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High-Speed Inter-City Transport System in Japan

Past, Present and the Future

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ABSTRACT

With the advent of Shinkansen in 1964, a unique inter-city transport network in which high-speed railway and air transport developed simultaneously, emerged in Japan, and modal choice between them based on price and speed has been manifested. Looking ahead, the next generation high-speed transport, the Maglev, is on the horizon.

In order to capture the full impacts of the Maglev technology, simulation analysis with a dynamic spatial nested logit model was conducted. From this, we identified a significant opportunity for the Maglev Super-express between Tokyo, Nagoya and Osaka, but with net benefitsexceeding net costs only with an annual economic growth of approximately 2% - 3% achieved in the next 65 years in Japan. If such economic condition were realized, the total air transport market would also continue to grow despite strong competition from the Shinkansen/Maglev system.

Another point of interest is Maglev's impact on reducing global warming. CO_2 emission from Maglev is one-third of air transport. Introduction of Maglev Super-express in inter-city transport, however, also attracts passengers from Shinkansen that has five times lower CO_2 emission intensity. Indeed, our simulation analysis shows that total CO_2 emissions from high-speed inter-city transport increases when Maglev Super-express is introduced. Increase in total CO_2 emission from electricity users including Maglev Super-express could be mitigated by energy conversion sector's effort to reduce CO_2 content of electric power supply, for instance, by increasing utilization of nuclear energy. Further research in assessing possible impact of capacity constraint in existing network, not considered in this paper, would facilitate deeper understanding of the future high-speed inter-city transport system.

1. INTRODUCTION

Increasing the value of time in modern society has brought high-speed railway and air transport to the forefront of today's inter-city transport. With the advent of Shinkansen in 1964, Japan has unveiled the significant potential of high-speed railway in inter-city travel. ICE in 1991 and TGV in 1993 have opened a new era for Europe and with the start of twenty-first century, South Korea, followed by China, have introduced their system. This year, the President of the United States of America (USA) has announced his vision for high-speed railway.

Unlike in the USA where air transport long stands as a dominant mode of inter-city transport, air transport in Japan developed side-by-side with Shinkansen. Liberalization and infrastructure development have facilitated Japan's establishment of an extensive network of air transport market, filling the gap in market segments that Shinkansen could not fulfill. The two different modes of transport, high-speed railway and air transport, have provided Japan with a modern inter-city transport system, with the unique feature of having extensive competition between them.

Looking ahead, we see a new technology for the next generation of high-speed transport, the Maglev. A business plan to introduce Maglev system between Tokyo and Nagoya by 2025 has recently been released. We thus need to anticipate a new high-speed inter-city transport system with three different modes of travel.

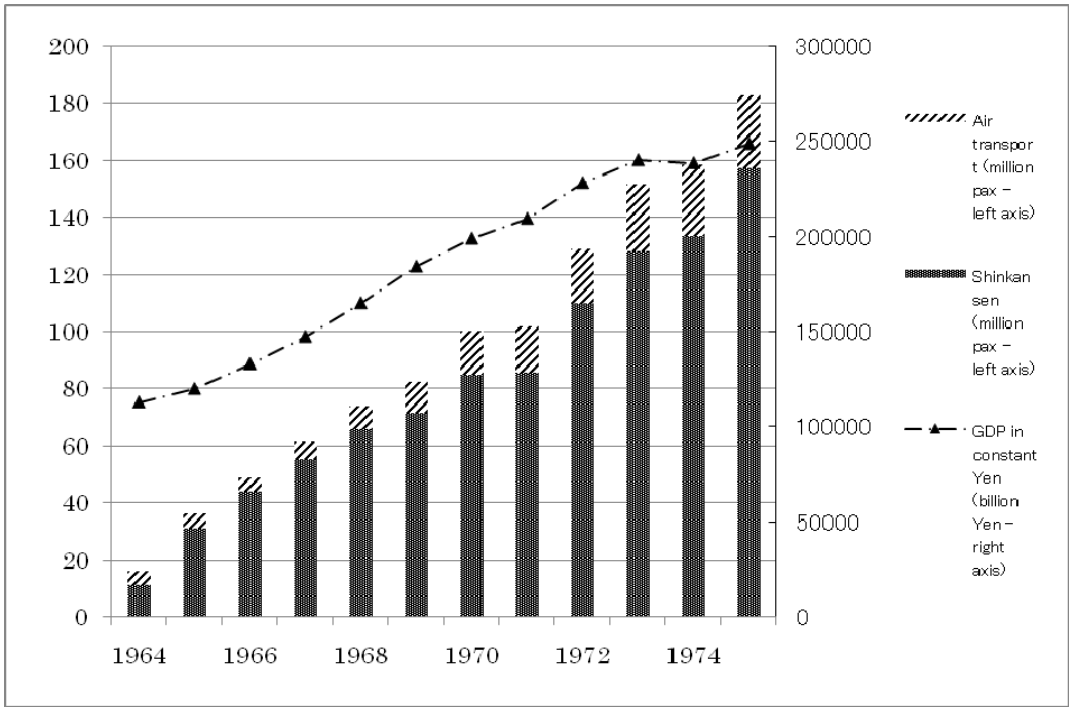
This paper highlights historical landmarks of how high-speed railway and air transport developed in Japan and takes a look beyond the horizon of future inter-city transport. Various transport statistics are compiled and analyzed in an attempt to underpin some/the characteristics of these transport modes. We also set up a dynamic spatial nested logit model to assess the nation-wide impact of Maglev Super-express.

2. EVOLUTION OF HIGH-SPEED INTER-CITY TRANSPORT IN JAPAN

2.1. 1960-70

It was October 1964. In the era when maximum speed of the railway system was 120km/h, Shinkansen , with a maximum speed of 210km/h, was considered as the super-express "dream come true". The seven-hour trip between Tokyo and Osaka, of a distance of 550km , was cut to four hours and ten minutes by the initial bullet train. At first, ten "Hikari" super-express trains, that only stopped at Nagoya and Kyoto between Tokyo and Osaka ,and ten "Kodama" express trains, that stopped at other stations, were operated. The first fleet consisted of twelve cars with a total of 987 seats. The capacity of the passenger railway transport between Tokyo and Nagoya increased by 42% even though rapid train service on existing network was reduced by more than 30%. Within one year, Shinkansen was speeded up to shortene the trip between Tokyo and Osaka to three hours and ten minutes. Frequency was increased to 55 round-trips per day. The fare between Tokyo and Osaka by Hikari was 2 480 Yen. In six months, Shinkansen's ridership reached 11 million. Speed and price significantly attracted business trip-makers in particular. Figure 1 shows that by 1970, annual Shinkansen passenger ridership reached 85 million.

Figure 1. **Demand of air transport and Tokaido Shinkansen in passenger-kilometers (1964-1975)**



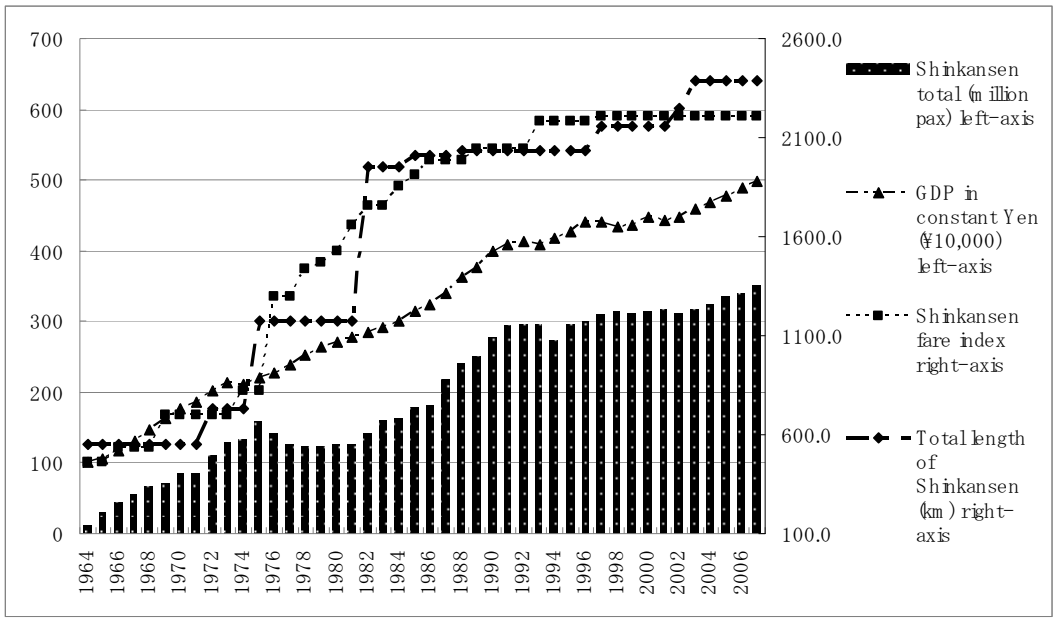
At the initial stage of air transport development, the national flag carrier, Japan Air Lines (JAL), was tasked to operate on international routes and domestic trunk routes. Routes between Tokyo, Osaka, Sapporo, Fukuoka and Okinawa were designated as domestic trunk routes. Other airlines were assigned to operate on domestic local routes. Increase in demand and severe airline competition called for a new framework to secure fair competition and the orderly development of the market. Policy recommendation by the Transport Policy Council, under the Ministry of Transport[1] in 1970 and the Ministerial Order in 1972, outlined the subsequent regime of air transport in Japan. Under this so called 45/47 regime[2], JAL was to serve on international and domestic trunk routes, All Nippon Airways (ANA) on domestic trunk and local routes and Toa Domestic Airlines (TDA)[3] on domestic local routes. This regime continued to be the framework for Japanese air carriers until the mid-1980s.

When Shinkansen started its operation in 1964, air transport was at the initial stage of introducing turbo-jet aircrafts. The first turbo-jet to fly in the domestic market was the Conveyer 880 in the Tokyo-Sapporo route in 1961. By 1964, Boeing 727 and DC8 joined the fleet of Japanese air carriers. The Tokyo-Osaka route, however, was still operated by turbo-prop aircrafts when Shinkansen started its operation. In those days, the average speed of domestic air transport was 333km/h and it took an hour and forty-five minutes to fly from Tokyo to Osaka. During the first six months of Shinkansen operation,, 3.6 million passengers, equivalent to 14% of the Tokyo and Osaka air transport market, shifted to rail. Despite the dramatic success of Shinkansen, air transport marked rapid growth in the subsequent years. By 1970, the number of annual air transport passengers was above 15 million.

