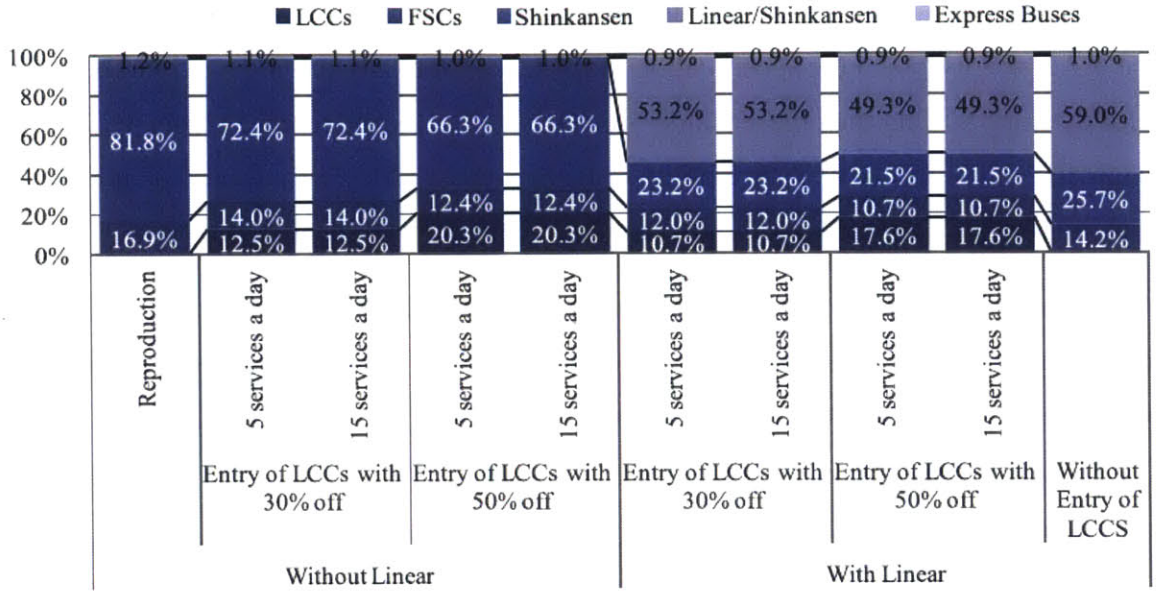
	From / To	HND -ITM	HND -KIX	NRT -ITM	NRT -KIX
JAL	Network carrier	15	3	2	-
ANA	Network carrier	15	10	2	-
Star Flyer	regional carrier	-	5	-	-
Jetstar	LCC	-	-	-	4
Peach Aviation	LCC	-	-	-	3

HND: Tokyo International Airport (Haneda)
ITM: Osaka International Airport (Itami)
NRT: Narita International Airport (Narita)
KIX: Kansai International Airport

Table 5-9: Access for the airports in Tokyo and Osaka as of Apr.25.2016

airport	City center	Distance	Travel time	Travel cost	note
HND	Tokyo station	20 km	30 min	¥637	via Tokyo monorail
NRT	Tokyo station	80 km	1 hour	¥3,017	via JR East Narita Express
ITM	Osaka station	15 km	40 min	¥420	via Hankyu rail
KIX	Osaka station	50 km	1 hour	¥1,100	via Nankai rail

Inoue et al. estimate the changes in transport demand and mode choice between Tokyo and Osaka after the commencement of the Chuo Shinkansen Tokyo-Nagoya in 2027, considering the competition among traditional air carriers, Low Cost Carriers (LCCs), buses, the Tokaido Shinkansen and the Chuo Shinkansen Maglev (Inoue et al. 2015). Their research uses stated preference data in order to include the Chuo Shinkansen Maglev for demand modeling. Figure 5-13 shows the result. It shows that even though the Chuo Shinkansen Maglev service (Tokyo-Nagoya) will be available in 2027, if LCCs begin to use HND with affordable fares (30% or 50% discount in the simulation), the share of air mode might increase from the current 16.9% to 22.7-28.3%.



The series "Shinkansen", "Linear/Shinkansen" in the diagram represents the Tokaido Shinkansen, and the Chuo Shinkansen Maglev, respectively.

Source: (Inoue et al. 2015)

Figure 5-13: Simulation result of mode choice between Tokyo and Osaka (business customers)

As for the future projection of the competitive situation with airlines in Tokyo-Osaka corridor, we summarize as follows:

- The average airfare may decrease by the new slot allocation for LCCs in HND, and/or by the aggressive fare reduction in the existing major carriers.
- However, the total capacity for HND is a limited, and HND's slots for Tokyo-Osaka flights might not increase significantly from now.
- Also, the number of passengers in the international flights is projected to increase more largely than that in the domestic flights (Inoue et al. 2015). Hence, the slot allocation for the international flights might be prioritized.
- Therefore, after the commencement of the Chuo Shinkansen Maglev, the combined market share of the Chuo Shinkansen Maglev and the Tokaido Shinkansen may probably be more dominant than present.

5.7.3 Implication for the dynamic pricing application in the Chuo Shinkansen Maglev

In Section 5.7.1, we discussed the specification of the Chuo Shinkansen Maglev would be more suitable for dynamic pricing than the Tokaido Shinkansen. The discussion in Section 5.7.2 suggests that the combined market share of the Chuo Shinkansen Maglev and the Tokaido Shinkansen in Tokyo-Osaka after 2027 may be more dominant than the present.

From the results, this thesis proposes that softening the negative impression of the introduction of dynamic pricing (i.e. the feeling of price gouging) would be a pivotal factor in order to achieve the successful implementation of dynamic pricing and increase the profitability of the Chuo Shinkansen Maglev.

Our analysis in Section 5.4 and 5.5 suggests that in order to soften the negative impression of the introduction of dynamic pricing, the transparency in fare setting and the moderate fare change in a short time period may be the most important factor.

As for the transparency in fare setting, it may be desirable that the reason for setting higher fare becomes understandable for customers. According to economic theory, in terms of the time of departure, the peak time trains deserve higher fare than the off-peak trains, since the capacity for the peak time trains is limited. Also, in terms of day of booking, it may be rational to set the relatively higher fare for walk-in tickets since keeping empty seats without reservation requires larger cost (risk for spoilage) for a supplier. If we compare the pricing behavior of TGV Paris-Lyon and Acela BOS-NY/NY-DC, TGV is more consistent with this economic rationale as we have seen in Section 5.4. In order to achieve this, the revenue management system which enables more accurate demand estimation and finer price discrimination (larger number of fare classes) would be required. In addition, the company policy should support the consistency of the pricing strategy with the transparent fare setting for customers, instead of trying to squeeze as much as money from customers' pocket.

The finer price discrimination with the revenue management system would also be beneficial in order to achieve the moderate fare change in a short time period, as the pricing system of TGV realizes it. According to the author's interview with JDA software group, the initial cost for the software development for the revenue management system would require $3-6 million, and the service implementation would require $3-9 million; thus the total cost for initial investment for the system would be $6-15 million. Although the actual cost would depend on the detailed specification of the system, the scale of the cost may be low compared to the annual operating cost as well as the annual revenue.

As for the degree of the price variation, while TGV occasionally offers affordable fares, which is sometimes less than one fourth of the maximum fare for the train (Table 5-4), this may not be possible in the Chuo Shinkansen Maglev. In Chapter 4, the appropriate fare level of the Chuo Shinkansen Maglev in Tokyo-Osaka was discussed. It would be ¥800 higher than the Tokaido Shinkansen, if we consider the willingness to pay (WTP) for the travel time saving between Tokyo and Osaka with the disutility of transfer at Nagoya Station. The upper-limit fare (in incremental value with respect to the Tokaido Shinkansen) would be larger than ¥800 ($6.67). Hence, it may be possible to set the maximum fare of the Chuo Shinkansen Maglev (in incremental value with respect to the Tokaido Shinkansen) as more than ¥800 ($6.67), in order to make the average fare of the Chuo Shinkansen Maglev become ¥800 ($6.67) higher than the Tokaido Shinkansen. Since the majority of the users of the Chuo Shinkansen Maglev will be business travelers, whose WTP for travel time saving are higher than other users, the maximum fare of the Chuo Shinkansen Maglev might be just slightly higher than +¥800 ($6.67)of the Tokaido Shinkansen.