2.2. 1970-90

In 1972, Shinkansen was stretched out to Okayama, 150km west of Osaka, and in 1975, to Hakata in North Kyushu, 644km from Osaka. Now, Shinkansen is composed of 553km of Tokaido Shinkansen and 644km of Sanyo Shinkansen. Between 1965 and 1975, Shinkansen enjoyed 15% of annual growth rate in passenger ridership and reached a total of 157 million passengers by 1975.

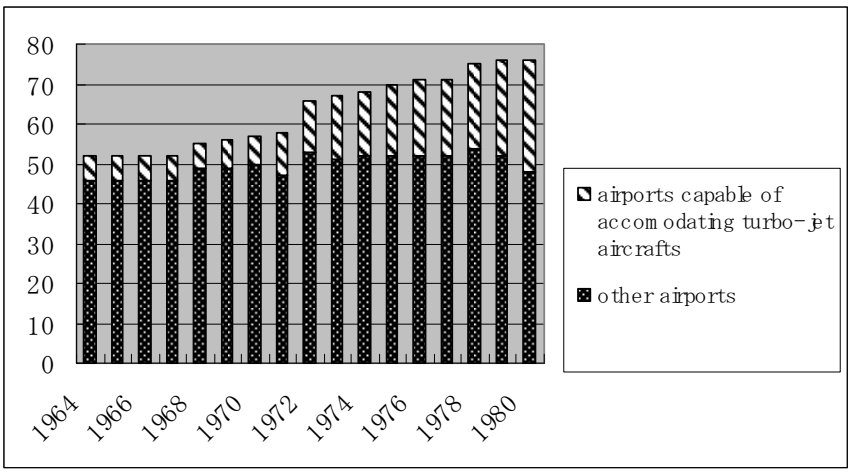
Figure 2. **Historical data regarding Shinkansen (1964-2007)**



In the following years, however, Shinkansen demand started to decline. Apart from economic downturn from the exchange rate reform of 1971 and the oil crisis of 1973, the Japan National Railway (JNR) was suffering from huge financial deficit accumulated year by year. Investment, maintenance and operation costs were basically self managed by the JNR. Rapid motorization in urban and regional transport led the JNR to severe financial distress. In particular, the expansion of the railway network in rural areas amplified the problem. Accumulated loss of the JNR skyrocketed from 83 billion Yen in 1965 to 678 billion Yen in 1975 at which point it was still growing fast. The government and the JNR took steps to restore financial distress by increasing fares. The one way Shinkansen ticket from Tokyo to Osaka, initially set at 2,480 Yen,was hiked to 5 050 Yen by 1974 and reached 10 800 Yen by 1981; thus increasing by four-fold in 17 years. The JNR's price hike had over-ridden CPI and Tokyo-Osaka air fares that rose by 2.7 and 2.3 times respectively during the same period. Railway fares continued to be increased until the JNR was privatized in 1987. By then, the Shinkansen ticket from Tokyo to Osaka was 13 100 Yen. Historical data depicted in Figure 2 illustrates the effect of the price hikes.

Demand for air transport had also stagnated during the late 1970s but not as severely as Shinkansen. Turbo-jet aircrafts with greater speed rates and larger capacity than turbo-prop aircrafts were introduced rapidly. As shown in Figure 3, the number of airports accommodating turbo-jet aircrafts was increased from 6, in 1965, to 28, in 1980.

Figure 3. **Number of airports in runway categories (1964-1980)**



Class One international airports in Tokyo and Osaka were built and entirely funded by the government[4]. The central government was also tasked to own and operate Class Two airports in major cities such as Sapporo and Fukuoka. Two-thirds were funded by the central government and the rest was covered by the local government. Class Three airports in local cities were built and managed by local governments with half of the investment subsidized by the central government. In 1967, the first of the Five Year Airport Construction Plans was adopted. The central government established a Special Account for Airport Development in 1970 to invest and maintain the Class One and Two airports and subsidize the Class Three airports. The financial source of the Special Account could be classified into two categories. One is direct income of landing fees and 11/13 of the jet fuel tax levied on domestic air transport operation sourced through the General Account of the Japanese government. This accounts for 70-80% of the total revenue. The rest is composed of generic funds from the General Account and provisions from the local government of Class Two airports. In the 1980s

Government loans were injected into the Special Account for Airport Development to finance a large

part of the investment for the Haneda Airport. In 1966, the New Tokyo International Airport Agency (Narita) was established by the government. After twelve years of difficulty, Narita Airport was opened in 1978. International flights were basically shifted from Haneda to Narita giving room to facilitate untapped demand in the domestic air transport market.

In the 1980s, Japan steadily recovered from (the previous decade's) economic shocks. Rapid growth was experienced in both international and domestic air transport markets. In 1985, the Transport Policy Council reviewed the 45/47 framework and recommended that the government turn to a pro-competitive policy. The operation of multiple airlines on routes was liberalized on high-density routes. The threshold demand levels allowing two airlines (double tracking) and three airlines (triple trucking) to operate were set out by the Ministry of Transport. The thresholds of double/triple tracking were cut down in 1992 and in 1996 for further promotion of competition. In 1997, the threshold itself was abolished so that any number of airlines could enter into any route, regardless of the volume of that route. As a consequence, the ratio of available seats in routes with multiple numbers of airlines against total available seats in the domestic air transport market rose from 53% in 1985 to 80% in 1999. The new aviation policy, set out in 1985, also allowed airlines other than JAL to operate in international routes and privatized JAL.

Domestic airfare was regulated to control airfares based on cost. When the airlines applied for increase in airfares due to inflation or upspring in fuel price etc., the overall cost of airline operation was reviewed by the government. Airfare increase was only allowed to the level justified by aggregate cost under efficient operation. Such an "aggregate cost formula" was common in the public utilities.

2.3. 1990-Present

2.3.1. Liberalization in the air transport market

In the early 1990s, due to the burst of the "economic bubble", the Japanese economy plunged into recession and prices became deflationary. The opening of the Kansai International Airport in 1994 would have been welcomed more if it were not for the great depression. The private sector was facing difficulty in deteriorating demand and prices. Public utilities including transport services, however, tried to pass excessive cost to the consumers by raising prices.

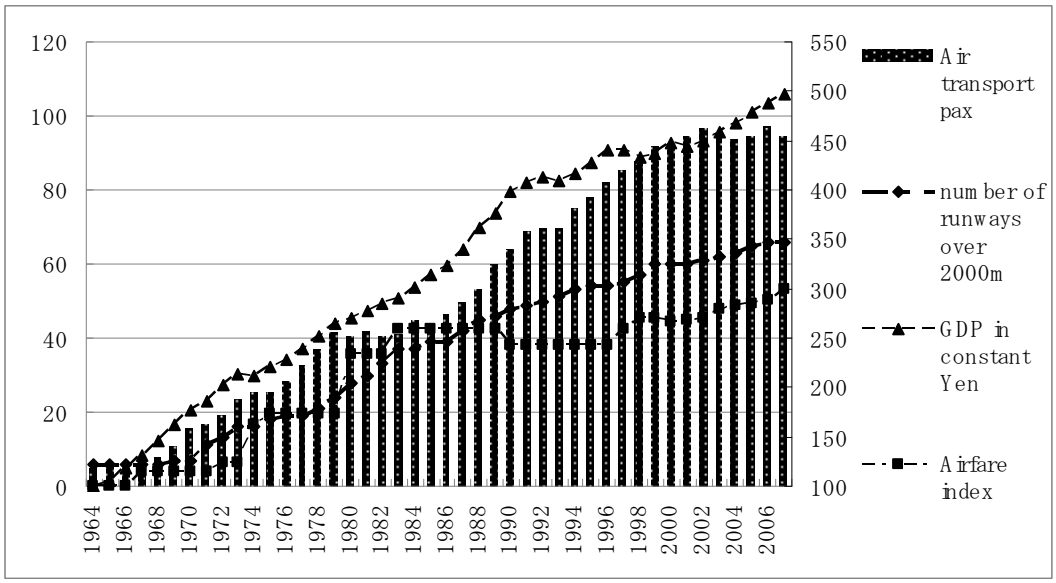
After 1994, strong criticism concerning price hikes of public utilities pushed the regulatory reform of public utilities into a policy agenda. Amidst countervailing forces, the airfare regulation was deregulated to introduce a "zone airfare scheme." This allowed airlines to obtain automatic approval within a specific zone. The new zone airfare system provided airlines flexibility in airfare setting. Seasonality difference and flight by flight pricing were now possible. In 1996, airlines' applications were approved under the new regulation. Under the new price regulation regime, incumbent airlines increased the normal fares in trunk routes while introducing various discount fares such as advance booking discounts and frequent flyer programs (FFPs). Despite the introduction of various discount fares, normal airfare hikes on trunk route, such as Tokyo-Fukuoka and Tokyo-Sapporo ,were confronted with strong criticism in the Fukuoka and Sapporo regions.

This opened a window of opportunity for entrepreneurs to set up new airlines. The capacity expansion of the highly congested Haneda Airport was under construction. In March 1997, a new runway was opened and 40 landing slots were added each day. These slots were allocated to airlines in two stages: July 1997 and April 1998. At that time, there were six projects launched to raise new airlines and the first two to be on the market were Skymark Airlines, in September 1998, and Hokkaido International Airlines (AIR DO), in December 1998. They entered the Tokyo-Fukuoka and Tokyo-Sapporo routes respectively. Apart from subsidiaries of the major three air carriers, it was indeed a new air carrier entry in 35 years.

At the launch of their services, the two airlines set out extremely lower airfares compared to incumbent carriers. Skymark offered normal fare at half the price and AIR DO at 36% below the incumbents. This "everyday low fare" strategy became popular and their load factor rose as high as 80%. On the contrary, incumbent carriers suffered sudden drop in passengers. These routes were lucrative trunk routes with many business travelers. The incumbent carriers started to offer discount fares on flights just before and after the flights of new entrants. They also upgraded their frequent flier programs. These counter measures were quite effective and by March 1999 the incumbent carriers regained their demand to the same level as that of a year ago. Enhanced competition facilitated an annual passenger increase on the Tokyo-Fukuoka and Tokyo-Sapporo routes by 16.3% and 9.4% respectively.

Since then, pro-competitive slot allocation policy at congested airports such as Haneda Airport have become an important agenda for the Ministry of Transport. The new slot allocation policy was introduced to review slot allocation in congested airports every five years. Figure 4 illustrates the historical trend of air transport. It could be observed that despite economic stagnation in the mid 1990s, air transport experienced moderate growth due to market stimulation from deregulation.

Figure 4. **Historical data regarding air transport (1964-2007)**



In Japan, deregulation in the transport sector has been implemented step by step. In December 1996, with a view to accelerate deregulation in every transport sector and to promote administrative reform, the Ministry of Transport decided to abolish supply/demand tests in the entire transport sector by the end of the century (within the next four years?). Based on the report of April 1998 from the Transport Policy Council, the air transport market was totally liberalized while measures for maintaining essential air services to remote islands and the rule for slot allocation in congested airports were reinforced. Having set out necessary measures for liberalization, Civil Aeronautics Law was amended and put into effect in February 2000, so that supply/demand regulation policy was abolished and license for each route was no longer needed. The airfare regulation was also deregulated from approval regulation to prior notification. With regards to the congested airports, slot allocation was adopted, subject to review every five years and based on pre-set allocation criteria.

According to Yamaguchi (2005), accumulated increase for the 1980-1998 period in consumer surplus from deregulation and public investment related to air transport amounted to 1.2 trillion Yen and 3.5 trillion Yen respectively.

2.3.2. JNR reform and Shinkansen

The year that Shinkansen started its operation was the year during which JNR's severe financial problems became apparent. In 1964, JNR reported the first operating loss that grew year by year. By 1966, capital reserve accrued in the past was washed away and net loss started to accumulate. In 1971, JNR reported operating loss before depreciation. Fares were raised almost every year. Total government subsidy reached 6.6 trillion Yen. Despite these measures, long-term debt reached 37.1 trillion Yen, of which 15.5 trillion Yen was JNR's accumulated loss. In 1987, the government put an end to JNR's financial crisis through privatization. The JNR reform package of 1987 was composed of the following;

- Privatization of JNR into six regional passenger railway transport corporations and one freight transport corporation.
- Shinkansen would be held by a special purpose government agency and leased to JR companies.
- 11.6 trillion Yen of the total of 37.1 trillion Yen long-term debt would be born by major JR companies and the rest, 25.5 trillion Yen, by a special purpose government agency.

In 1993, JR East was floated on the stock market followed by JR West and JR Central in 1996 and 1997 respectively (used a lot throughout the text). In 1991, Shinkansen assets, spun-off in the 1987 JNR reform package, were acquired back by the three JR companies. A final solution to the 25.5 trillion Yen long-term debt, born by a special purpose government agency, was achieved in 1998.

Law stipulating nation-wide plan for Shinkansen developments was enacted on 1970. Under the plan, decided in 1973, the extension of the network up north to Sapporo in Hokkaido and down south to Kagoshima in Kyushu, and the development of Hokuriku Shinkansen connecting Tokyo and Osaka via Nagano and Toyama were included in Development Plan phase. These new routes were christened *Seibi-Shinkansen*.

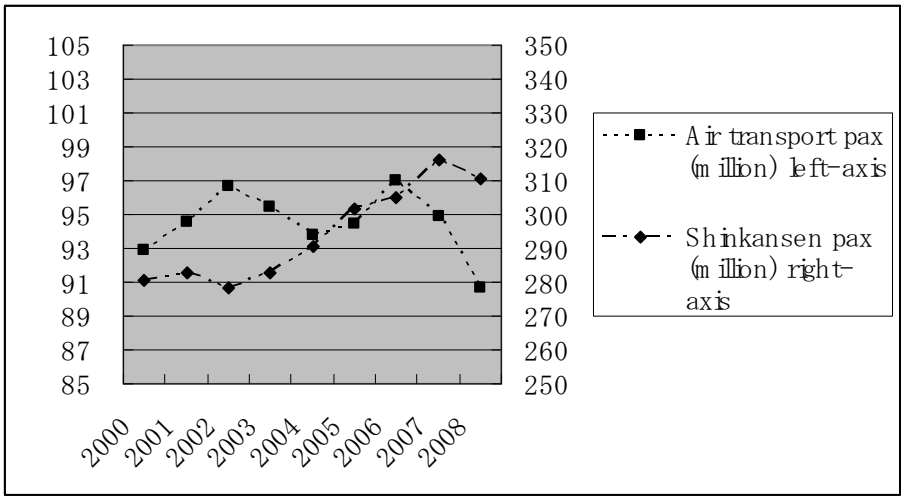
Over-investment was one of the major causes of the financial turmoil of JNR. Thus, an important feature of the new Shinkansen funding scheme was to avoid financial crisis from reoccurring. The funding scheme established in 1989 for the extension to Nagano, the first of the routes to be constructed as *Seibi-Shinkansen*, was divided as follows: 50% JR, 35% central government and 15% local government. The funding scheme was revised in 1996 so that JR would only bear the investment cost up to the level of their benefits. The rest of the investment cost would be covered by the government; 2/3 by the central government and 1/3 by the local government.

2.4. Towards the future

2.4.1. Shinkansen and air transport

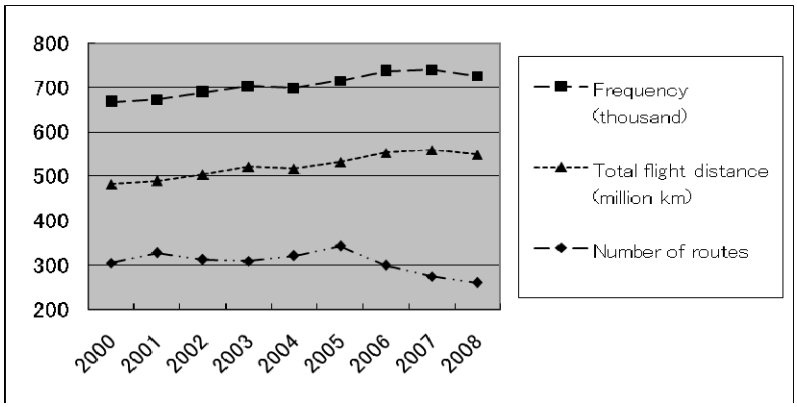
With the turn of the century, Shinkansen constantly increased its demand and complementary relationship between air transport has continued to be manifested in recent years. Figure 5 shows recent the annual number of passengers of Shinkansen in comparison with air transport.

Figure 5. **Recent trend in the number of passengers on air transport and Shinkansen (2000-2008)**



The extension of the existing Shinkansen under operation is currently 2 387km in total. There are 1,173km of unfinished Shinkansen network, *Seibi-Shinkansen*. Due to constraints in government funds, it is envisaged to take about ten years for the *Seibi-Shinkansen* to be completed. Apart from the *Seibi-Shinkansen*, the Maglev Super-express is planned to be constructed as part of the grand design of the national Shinkansen network stipulated under the National Shinkansen Law of 1970. The major difference between the *Seibi-Shinkansen* and the Maglev Super-express is that the latter is proclaimed to be self-financed by JR Central.

Figure 6. **Recent trend in air transport (2000-2008)**



Since the turn of the century, except for 2005 when Chubu Centrair International Airport was opened, the total number of routes in the domestic air transport market has marked a gradual decline. On the contrary, as depicted in Figure 6, the total frequency and total flight distance have increased. Routes to and from Tokyo (Haneda) are increasing in capacity and demand, while other routes, local-to-local routes in particular, are losing both. Route concentration has lead overall average frequency per route to increase by approximately 30% between 2000 and 2008. Figure 7 shows the trend in the number of monthly passengers on routes to and from Tokyo and local-to-local cities. While demand for Tokyo routes

increased by 10%, local routes decreased by 35%.

As for the total domestic air transport demand, with the rise of fuel cost, average fare (yield) per passenger-kilometer has increased from 15.0 Yen/paxkm, n 2002, to 17.6 Yen/paxkm, in 2008. As a result, the total number of passengers has declined from 96.7 million, in 2002, to 90.7 million, in 2008. The merger of JAL and JAS in 2002 also had an impact on the market in general. Figure 8 illustrates the recent trend.

Figure 7. **Monthly number of passengers in thousands on routes to and from Tokyo and between local cities (Jan. 2000- Mar. 2009)**

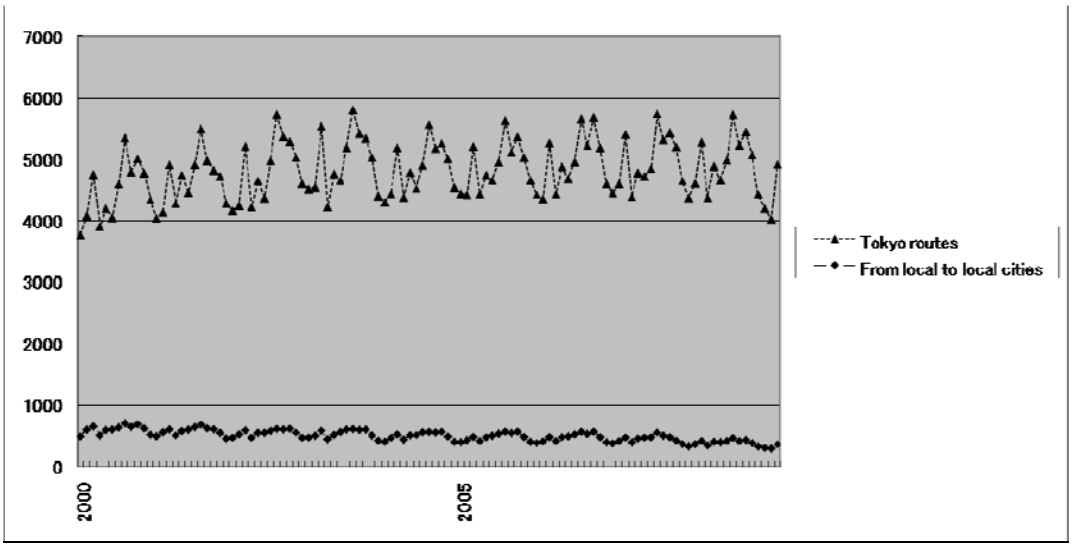


Figure 8. **Recent trend of passengers and average price of air transport (2000-2008)**

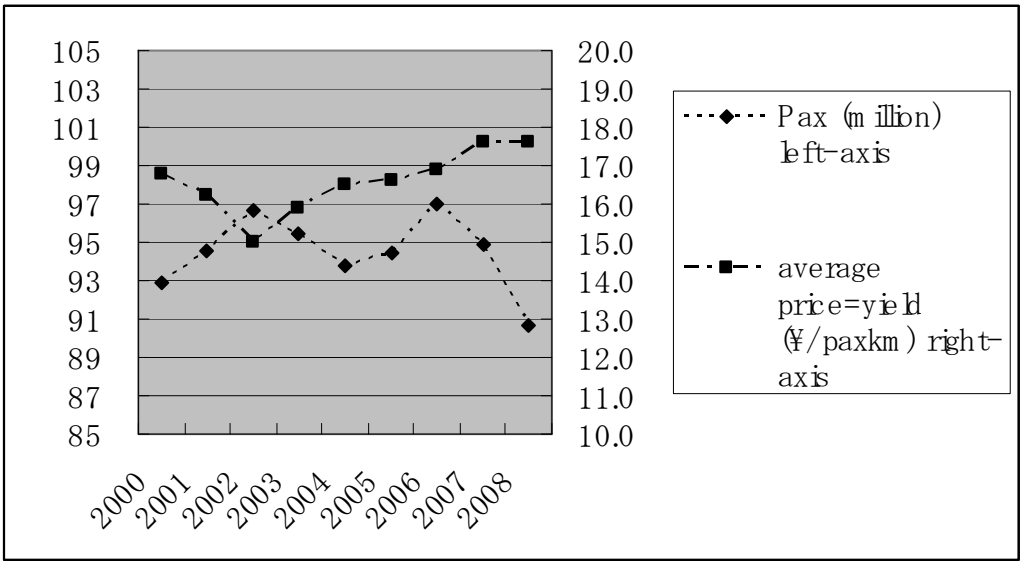


Figure 9 shows the profound effect of the world-wide economic down-turn since September 2008 on air transport and Shinkansen. Both transport modes have experienced unprecedented decrease in demand in recent months. Speculators view February 2009 to be the bottom. There are hopes that the transport market, mirroring the general economic activity, will rebound in the foreseeable future.