Finally, we will return to the purpose of maximizing profitability. Since the Chuo Shinkansen Maglev project has to be financed by JR Central's retained earnings as well as a limited amount of long-term debt of JR Central, the construction period will be long and 18-year long interval is expected between Tokyo-Nagoya commencement in 2027 and Tokyo-Nagoya commencement in 2045 (Chapter 1). The increase in profitability by the introduction of dynamic pricing could contribute to shrinking the project period, which will lead to the users' benefit. Especially, shrinking 18-year long interval would be beneficial for future users. The author emphasizes that JR Central needs to prioritize the completion of the project rather than the maximization of the return for investors. Dynamic pricing has been developed in the U.S. airline industry, in which private airlines aimed to maximize the profit (i.e. the return for investors) under the fierce competition as we have seen in Section 2.4. As the projected market situation in the Chuo Shinkansen Maglev will be close to monopoly, the priority in dynamic pricing strategy should also be different from that in the U.S. airline. Therefore, this thesis recommends that dynamic pricing in the Chuo Shinkansen Maglev should be cautious about giving negative impression for customers.

5.8 Conclusion

In this chapter, we have examined the pricing strategy of SNCF in France on TGV Paris-Lyon and Amtrak in the U.S. on Acela in the Northeast Corridor (NEC) from the customers' perspective. From the pricing behaviors observed by the actual fare data captured via each company's website, we discussed the implications regarding the application of dynamic pricing for the Chuo Shinkansen Maglev. In order to analyze the pricing behavior of each firm, two approaches are proposed in the thesis: dynamic pricing based on time of departure, and day of booking.

As for the observation regarding time of departure, while both TGV and Acela set relatively high fare for peak time as a trend, some differences are observed. Acela sometimes offers the same low fare even for peak-time trains as that of off-peak time trains. On the other hand, TGV consistently offers higher fare fares for trains in peak time than those in off-peak time.

If we compare the unit fare of TGV and Acela, the maximum fare for TGV is less than Acela. The difference in the price regulation imposed by each government seems to influence this difference. While Amtrak is not influenced by any price regulation by the US government, the upper fare of TGV is constrained by the French state's price regulation, similarly to railways in Japan.

If we compare NY-DC and BOS-NY in Acela, while the minimum fare for Acela NY-DC is almost the same as that for BOS-NY, the maximum fare for NY-DC was higher than that for BOS-NY. The difference in the dominance in market share regarding rail-air market between NY-DC and BOS-NY might lead to the difference. Since Acela in NY-DC has dominant market share with respect to airlines, it may be capable to set higher maximum fare than BOS-NY. Also, the road transportation is the most popular transportation mode in NY-DC if we include it in the intermodal competition, which further encourage Amtrak to set higher maximum fare of Acela NY-DC. This is because the social equity may less likely be the argument in this case.

As for the degree of fare variation, the fare of TGV varies in a wider range than Acela; thus the minimum fare of TGV is quite affordable compared to Acela. One reason of this may be the intermodal competition with the intercity bus services, which is deregulated for the first time in France. Another reason would be that SNCF might care about social benefit more than profit as a public entity.

From the observation regarding time of departure, some differences are also observed between TGV and Acela. In theory, a firm implementing dynamic pricing intends to increase the fare as the day approaches the departure, and TGV seems consistently to follow the theory. On the other hand, the fare of Acela goes up and down as it approaches the departure. From the customers' point of view, TGV's pricing strategy is more acceptable than Acela from two perspectives: transparency in fare setting and price change in a short time period.

Interestingly, even though the fare of TGV monotonically increases as it approaches the departure instead of decreasing sometimes in order to fill the seats like Acela, the load factor of TGV Paris-Lyon is high. The primary reason for this may be the pricing system of SNCF, which enables finer price discrimination. This may be also the reason that the degree of the day-to-day change in the fare of TGV is modest.

If we consider the specification of the Chuo Shinkansen Maglev in the context of the applicability of the dynamic pricing, the Chuo Shinkansen Maglev might share some common features with TGV, more than Acela as well as the Tokaido Shinkansen. As for the flexibility in frequency design, the flexibility in the Chuo Shinkansen Maglev might be smaller than the Tokaido Shinkansen, because of the technological constrains imposed by the power conversion systems. TGV has a small leeway to change the number of trains, while Acela has nothing. As for the existence of standee on a train, the Chuo Shinkansen Maglev would require a seat reservation in advance of the journey, unlike the Tokaido Shinkansen. Also, the number of stops of the Chuo Shinkansen Maglev train might be smaller than the Tokaido Shinkansen, which is also similar specification with TGV, rather than Acela.