Figure 9. **Percentage change of monthly passengers on air transport and Shinkansen (March 2007-March 2008)**

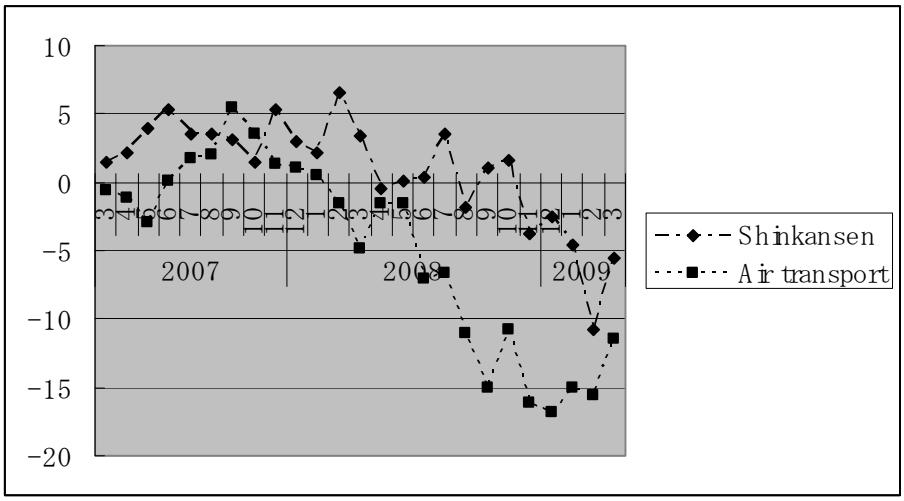
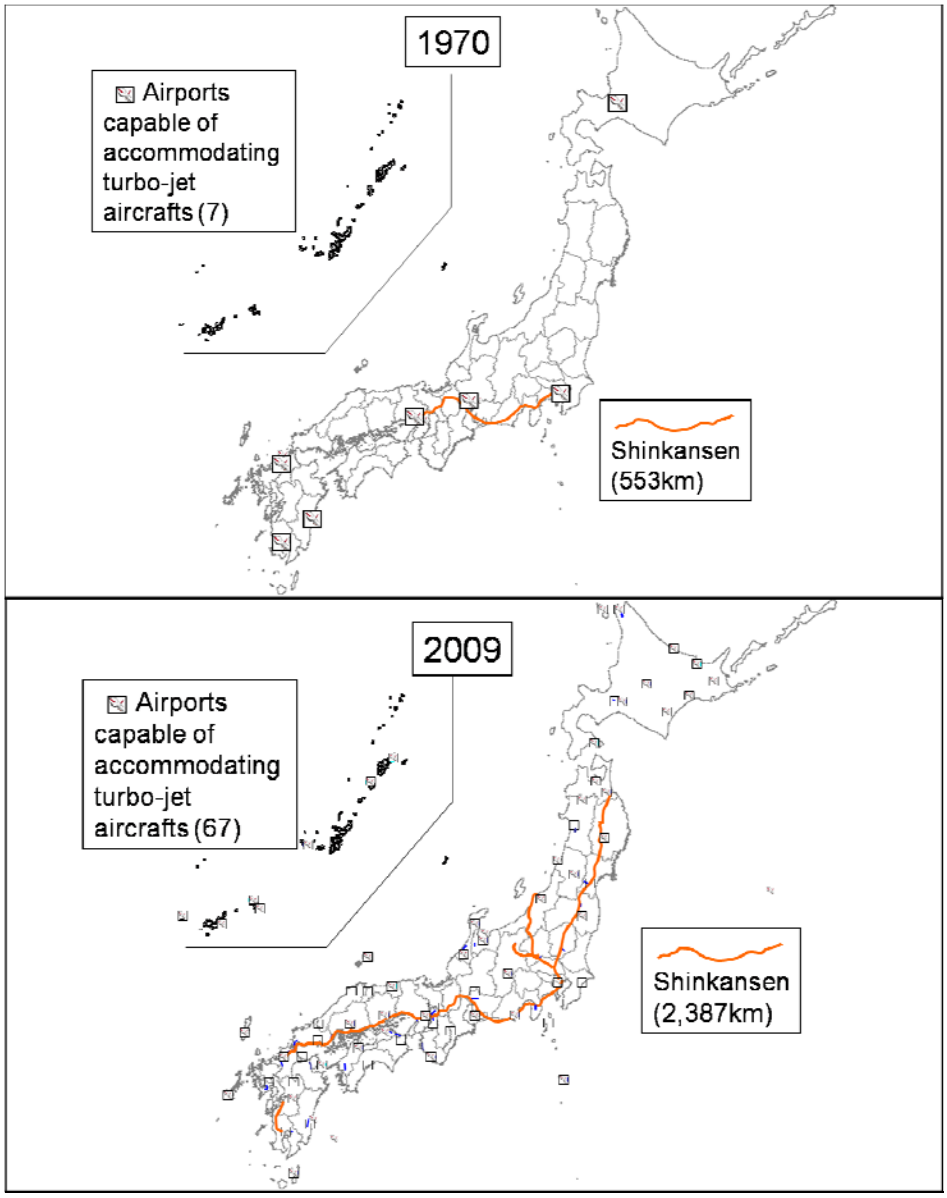


Figure 10 gives snap-shots of the Shinkansen network and airports in 1970 and 2009. It should be noted that regional airport developments have basically come to an end. Now, there is a need to facilitate capacity increase in the Tokyo metropolitan area. In 2010, landing slots in Tokyo Haneda Airport and Narita International Airport are to be increased substantially. In particular, the opening of the fourth runway at Haneda Airport is expected to have a profound impact on domestic and near-by East Asian inter-city air transport. As of 2009, there are 806 domestic flights and 24 international charter flights operated daily at Haneda Airport. Domestic flights will be increased to 826 in October 2010 and to 880 within the following six months.

Back in 1978, when Narita International Airport was opened, international scheduled flights were basically shifted away from Haneda Airport. With the expansion in 2010, Haneda Airport will accommodate 40 international scheduled flights daily to major near-by East Asian cities during daytime and another 40 international flights between late evening and early morning. Furthermore, an additional 72 fights will eventually be added, of which the allocation is still to be determined.

Figure 10. **Shinkansen network and airports in 1970 and 2008**



2.4.2. The Maglev

Technology of super-conductivity magnetic levitated super express the so-called "Maglev" goes back to 1962. Ten years after the start of the research project in JNR, the first operation test was undertaken on a 220m strip test guide-way in a research center at Kunitachi, Tokyo. In 1974, the construction of 7km testing lane was initiated in Miyazaki where test-runs were conducted until the test-bed was switched to Yamanashi in 1996. In the current 42.8km stretch of test-course in Yamanashi, maximum speed of 581km/h was recorded in 2003 and in that year government technology committee announced that the

Maglev Super-express was now technologically feasible. By 2006, accumulated test run had exceeded 500 000km and in 2007, the test course was designated to be part of the commercial path of Chuo Shinkansen. That year, JR Central announced that they would plan to open Tokyo-Nagoya Maglev Super-express by 2025 and be the sole investor to the 500 trillion Yen project.

Chuo Shinkansen is listed as one of the routes to be developed under the National Shinkansen Development Law. The Maglev Super-express planned by JR Central is an integral part of the Chuo Shinkansen. Currently there is debate over which specific route the Chuo Shinkansen should take. Local governments are requesting diversion of the route to local cities which would inevitably increase construction cost of the overall Maglev infrastructure.

Table 1. **Comparison of Shinkansen, Maglev (plan) and air transport**

	Tokyo-Nagoya (366km*)			Tokyo-Osaka (553km*)		
	time	fare	CO2/pax	time	fare	CO2/pax
Shinkansen (Nozomi)	103min	10,780Yen	5.2kg	156min	14,050 Yen	7.9kg
Maglev (plan)	40min	(11,780 Yen)	15.7kg	60min	(15,000 Yen)	23..8kg
Air	-	-	-	68min	13,600 Yen	68.8kg

*Distance in railway mileage.

Table 2. **CO_2 intensity**

mode	CO_2- g /paxkm
Shinkansen	14.2
Maglev	43.0
Air	124.5

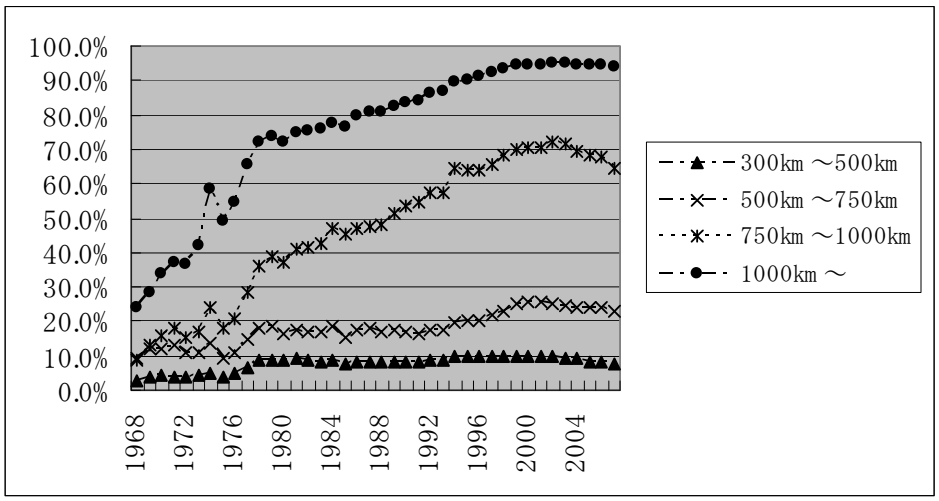
3. MARKET CHARACTERISTICS OF HIGH-SPEED INTER-CITY TRANSPORT SYSTEM

3.1 Average travel distance of Shinkansen and air transport

Originally, Shinkansen was utilized for long distance travels, the majority of which exceeded 300km. Since 2007, however, more than half of Shinkansen ridership uses it for journeys of less than 300km. The average distance declined from 319km, in 1968, to 234km, in 2007. The break-down of Shinkansen average travel distance into segments is as follows: Tokaido=308km, Sanyo=251km, Tohoku=168km, Jouetsu=126km, Hokuriku=82km, Kyushu=103km. Only Tokaido Shinkansen is maintaining an average ridership of more than 300km.