If we consider the projection of the airline market in Tokyo-Osaka corridor in the future, since the total capacity of Tokyo International Airport (HND) is limited, the runway slots of HND for domestic flights could not significantly increase in the future. Therefore, after the commencement of the Chuo Shinkansen Maglev, the combined market share of the Chuo Shinkansen Maglev and the Tokaido Shinkansen may probably be more dominant than present.

Based on the analysis above, the pricing strategy observed in TGV, which can soften the negative impression of the dynamic pricing such as the feeling of the price gouging, would be a suitable strategy in order to achieve the successful implementation of the dynamic pricing and increase the profitability of the Chuo Shinkansen Maglev.

Specifically, the fare differentiation transparent for customers, in terms of both the time of departure and the day of booking, would be recommended. Since the capacity of the Chuo Shinkansen Maglev in peak time period will be limited, the peak time trains may deserve higher fare than the off-peak trains. Also, it may be rational to set the relatively higher fare for walk-in tickets since keeping empty seats without reservation requires larger cost. In addition, the moderate fare change in a short time period is also recommended. In order to achieve the transparency in fare setting and the moderate fare change in a short time, the revenue management system which enables finer price discrimination would be required. The company policy, in other words, the day-to-day operation of the operators in the pricing/revenue management department, should pursue the consistency of the pricing strategy. Since dynamic pricing system has been originally developed in the U.S. airline industry, in which airlines aimed to maximize the return for investors, the Chuo Shinkansen Maglev should be cautious about giving negative impression from customers for the introduction of dynamic pricing.

Chapter 6 Conclusions

6.1 Conclusions

The Chuo Shinkansen Maglev project is the world's first application of the Superconducting Maglev for HSR, which will provide a dramatic travel time saving for the artery of Japan, Tokyo-Nagoya-Osaka corridor. The thesis examines a viable pricing strategy of the Chuo Shinkansen Maglev, in terms of the determination of the appropriate price level (Chapter 4) as well as the application of dynamic pricing (Chapter 5). In order to discuss these perspectives, we have to take into account the unique specification of the Chuo Shinkansen Maglev, which is described in Chapter 1. The uniqueness affecting the pricing strategy is summarized as follows:

- The second HSR in the Tokyo-Nagoya-Osaka corridor, which will be operated by the same operator of the existing HSR in the same corridor.
- The capacity constraints imposed by the power conversion system (PCS); thus it might lead to a need to change JR Central's business strategy, in which the frequency of the Tokaido Shinkansen is adjusted for a demand fluctuation, instead of changing the fare as typical HSRs in the world currently do.
- The private project without any subsidy from the government; thus the two-stage project scheme with 18-year long interval will be required.

Based on the uniqueness above, as a process of the examination of a viable pricing strategy for the Chuo Shinkansen Maglev, the thesis set a goal to accomplish four objectives below. The rest of this section explains the accomplished work toward these objectives.

Objective 1: Propose a framework of the fare level determination for an introduction of the second HSR in a corridor (Chapter 4)

Since there has been no situation in the world such that multiple HSRs are operated **in a same corridor** and **by a single operator**, there is no literature which can deal with the fare level determination for the Chuo Shinkansen Maglev. Therefore, the thesis proposed a 3-step framework as shown in Figure 4-1 (Section 4.1).