On the other hand, average trip length for domestic air transport has increased over time; 605km in 1968 and 881km in 2007. Average distances of Shinkansen and air transport have been diverging over the years. As a result, modal share of air transport in long-distance travel has been increasing as depicted in Figure 11.

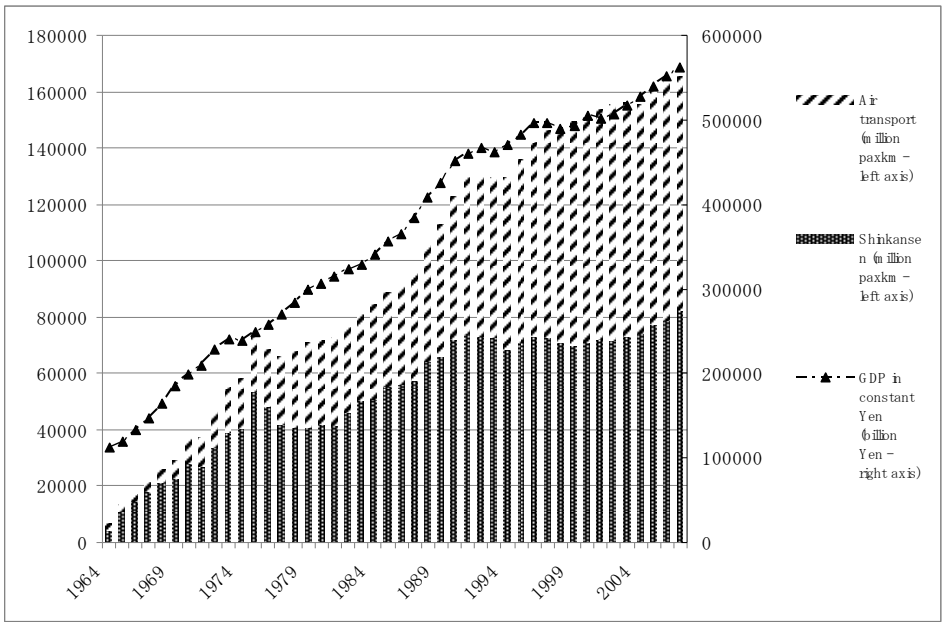
Figure 11. **Trend in share of air transport in distance groups**



3.2 Modal split between Shinkansen and air transport

From Figure 12, we can see that the aggregate demand growth of Shinkansen and air transport has basically paralleled that of GDP. When Shinkansen ridership growth stagnated between 1975 and 1985, air transport seems to have filled the gap. In order to clarify this modal choice relationship, the following logit model was estimated.

Figure 12. **Trend in GDP and passenger kilometer of Shinkansen and air transport**



3.2.1. Logit model

Here we conduct a logit model analysis using pooled historical data. Let U_k be the utility of choosing transport mode k composed of deterministic portion V_k and random variable δ so that,

$U_k = V_k + \delta$.

There are two transport modes; railway (R) and air transport (A). Let V_k be a function of price and defined as follows:

$V_k = \alpha + \beta\, p_k$

where ,

p_k : fare of mode k, and,

α, β : parameters.

The probability of choosing air transport or railway would be,

$P_A = \dfrac{\exp(V_A)}{\exp(V_R) + \exp(V_A)}$ and $P_R = \dfrac{\exp(V_R)}{\exp(V_R) + \exp(V_A)}$.

Let X be total demand of air transport and railway. Then,

$X_A = s_A X = P_A X$ and $X_R = s_R X = P_R X$. Thus,

$$X_A / X_R = P_A X / P_R X = P_A / P_R = \exp(V_A) / \exp(V_R).$$

Taking natural log of both sides, formula to be estimated is as follows:

$$\ln[X_A / X_R] = \ln[P_A / P_R] = \alpha + \beta(p_A - p_R) + \varepsilon$$

Where ε is the error term.

3.2.2. Description of data

The ridership statistics is available for both Shinkansen and air transport. While route segment data is available for air transport, railway on-board segment data including that of Shinkansen, is however not available. It is not possible, from railway statistics to discern how many passengers got on-board Shinkansen at Tokyo and got off at Osaka.

In order to identify inter-prefectural transport, a Regional Passenger Flow Survey has been conducted annually since 1960. Through this survey, it is possible to know how many people traveled between and within the 47 prefectures. A break-down in different modes of travel is provided. Therefore, it is possible to know how many people traveled between the Tokyo and Osaka Prefectures. When a multi-modal trip is made, each ridership on individual mode is counted as one. Also, the purpose of travel is unknown. These limitations given, this survey does give valuable inter-prefectural data.

In order to complement the unknown factors, Trunk Route Passenger Flow Survey has been conducted every five years since 1990. The latest survey was conducted in 2005. This detailed survey is conducted for a single day in autumn and compiled into 207 zones. Level of transport service between zones is compiled from publicly available timetables.

There are two datasets for X. Data-set A is composed of a number of annual passenger-kilometers performed by Shinkansen and air transport (1965-2007). Data-set B is composed of a total number of trips made over 300km via railway and air transport (1968-2007). As for transport cost p, Shinkansen and airfare between Tokyo and Osaka are chosen as representative price data (1964-2007). Prices are inflation-adjusted by Consumer Price Index. These data are pool and regressed by ordinary least square method.

3.2.3. Result of the estimate

Estimate of β for the two datasets are -1.2 and -1.7 respectively and both statistically significant (Table 4). They are consistent with past studies.

Table 3. **Modal split parameter**

Parameters	Data set A		Data set B	
	Parameter	t-ratio	Parameter	t-ratio
Constant(α)	0.070	1.194	0.399	4.682*
Transport Cost (β)	-1.242	-11.804*	-1.711	-9.535*
R^2	0.699		0.705	
Sample Size	43		40	

*significant at 1% level.

Average own price elasticity $\left|\beta p_k (1-s_k)\right|$ and average cross price elasticity $\left|\beta p_k s_k\right|$ calculated from estimated parameter and data sets A and B are listed in Table 4. These figures are consistent with past studies.

Table 4. **Average price elasticity**

	Data set A	Data set B
Own price elasticity (average)	0.70	0.89
Cross price elasticity (average)	0.94	1.51

Transport demand share between air transport and Shinkansen or travel over 300km by air transport and railway is significantly correlated with relative price difference. In this model however, spatial conditions and speed factors are ignored. In order to analyze the air-rail relationship in a more comprehensive manner, we need to develop a spatial model that breaks region into zones as well as to take different trip purposes into account. Looking into the future, there is also a need to consider change in population, economic growth and new technology in inter-city transport. In the following section, we develop a nation-wide inter-city transport demand model to assess the impact of the Maglev Super-express.

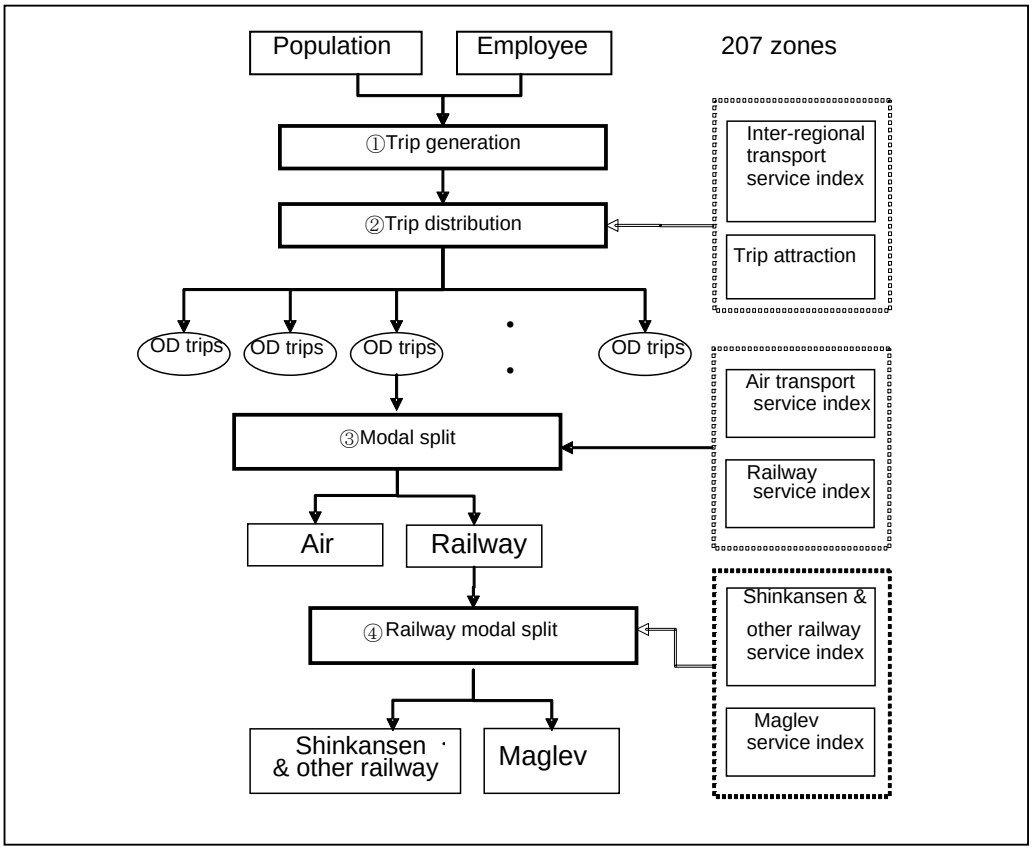
4. SIMULATION ANALYSIS OF FUTURE HIGH-SPEED INTER-CITY TRANSPORT SYSTEM WITH MAGLEV

4.1 Model structure

The model is structured in four stages as illustrated in Figure 13.

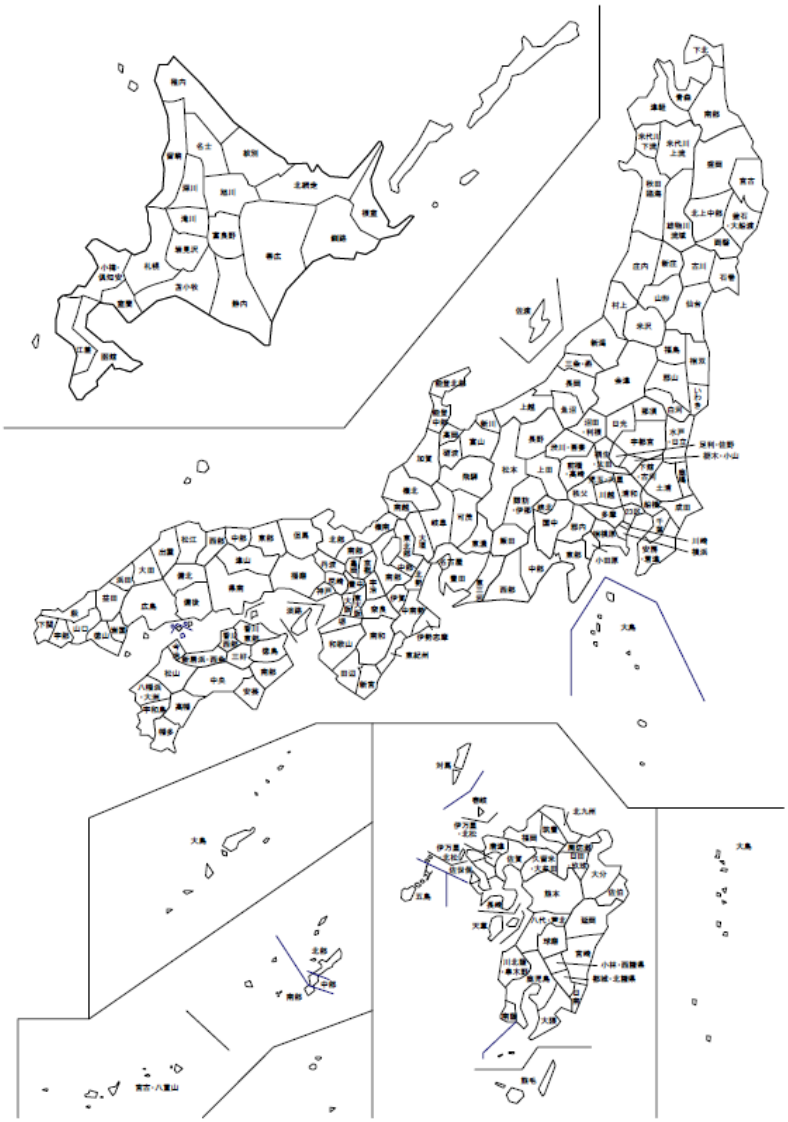
- National trip generation model;
- Zone to zone trip distribution model
- Air vs. rail modal split model
- Shinkansen and vs. Maglev choice model

Figure 13. **Model structure**



A spatial inter-city demand model is developed by breaking Japan into 207 zones as depicted in Figure 14. The model is separated into three different trip purposes: business, tourism and private.

Figure 14. **Japan in 207 Zones**



4.2. Trip generation model

4.2.1. Model structure

Trip generation is modeled as a function of population and trips per capita. For business travel, the number of employees is used for population.

$$T_{im} = POP_{im} GA_{im} \qquad (1)$$

T_{im}: trip generation in zone i with trip purpose m

POP_i: population of zone i

GA_{im}: per capita number of trips from zone i trip purpose m

4.2.2. Trip generation model

Trip generation per capita is modeled as a function of level of service and price and income elasticities. The parameter is calibrated so that current trip generation per capita of that zone matches the model value.

$$GA_i = \beta_{0i} q_i^{\beta_1} (1+n\eta) \qquad (2)$$

β_{0i} : parameter to be caliberated from current level of GA_i and accessibility index to other zones q_i

β_1: price elasticity

q_i : accessibility index derived form the trip distribution model

n: annual GDP growth rate

η: income elasticity

4.3. Trip distribution model

The objective of the trip distribution model is to allocate trips generated in a specific zone (zone i) to other destinations. We use a nested logit model to calculate the proportion of the trips to the destinations. From zone i, probability of zone j being selected as a destination (P_{ij}) depends on utility level of trip between zone i and zone j (Vij) among the available destinations. The utility level of a trip between zones i and j depends on the service level of transport modes between the two zones (q_{ij}) and the attraction factor of the destination zone j (S_j). q_{ij} is derived from log-sum of transport mode selection model described below. The aggregation of trips destined to zone j is used as the attraction factor of zone j.

Parameter θ_1^D used in the log-sum factor is an estimated figure from the Appendix.

$$q_i = \frac{1}{\theta_1^D} \ln\left[\sum_j \exp\left(V_{ij}\right)\right] \qquad (3)$$

$$P_{ij}^D = \frac{\exp\left(V_{ij}\right)}{\sum_j \exp\left(V_{ij}\right)} \qquad (4)$$

$$V_{ij} = \theta_1^D q_{ij} + \theta_2^D \ln S_j \qquad (5)$$

$$q_{ij} = \frac{1}{\theta_1^S} \ln\left[\exp\left(\theta_1^S q_{ij}^A + \theta_2^S\right) + \exp\left(\theta_1^S q_{ij}^R\right)\right] \qquad (6)$$

P_{ij}^D: probability of choosing zone j as destination

V_{ij}: utility of travelling between zones i and j

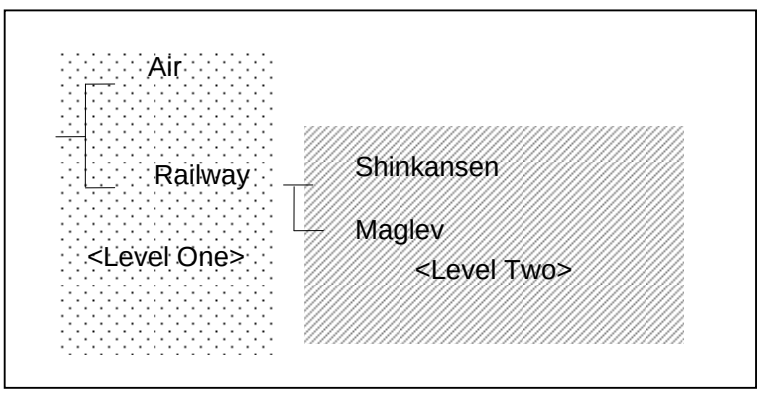
S_j: aggregate trip destination of zone j

q_{ij}: log sum value of travelling between zones i and j

4.4. Transport mode selection model

The transport mode selection model gives the modal split of the total trips between zones. We use a nested logit model. As depicted in Figure 15, the model is structured to provide two basic transport modes "Air" and "Railway" and choice of "Shinkansen and other railway[5]" and "Maglev" for "Railway."

Figure 15. **Transport mode selection model structure**



4.4.1. Level One

The probability of transport mode k chosen for trip between zones ij is expressed in the form of aggregate multi-nominal logit function. V_{ij} is the deterministic portion of the utility associated with mode k. q_{ij}^K is the generalized price composed of time factor and out of the pocket cost. Value of time w is set exogenously from past research (See appendix for details). In the case of railway, generalized price is the weighted average of Shinkansen and Maglev. θ_1, θ_2 are parameters to be estimated.

We assume the following utility function U_{ij}^{k} of travelling between zones i and j by transport mode k composed of deterministic portion $V_{ij}^{k} = \alpha + \beta p_{ij}^{k}$ and random variable so that,

$$U_{ij}^{k} = \beta p_{ij}^{k} + \alpha + \varepsilon_{ij}^{k} \quad (7),$$

where $p_{ij}^{k} = M_{ij}^{k} + \theta T_{ij}^{k}$ as generalized cost of travelling between zones i and j by transport mode k,

M_{ij}^{k} as fare of travel between zones i and j by transport mode k,

θT_{ij}^{k} as product of θ, value of time, and T_{ij}^{k}, time it takes to travel between zones i and j by transport mode k,

α as constant and β as parameter, and

ε_{ij}^{k} as random variable with Gumbel distribution.

Then, the probability of choosing mode travelling by transport mode k between zones i and j could be expressed as follows:

$$P_{ij}^{k} = \frac{\exp\left(V_{ij}^{k}\right)}{\sum_{k=A,R} \exp\left(V_{ij}^{k}\right)} \quad (8)$$

Thus, when X_{ij} is the total travel demand between zones i and j, demand function of transport mode k would be,

$$x_{ijk} = P_{ij}^{k} X_{ij} = \frac{\exp\left(V_{ij}^{k}\right)}{\sum_{k=A,R} \exp\left(V_{ij}^{k}\right)} X_{ij} \quad (9)$$

$$P_{ij}^{\mathrm{A}} = \frac{\exp\left(V_{ij}^{Air}\right)}{\exp\left(V_{ij}^{Air}\right) + \exp\left(V_{ij}^{Rail}\right)} = \frac{\exp\left(\theta_1^S q_{ij}^{\mathrm{A}} + \theta_2^S\right)}{\exp\left(\theta_1^S q_{ij}^{\mathrm{A}} + \theta_2^S\right) + \exp\left(\theta_1^S q_{ij}^{\mathrm{R}}\right)}$$

$$q_{ij}^{R} = P_{ij}^{Linear} \cdot q_{ij}^{Linear} + P_{ij}^{Shinkansen} \cdot q_{ij}^{Shinkansen} \quad (10)$$

$$q_{ij}^{A} = w \cdot t_{ij}^{A} + p_{ij}^{A}$$

P_{ij}^{k}: Probability of choosing transport mode k between zones i and j

(k = A; air transport, k=R; railway)

V_{ij}^{k}: Utility when choosing transport mode k between zones i and j

q_{ij}^{R}: Log-sum value of railway from the Level Two model

4.4.2. *Level Two*

$$P_{ij}^{S} = \frac{\exp\left(V_{ij}^{S}/\lambda\right)}{\exp\left(V_{ij}^{S}/\lambda\right)+\exp\left(V_{ij}^{M}/\lambda\right)} = \frac{\exp\left(\theta_1^{S} q_{ij}^{S}/\lambda\right)}{\exp\left(\theta_1^{S} q_{ij}^{S}/\lambda\right)+\exp\left(\theta_1^{S} q_{ij}^{M}/\lambda\right)} \tag{11}$$

$q_{ij}^{S} = wt_{ij}^{S} + p_{ij}^{S}, q_{ij}^{M} = wt_{ij}^{L} + p_{ij}^{M}$

P_{ij}^{S}, P_{ij}^{M}: Probability of choosing S (Shinkansen) or M (Maglev)

V_{ij}^{K}: Deterministic portion of utility when travelling by K ($K \in S, M$)

q_{ij}^{R}: Log sum of travelling by railway

λ: correlation factor between S and M

The nested logit model is used to reflect consumer preference of Shinkansen and Maglev that are closer substitute than air transport and railway in general. Thus, in the second stage of modal choice, λ is a parameter that gives the level of correlation between the two alternatives, Shinkansen and Maglev. Higher the λ the two choices are independent and adding Maglev as an alternative is valued higher by trip makers. Since we do not have observable data of degree of independence between Shinkansen and Maglev, we shall use an exogenous value of 0.8 as λ.