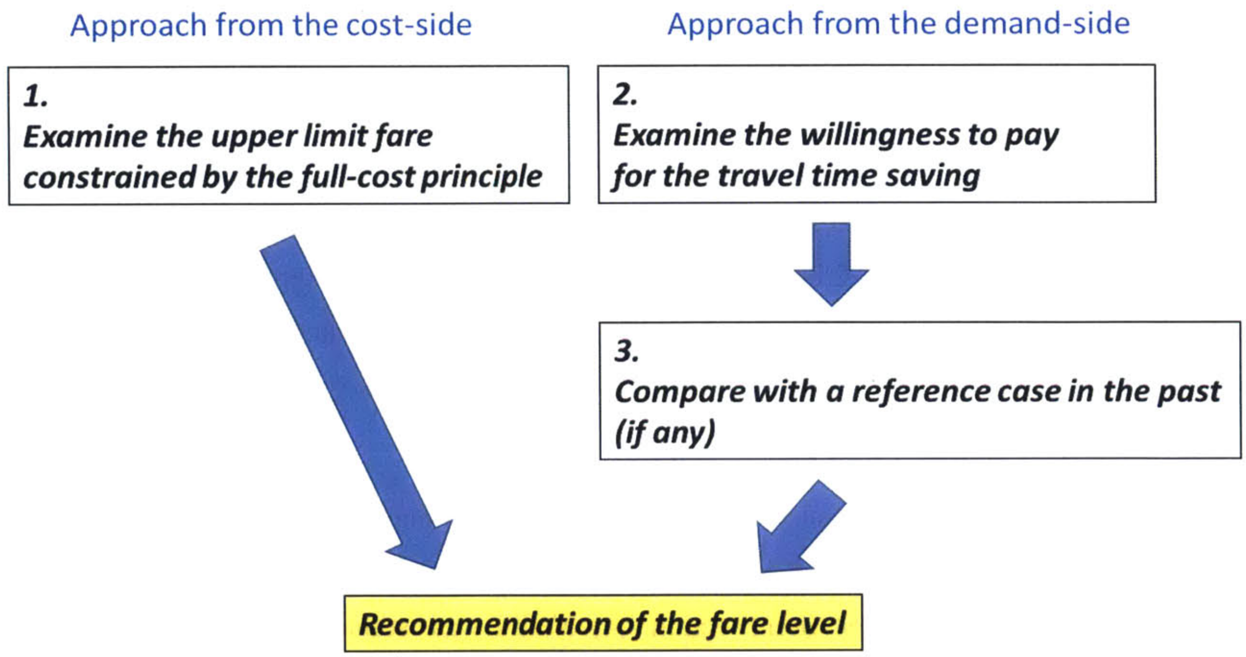


Figure 4-1: Framework of the fare level analysis of the Chuo Shinkansen Maglev

As the first step, the upper-limit fare constrained by the price regulation scheme is discussed. In particular, the railway price regulation is based on the full-cost principle; thus this step requires the cost-side approach for the fare level determination of a new line. As the second step, the willingness to pay (WTP) for the travel time saving of the new HSR, in comparison to the existing HSR in the same corridor, is analyzed. This is the demand-side approach for a fare-level determination. As the third step, in order to validate the theoretical estimation in the second step, a reference case of the fare determination in the past, if any, is applied. Based on the cost-side (Step 1) and the demand-side approach (Step 2 and 3), the appropriate scope of the fare level for a new HSR can be discussed.

Objective 2: Apply the framework for the fare level determination of the Chuo Shinkansen Maglev Tokyo-Nagoya-Osaka (Chapter 4)

Based on the framework in Objective 1, the thesis has analyzed the price level of the Chuo Shinkansen Maglev (Section 4.3-4.6), focusing on the project's first-phase operation in which the Chuo Shinkansen Maglev Tokyo-Nagoya segment is under operation (during 2027-2045, as projected by JR Central).

As the first step, the actual calculation and evaluation procedure based on the full-cost principle were reviewed (Section 4.3). The thesis used the recent HSR projects in Japan, the Hokuriku Shinkansen and the Hokkaido Shinkansen, as reference cases. Then the total revenue on the Chuo Shinkansen Maglev (Tokyo-Nagoya) and the total cost of the segment are estimated. As a result, the upper-limit fare of the Chuo Shinkansen Maglev is estimated as at least ¥13,090 ($109), which is ¥2,000 ($17) larger than the Tokaido Shinkansen. Although the precise estimation of the upper-limit fare should be implemented with latest demand and cost data, the result demonstrates a useful range for the approvable fare level of the Chuo Shinkansen Maglev.