4.5. Parameter estimation and exogenous values

Parameter estimation is conducted for a trip distribution model and a modal split model. They are detailed in the appendix.Price elasticity in the trip generator model is taken from past surveys. We use the following values. See appendix for a list of price elasticity values in past surveys.

Table 5. **Demand elasticity**

	Business	Sightseeing	Private
Price elasticity (β1)	0.7	1.5	1.5

Income elasticity in the trip generation model is also taken from past research. Income elasticity of 1.78 is used in the model based on Murakami *et al.* (2006). See appendix for a list of income elasticity values in past surveys.

4.6. Future setting of socio-economic factors and service characteristics of Maglev

4.6.1. *Population and economic growth*

Future estimates of population sizes is given by the National Institute of Population and Social Security Research at the city level. According to this estimate, national population is to decrease from 127 million to 119 million individuals; representing an approximate 6% decrease[6]. Additionally, city level data aggregated to 207 zones indicate that while metropolitan areas such as Tokyo, Yokohama, Toyota (in Nagoya region) and Amagasaki (in Kansai region) increase their population, other areas suffer decrease.

As for economic growth, the current economic situation makes it difficult to specify robust economic prospects. Thus, we consider a number of scenarios with annual growth rate ranging from 0.5% to 3%, in 0.5% intervals. The base year of the data set used in the model is 2005. Maglev Super-express inauguration year is set at 2025. Standard project duration of fifty years is used for Maglev Super-express so that the

project is evaluated though the year of 2075.

4.6.2. Service characteristics of Maglev

Following trip time reduction and increase in price between Tokyo-Nagoya and Osaka is used as a scenario of future demand estimate.

Table 6. **Service characteristics of the Maglev Super-express**

	Tokyo - Nagoya	Tokyo - Osaka
Time	40 minutes	60 minutes
Cost	1,000 Yen increase	1,000 Yen increase

Note: Twenty minutes are added at transfer point when Maglev Super-express and other railway are used in a single journey.

4.6.3. OD zones that are affected by introduction of Maglev

We need to assign OD zones that are affected by the introduction of Maglev. It is clear that OD pairs that are geographically irrelevant to the Tokyo-Nagoya-Osaka corridor need to be eliminated. Using NITAS, we identify OD pairs that currently take trips via Tokaido Shinkansen. Potential OD pairs that are currently not taking Tokaido Shinkansen but may choose Maglev once it is introduced are also included in the simulation.

4.6.4. Metropolitan zones

Three major metropolitan regions include the following prefectures. They compose the metropolitan areas of Tokyo, Osaka and Nagoya respectively.

Table 7. **Three metropolitan areas and prefecture**

	Tokyo- Region	**Hanshin- Region**	**Chukyo- Region**
prefecture	Tokyo、Kanagawa、Chiba、Saitama	Nara、Kyoto、Osaka、Hyogo	Aichi、Mie、Gifu

4.7. Result of the simulation

4.7.1. Impact of Maglev Super-express on modal split

Table 8 shows an estimated annual number of trips for the national total in 2025. Due to the decrease in population, benchmark figures without Maglev decrease by 2% compared to 2005 population case. With the introduction of Maglev Super-express between Tokyo and Nagoya, nation-wide modal split for Shinkansen and Maglev combined shifts from 75.6% to 76.1%. Table 9 depicts estimated annual number of trips for the corridor between Tokyo and Hanshin regions in 2025. There is much larger impact in this

corridor; modal split for Shinkansen and Maglev combined changing from 78.6% to 81.4%. When the Maglev Super-express connects Tokyo and Osaka via Nagoya, then 84.4% would be shared by Shinkansen and Maglev combined. Although the introduction of the Maglev Super-express does have a strong impact on air transport, more significant is the impact on Shinkansen. Indeed, more than half of Shinkansen trips are taken away by Maglev in the corridor between Tokyo and Hanshin regions.

Table 8. **Estimated annual number of trips (in millions) – national total in 2025**

	Air	Shinkansen	Maglev	Total
without Maglev	84 (24.4%)	261 (75.6%)	- -	345
with Maglev Tokyo=Nagoya	83 (23.9%)	216 (62.6%)	46 (13.4%)	345
with Maglev Tokyo=Osaka	81 (23.4%)	200 (57.9%)	64 (18.6%)	346

Table 9. **Estimated annual number of trips (in millions) – between Tokyo and Hanshin regions in 2025**

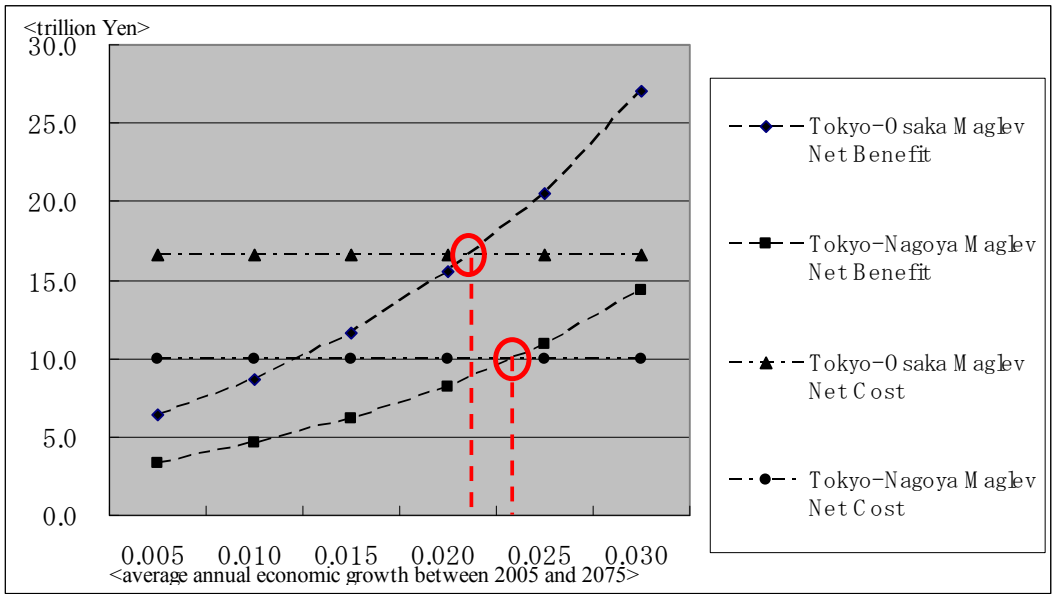
	Air	Shinkansen	Maglev	Total
without Maglev	8 (21.4%)	31 (78.6%)	- -	39
with Maglev Tokyo=Nagoya	7 (18.6%)	13 (32.8%)	19 (48.7%)	40
with Maglev Tokyo=Osaka	6 (15.6%)	11 (26.4%)	24 (58.0%)	41

4.7.2. Benefits and costs of Maglev Super-express

The future benefit of introducing Maglev Super-express depends on the level of economic growth. We conducted a sensitivity analysis of net benefit with annual growth rate ranging from 0.5% to 3% in 0.5% intervals. As for cost, we use data from a joint report by the Japan Railway Construction, Transport and Technology Agency (JRTT) and JR Central of July 2009, which revealed construction cost, maintenance cost and repair cost for the Tokyo-Nagoya Maglev Super-express with 50 years of project duration[7].

It could be observed from Figure 16 that net benefit exceeds net cost when economic growth is above the 2.0% to 2.5% range. It should be noted that net benefit is calculated in comparison to BAU case without any capacity constraint in Shinkansen or air transport. Net benefit would be greater if capacity constraint existed. With regards to annual economic growth, over 2% is a challenging target but not an inconceivable one. Future economic prospect released by the Cabinet Office of Japan in January 2009 indicates a number of different GDP growth rate cases. Depending on the speed of recovery of the world economy, Japan is expected to grow at approximately 1.5% to 2% and above for the next decade. Demand growth from emerging economies such as China and India is promising. New opportunities in environmental business, nano-technology and robotics, among others, are expected to generate growth in the Japanese economy through the twenty-first century.

Figure 16. **Net benefit and cost of Maglev introduction (trillion Yen)**



Impact of Maglev Super-express on CO_2 emission

The environmental friendly nature of Maglev technology should be noted. CO_2 emission intensity of Maglev Super-express is one third of air transport. One of the expectations of introducing Maglev Super-express is in its capability of mitigating CO_2 emission from high-speed inter-city transport.

This, however, is not precisely the case. Because Maglev Super-express, with CO_2 emission intensity five times higher than Shinkansen, attracts a considerable number of passengers not only from air transport but also from Shinkansen, total CO_2 emission from high-speed inter-city transport increases by 2.7% with Maglev Super-express between Tokyo-Nagoya and 4.9% between Tokyo-Osaka. If, however, capacity constraint in Shinkansen diverts considerable demand to air transport these estimates would need to be revised. We leave this question to future analysis.

Also, there is a possibility, that the increase in CO_2 from Shinkansen and Maglev could be mitigated by the reduction of CO_2 content of electric power supply. Due to the low utilization of nuclear energy, CO_2 content of electric power supply in Japan is five times higher than in France. There is potentially a large room for substantial reduction in CO_2 emission from this perspective.

5. CONCLUSION

In This paper, we revisited the evolution of high-speed inter-city transport in Japan and conducted a simulation analysis of introducing the next-generation transport mode, the Maglev. In a unique market in which both high-speed railway, the Shinkansen, and air transport developed simultaneously, modal choice based on price and speed has been manifested very clearly. So, in assessing the impact of Maglev Super-express planned to be introduced between Tokyo and Nagoya by 2025, we need to take into account the difference in price and speed characteristics of existing and the new transport mode.

From the simulation analysis through a dynamic spatial nested logit model, we identified a significant opportunity for the Maglev Super-express between Tokyo, Nagoya and Osaka. Accumulated social welfare and operational revenue, however, was found to exceed the net investment, maintenance and repair cost only when approximately 2% - 3% annual economic growth is achieved for the next 65 years. If such economic condition is realized, total air transport market would also continue to grow despite strong competition from the Shinkansen/Maglev system.

One other finding was Maglev's impact on CO_2 emission. Maglev could not take advantage of CO_2 emission intensity considerably lower than that of air transport. This is because Maglev attracts more passengers from Shinkansen that has five times lower CO_2 emission intensity. Increase in total CO_2 emission from electricity users including Maglev Super-express could be mitigated by energy conversion sector's effort to reduce CO_2 content of electric power supply through increase in utilization ratio of nuclear energy, for instance.

More analysis is needed to unveil the full impact of high-speed inter-city transport improvement. In particular, we need to take capacity constraint into consideration. When economic growth triggers additional trips capacity constraint in existing Shinkansen network, for instance, may divert considerable demand to air transport. If this is the case, we need to alter the BAU case and reassess net benefit and impact on CO_2 emissions. Furthermore, productivity gains, migration effects and national land-use efficiency are some of the themes that have not been covered by this paper. We look forward to further development in such areas of research.

ACKNOWLEDGMENTS

We express our appreciation to the research environment and support from the International Transport Policy Research Unit (ITPU), Graduate School of Public Policy, The University of Tokyo. We are also grateful to Kazuki Iwakami for his contributions in data analysis and Tae Hoon Oum for his enthusiasm in inter-city transport analysis.

ANNEX

Estimate of parameters for trip distribution and modal split model is conducted as follows.

i) Trip distribution model

a) Model to be estimated

Distribution model is in the following form. In order to derive function to be estimated we give a benchmark destination J_i for every i. Relative probability of allocation of trips to destination j ($i \neq j$) vis-à-vis benchmark destination J_i, leaving out OD pairs without any trips, are pooled as samples.

$$\ln\left(\frac{P_{ij}^C}{P_{iJi}^C}\right) = V_{ij} - V_{iJi} = \theta_1^D q_{ij} + \theta_2^D \ln S_j - \theta_1^D q_{ij} - \theta_2^D \ln S_{Ji}$$
$$= \theta_1^D \left(q_{ij} - q_{iJi}\right) + \theta_2^D \left(\ln S_j - \ln S_{Ji}\right)$$
$$= \theta_1^D \left(q_{ij} - q_{iJi}\right) + \theta_2^D \left(\ln \frac{S_j}{S_{Ji}}\right)$$

Ji: a random benchmark destination from zone i ($j \neq Ji$)

S_j: total trip destination to zone j

q_{ij}: log sum of trip between zones i and j

Distribution model is estimated by weighted least squares method.

$$Y = \left\{\ln\left(\frac{P_{ij}^C}{P_{iJi}^C}\right)\right\} = \theta_1^D \left(q_{ij} - q_{iJi}\right) + \theta_2^D \ln\left(\frac{S_j}{S_{Ji}}\right)$$
$$\sqrt{w_i}Y = \sqrt{w_i}\left\{\ln\left(\frac{P_{ij}^C}{P_{iJi}^C}\right)\right\} = \sqrt{w_i}\theta_1^D \left(q_{ij} - q_{iJi}\right) + \sqrt{w_i}\theta_2^D \ln\left(\frac{S_j}{S_{Ji}}\right)$$

$\sqrt{w_i}$: squared root of trip generation at zone i

b) Description of data

Table 10: **List of data**

	Item	Definition of data	Source of data
Zone data	Population	Population of the zone	National Population Census (2005, MHLW)
	Employment	Number of employees of the zone	National Population Census (2005, MHLW)
	Trip attraction factor	Aggregate number of destination trips to the zone	Inter-regional Travel Survey (2005, MLIT)
Inter-zone data	Number of O-D trips	O-D trip between zones by major transport modes and purpose of travel	Inter-regional Travel Survey (2005, MLIT)
	OD travel time	Time of travel between zones	NITAS : National Integrated Transport Analysis System (2008, MLIT)
	OD travel cost	Fares paid for travel between zones (including access and egress)	Survey of Air Passengers (2005, MLIT), JTB time table (2005, JTB)

c) Result of the parameter estimation

Result of parameter estimation is shown in Table 11. Parameters are statistically significant and R^2 at an acceptable level. Parameter for generalized cost (θ_1^D) is negative as we had expected.

Table 11: **Trip distribution parameter**

Trip distribution parameter	Business		Tourism		Private	
	Parameter	t-ratio	Parameter	t-ratio	Parameter	t-ratio
Generalized Cost (θ_1^D)	-0.294	-97.688	-0.286	-59.157	-0.361	-89.392
Trip attraction (θ_2^D)	0.765	122.545	0.703	75.642	0.551	66.505
R^2	0.684		0.531		0.642	
Sample Size	11,334		7194		7732	

ii) Modal split model

a) Model to be estimated

Probability of selecting air transport vis-à-vis railway could be expressed in the following form.

$$\frac{P_{ij}^{\mathrm{A}}}{P_{ij}^{R}} = \frac{\dfrac{\exp(V_{ij}^{\mathrm{A}})}{\exp(V_{ij}^{\mathrm{A}}) + \exp(V_{ij}^{\mathrm{R}})}}{\dfrac{\exp(V_{ij}^{\mathrm{R}})}{\exp(V_{ij}^{\mathrm{A}}) + \exp(V_{ij}^{\mathrm{R}})}} = \frac{\exp(V_{ij}^{\mathrm{A}})}{\exp(V_{ij}^{\mathrm{R}})}$$

$$\ln\left(\frac{P_{ij}^{\mathrm{A}}}{P_{ij}^{\mathrm{R}}}\right) = \ln\left(\frac{P_{ij}^{\mathrm{A}}}{1-P_{ij}^{\mathrm{A}}}\right) = V_{ij}^{\mathrm{A}} - V_{ij}^{\mathrm{R}} = \theta_1^S(q_{ij}^{\mathrm{A}} - q_{ij}^{\mathrm{R}}) + \theta_2^S$$

Larger weight is placed for OD pairs with high trip volume. We use squared root of the total OD trips between zones ij (w_{ij}). θ_1^S should be negative since higher generalized cost reduces incentive to choose that mode. Parameters θ_1^S, θ_2^S are estimated with weighted least squares method.

$$\sqrt{w_{ij}}\ln\left(\frac{P_{ij}^{\mathrm{A}}}{1-P_{ij}^{\mathrm{A}}}\right) = \sqrt{w_{ij}}\theta_1^S(q_{ij}^{\mathrm{A}} - q_{ij}^{\mathrm{R}}) + \sqrt{w_{ij}}\theta_2^S$$

w_{ij}: total number of trips between zones i and j

$$q_{ij} = \frac{1}{\theta_1^S}\ln\left[\exp\left(\theta_1^S q_{ij}^{\mathrm{A}} + \theta_2^S\right) + \exp\left(\theta_1^S q_{ij}^{\mathrm{R}}\right)\right]$$

$$q_{ij}^{\mathrm{A}} = p_{ij}^{\mathrm{A}} + wt_{ij}^{\mathrm{A}}、\ q_{ij}^{\mathrm{R}} = p_{ij}^{\mathrm{R}} + wt_{ij}^{\mathrm{R}}$$

q_{ij}^{A}: generalized cost of air transport, q_{ij}^{R}: generalized cost of railway

q_{ij}: expected generalized cost of travelling between zones i and j

w: value of time

b) Description of data

In addition to data used for estimating the trip distribution model, following value of time factor from existing literature is used to convert travel time into monetary value. This parameter is used by MLIT in air transport demand model for airport planning in Japan and is estimated from disaggregate data of air transport passengers.

Table 12. **Value of Time**

	Business	Sightseeing	Private
Time value（Yen／hr）	4,193	3,642	3,133
Time value（Yen／min）	69.88	60.70	52.22

c) Result of the parameter estimation

Result of the parameter estimation is listed in Table 13. Parameters are statistically significant. As we had expected parameter θ_1^S is negative.

Table 13. **Modal split parameter**

Modal split parameter	Business		Tourism		Private	
	Parameter	t-ratio	Parameter	t-ratio	Parameter	t-ratio
Transport Cost（θ1）	-1.433	-48.688	-0.846	-13.028	-1.113	-20.495
Constant(θ2）	-1.479	-27.462	-0.932	-11.259	-1.449	-24.511
R^2	0.699		0.303		0.487	
Sample Size	1,670		588		955	

iii）Price elasticity for trip generation model

Following is a list of major surveys of demand elasticity that were referenced.

Table 14. **Survey of demand elasticity**

		Leisure Travel	Business Travel
(i)	Air Passenger Travel (Cross-section)	1.52	1.15
	Intercity Rail Travel (Cross-section)	1.40	0.70
(ii)	Air Passenger Travel	1.10-2.70	0.40-1.60
	Intercity Rail Travel	1.40-1.60	0.60-0.70
(iii)	Air Passenger Travel (Short)	1.52	0.7

Sources:
(i) Oum, Waters and Yon (1992)
(ii) Oum, Waters and Yong (1990)
(iii) IATA and Inter VISTAS Consulting Inc. (2007)

iv) Income elasticity for trip generation model

Following is a list of major surveys of income elasticity for air transport market in Japan that were referenced.

Table 15. **Survey of income elasticity**

		Income elasticity
(i)	Ohashi *et al* (2003)	1.50
(ii)	Yamaguchi (2005)	1.44
(iii)	Murakami *et al* (2006)	1.78

NOTES

[1] As of January 2001, the Ministry of Transport was integrated with the Ministry of Construction etc., into the Ministry of Land, Infrastructure, Transport and Tourism (MLIT).

[2] 45/47 stands for 1970 and 1972 in Japan's Showa era.

[3] In 1988, the name was changed to Japan Air Systems (JAS). In 2002 it was merged with JAL to form the current Japan Airlines Inc.

[4] Apart from the two Class One airports, there are currently three others. New Tokyo International Airport, currently Narita International Airport, was constructed as a 100% government owned agency, while Kansai International Airport opened in 1994 and Chubu International Airport opened in 2005 were PFIs.

[5] Here-in-after referred to as "Shinkansen".

[6] Since there is no estimate for regional employees, we take the 2005 value as constant.

[7] Tokyo-Osaka Maglev Super-express costs were estimated by route length since no official figures were released as of July 2009. Both net benefit and net cost are present values at year 2025 depreciated by 4% per annum.

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