As the second step, the thesis constructed a model to estimate the WTP for the travel time saving of the Chuo Shinkansen Maglev, considering the value of travel time (VOTT) and the disutility of transfer at Nagoya Station (Section 4.4). VOTT was estimated by using the disaggregated binary logit model with 2010 Inter-Regional Travel Survey data. As a result, we obtained VOTT for Tokyo-Osaka users as ¥52/min ($0.43/min). Based on this estimation, the thesis calculated that WTP for Tokyo-Nagoya users traveling by the Chuo Shinkansen Maglev is ¥3,152 ($26) larger than the current Tokaido Shinkansen, while WTP for Tokyo-Osaka users traveling by the Chuo Shinkansen Maglev (Tokyo-Nagoya) and the Tokaido Shinkansen (Nagoya-Osaka) via a transfer at Nagoya Station is ¥1,051 ($9) larger than the current Tokaido Shinkansen. The result suggests that the fare of Tokyo-Nagoya segment of the Chuo Shinkansen Maglev might likely be constrained by the full-cost principle (i.e. WTP > upper fare limit).

As the third step, in order to validate WTP approach with a real case, the thesis analyzed the fare setting of Nozomi Super-Express on the Tokaido Shinkansen as a reference case (Section 4.5). The incremental fare of Nozomi at its introduction in 1992 with respect to the fare of the second fastest train Hikari was ¥43.18/min ($0.36/min), while that difference between Nozomi and Hikari became ¥18.75/min ($0.19/min), when the fare of Nozomi was reduced in 2003. The result suggests that our approach may be reasonable because the incremental fare is lower than WTP. However, in this step, we have discussed that there may be a possibility of overlooking impacts on travel behavior, led by an unprecedented transport system (Section 4.5.4). The dramatic travel time saving which will be provided by the Chuo Shinkansen Maglev might worth beyond WTP, which is calculated our incremental approach.

Based on the three steps above, as a recommendation of the appropriate fare-level determination, the thesis suggested two plans for the fare of the Chuo Shinkansen Maglev (Section 4.6): set the incremental fare for Tokyo-Nagoya as well as Tokyo-Osaka as ¥800 with respect to the Tokaido Shinkansen (Plan A), or set the incremental fare for Tokyo-Nagoya as ¥2,000, while the the incremental fare for Tokyo-Osaka as ¥800 (Plan B). As for Plan B, in order to ensure the fare increase in Tokyo-Nagoya is higher than that in Tokyo-Osaka, it may require ¥1,200 discount for the Tokaido Shinkansen Nagoya-Osaka segment, which is only applied if the users take the Chuo Shinkansen Maglev in Tokyo-Nagoya. In Section 4.6, the thesis proposed the merits/demerits of both plans, by comparing two plans from three perspectives: customer surplus, producer surplus, and simplicity, respectively.

Also, as our model in Chapter 4 shows, WTP for the travel time saving of the Chuo Shinkansen for Tokyo-Osaka users largely depends on the disutility of transfer at Nagoya Station. It suggests that the design of Nagoya Station (e.g. transfer route between the Chuo Shinkansen Maglev and the Tokaido Shinkansen) will be very important. Our model suggests that if the transfer time is shrunk to 10 minutes from 15 minutes, WTP for travel time saving for Tokyo-Osaka users will increase by as much as ¥520 ($4), which might have significant impact on the revenue from the Chuo Shinkansen. Therefore, it is strongly recommended to reduce the transfer time in Nagoya Station.

As described above, the results based on the proposed framework gave a practical recommendation for the fare level determination of the Chuo Shinkansen Maglev. Also, since the information inside the rail operator regarding fare setting is rarely available in public, even for an academic purpose, the analysis in the thesis may become a useful case study applicable for any fare level determination for HSR or conventional express trains.

Objective 3: Analyze the pricing behavior of TGV Paris-Lyon and Acela in Northeast Corridor from the customers' point of view (Chapter 5)

This thesis benchmarked the pricing strategy of SNCF in France on TGV Paris-Lyon and Amtrak in the U.S. on Acela in the Northeast Corridor (NEC) from the customers' perspective (Chapter 5). Not only can this analysis give useful insights regarding how to apply dynamic pricing for the Chuo Shinkansen Maglev, but also it gives the comparison of the pricing behavior for different HSRs, which have different specifications, market situations, and company policies, would yield meaningful insights for the future study of the pricing strategy for HSR. In order to analyze the dynamic pricing behavior of each firm, two approaches are proposed in the thesis: dynamic pricing based on time of departure, and day of booking. The key findings are as follows:

- As for the observation regarding time of departure, while TGV consistently offers higher fare fares for trains in peak time than those in off-peak time, Acela sometimes offers the same low fare even for peak-time trains as that of off-peak time trains.
- The maximum fare for TGV (in the unit $/km) is less than Acela, probably because of the price regulation imposed by French government, which is a similar regulatory scheme with railways in Japan.
- While the minimum fare for Acela NY-DC is almost the same as that for Acela BOS-NY, the maximum fare for NY-DC was higher than that for BOS-NY, probably because of the difference in the dominance in market share regarding rail-air market. Since Acela in NY-DC has dominant market share with respect to airlines, it may be able to set higher maximum fare than BOS-NY. Also, road transportation (buses and cars) is the most popular transportation mode in NY-DC, which further encourage Amtrak to set higher maximum fare of Acela NY-DC, because in such a situation, Amtrak may be allowed to set a fare targeting less-price sensitive customers.
- As for the degree of fare variation, the fare of TGV varies in a wider range than Acela; thus the minimum fare of TGV is quite affordable compared to Acela. One reason for this may be the intermodal competition with the intercity bus services, which is deregulated for the first time in France in August 2015. Another reason would be that SNCF might care about social benefit more than profit as a state-owned company.
- From the observation regarding time of departure, some differences are also observed between TGV and Acela. In theory, a firm implementing dynamic pricing intends to increase the fare as the day approaches the departure, and TGV seems consistently to follow the theory. On the other hand, the fare of Acela goes up and down as the day of departure approaches. From the customers' point of view, TGV's pricing strategy is more acceptable than Acela from two perspectives: transparency in fare setting and price change in a short time period.
- Even though the fare of TGV monotonically increases as the day of departure approaches instead of offering "last minute deal" in order to fill the seats like Acela, the load factor

of TGV Paris-Lyon is high. The primary reason for this may be the pricing system of SNCF, which has a larger number of fare classes. This may be also the reason that the degree of the day-to-day change in the fare of TGV is relatively modest compared to Acela.

Objective 4: Give recommendations for the application of the dynamic pricing on the Chuo Shinkansen Maglev (Chapter 5)

The thesis analyzed the specification of the Chuo Shinkansen Maglev in the context of the applicability of dynamic pricing (Section 5.7.1). Also, the thesis analyzed the competitive situation with respect to airlines in Tokyo-Osaka corridor (Section 5.7.2). Key findings are as follows:

- The Chuo Shinkansen Maglev might share some common features with TGV, more than Acela as well as the Tokaido Shinkansen.
  - The flexibility in frequency design of the Chuo Shinkansen Maglev might be smaller than the Tokaido Shinkansen, because of the technological constrains imposed by the power conversion systems (PCS) for a Maglev train. TGV sometimes slightly changes the number of trains according to the demand, while Acela always keeps the same number of trains.
  - The Chuo Shinkansen Maglev would require a seat reservation in advance of the journey, unlike the Tokaido Shinkansen. Also, the number of stops of the Chuo Shinkansen Maglev train might be fewer than the Tokaido Shinkansen, which is also similar to TGV, rather than Acela.
- As for the projection of the airline market in Tokyo-Osaka corridor in the future, since the total capacity of Tokyo International Airport (HND) is limited, the runway slots of HND for domestic flights cannot significantly increase in the future. Therefore, after the commencement of the Chuo Shinkansen Maglev, the combined market share of the Chuo Shinkansen Maglev and the Tokaido Shinkansen may probably be more dominant than present.
- Based on the analysis above, the thesis recommends the pricing strategy observed in TGV, which can soften the negative impression of the dynamic pricing such as the

feeling of the price gouging. This would be a suitable strategy in order to achieve the successful implementation of the dynamic pricing for the Chuo Shinkansen Maglev.

  - Specifically, the transparent fare differentiation for customers, in terms of both the time of departure and the day of booking, would be recommended. Since the capacity of the Chuo Shinkansen Maglev in peak time period will be limited by the constraints of PCSs, the peak time trains may deserve higher fare than the off-peak trains. Also, it may be rational to set the relatively higher fare for walk-in tickets since keeping empty seats without reservation requires larger cost.
  - The moderate fare change in a short time period is also recommended. In order to achieve this, the revenue management system which enables finer price discrimination would be required. Also, the operators, which supports the day-to-day decisions regarding the seat allocation recommended by the system, should consistently pursue the customer-friendly pricing strategy, instead of trying to squeeze as much money as they can.

- Dynamic pricing system has been originally developed in the U.S. airline industry, in which private airlines aimed to maximize the return for investors under the fierce competition. Since the projected market situation for the Chuo Shinkansen Maglev is different from that in the U.S. airline industry, JR Central should be cautious about giving negative impression from customers, if it introduces dynamic pricing.

6.2 Future work

This research is aimed to provide a comprehensive analysis of the pricing strategy for the Chuo Shinkansen Maglev, which comprises the fare level analysis and the examination of the dynamic pricing application. The author recognizes that further research can be done for each part. Some suggestions for future work include following points:

Fare level analysis

- In order to estimate the upper-limit fare approvable by the full-cost more precisely, both the cost and the revenue estimation should be updated with the latest data.

- The construction cost, which will be reflected as the depreciation cost in the full-cost principle, may be unclear. The cost components such as the land acquisition and the tunnel construction are especially difficult to predict.
- The operating cost for a Superconducting Maglev train could change, since the technological development still continues to be done by JR Central. The annual capital investment for the cost reduction of the Superconducting train operation was ¥21billion ($175million) in FY2014 and ¥30billion ($250million) in FY2015 (Central Japan Railway Company 2014a; Central Japan Railway Company 2015a).

- As our model in Chapter 4 shows, the willingness to pay (WTP) for the travel time saving largely depends on the disutility of transfer at Nagoya Station for Tokyo-Osaka passengers, before the Chuo Shinkansen extends to Osaka. Our model follows the relatively simple assumption recommended by MLIT (Ministry of Land, Infrastructure, Transport and Tourism 2012c). Since the disutility of transfer may vary according to the stresses on the transfer experience, which may be uncertain since the structure of Nagoya Station for the Chuo Shinkansen Maglev is unknown, further research on the estimation of the disutility of transfer is worthwhile to be done.
- As described in Section 4.5.4, the dramatic travel time saving of the Chuo Shinkansen Maglev might not follow the incremental approach proposed in the thesis, since the "This-changes-everything" service may affect the people's business style and lifestyle. Further empirical research can be done regarding the willingness to pay for the travel time saving for an introduction of an innovative transportation mode.

Application of dynamic pricing

- Since the analysis in Chapter 5 focuses on the customers' perspective, further research is needed for the analysis from the operator's perspective, which requires a lot of confidential data from the operator. For example, the passenger demand for each departure time and each trip purpose would be necessary for the design of fare variation with respect to time of departure. Also, historical booking patterns, such as when the passengers booked a specific train, would be needed for the design of fare variation with respect to day of booking.

- The research which can bridge the customers' perspective and the operator's perspective is a meaningful research area. For example, how the pricing strategy which can soften the negative impression of the dynamic pricing affects the incremental revenue for the operator is interesting question.
- Although this thesis focuses on the pricing strategy for the Chuo Shinkansen Maglev, the pricing strategy for the Tokaido Shinkansen is also important, since the Tokaido Shinkansen will be highly substitutable for the Chuo Shinkansen Maglev and strongly influence the demand of the Chuo Shinkansen.
- Not only pricing strategy, but also capacity management of the Tokaido Shinkansen will be also important after the commencement of the Chuo Shinkansen Maglev. Currently, the capacity of the Tokaido Shinkansen is adjusted day-to-day basis according to the demand forecasting as we have seen in 2.5.1. The demand forecasting for the Tokaido Shinkansen will be more difficult since the price as well as the frequency of the Chuo Shinkansen Maglev will influence the demand of the Tokaido Shinkansen.
- As described in Section 1.2.5, the Chuo Shinkansen Maglev is the unique case, in which a firm will own and operate two parallel HSRs in a same corridor. Although these two HSRs have different attributes, such as travel time, one can be substitutable for the other. Given the situation, how to design operational institutions inside the company is worthwhile to discuss. If the company adopts two independent operating divisions, while the managerial efficiency in the division might increase, the two operating division possibly compete with each other. The price and/or frequency battle between these divisions could benefit customers, but both destructive price battle and inefficient frequency battle should be avoided in order to sustainable operation, otherwise customers eventually worse off.

Having reached this point, the author would like to thank readers for considering the ideas raised by this thesis. This thesis represents a first attempt to examine a viable pricing strategy for the Chuo Shinkansen Maglev, hoping to lead to further discussions on the project as well as the academic research on the pricing strategies for HSRs around the world.

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