Topic Area code: A3

Comparative Analysis of Swiss and Japanese Trunk Railway Network Structures

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Topic Area:

A3

Paper Number:

1123

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Title:

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Abstract:

There are two typical trunk railway policies. Japanese policy established in 1970 is for building a high-speed rail network, and Swiss policy started in 1987 is for better connections at stations. Which has made up the more convenient trunk railway system? In this study, we compared trunk railway network structures of these two countries in order to answer to the question and consider what kind of policy should be a new basic rule for Japanese trunk railway network. For the purpose of detailed consideration, we calculated how much Swiss "Rail 2000" policy has shortened intercity traveling time from 1987 to 2005, using two kinds of indicators designed for intercity transportation.

Keywords:

Trunk railway policy, Rail 2000, Switzerland, Japan, Hub system, Traveling Time

Method of Presentation:

(1) OHP ( )

(2) Slide Projector ( )

(3) LCD Projector (x)

1. INTRODUCTION

1.1 Aim

Both Switzerland and Japan have developed trunk railway networks on which trains are operated very punctually. Each country has their/our own trunk railway policy, but it is very different from another one as shown in Table 1. Japanese policy established in 1970 is for construction of a high-speed rail network, and Swiss policy started in 1987 is for better connections at stations. Tens of years have passed since these policies started. Which has made up the more convenient trunk railway system?

Table 1 Trunk Railway Policies of Switzerland and Japan

	Year	Policy	Method
Switzerland	1987	Improvement of transit conditions at stations by introduction of railway hub system	Construction of high-speed lines, introduction of high-performance cars, and improvement of conventional lines to run in certain minutes
Japan	1970	Building a nationwide Shinkansen network	Only construction of high-speed lines for Shinkansen trains

In this study, we compared trunk railway network structures of these two countries in order to answer to the above question and consider what kind of policy should be a new basic rule for Japanese trunk railway network.

For the purpose of detailed consideration, we calculated how much Swiss "Rail 2000" policy has shortened intercity traveling time from 1987 to 2005, using two kinds of indicators designed for intercity transportation. One of these indicators is an integrated index for measuring convenience of transportation. It expresses average traveling time includes not only length of boarding hours but also loss time caused by intervals of train departures or transits at stations. One of others expresses only loss time and the rest for just length of boarding hours.

1.2 Intercity Railway Policies in Japan

Since the opening of the Tokaido Shinkansen in 1964, the Shinkansen network has gradually expanded with interruptions of construction. Other conventional trunk rails were constructed in Japan during Meiji era (1868-1912). After the completion, a differential of trunk rail service was sustained at a small level everywhere in Japan for almost fifty years. But the Shinkansen's appearance divided national land into two areas: with high-speed transportation and without.

In 1970, a basic plan was specifically legislated for Shinkansen network construction that included not only already opened lines or second-phase lines but also a nationwide Shinkansen network. If the entire network is completed, almost everyone who lives in any region of Japan will be able to access to high-speed rails. But more than ten years have passed without any construction of the second-phase Shinkansen lines. There is little possibility of quickly shrinking the difference of high-speed rail service levels.

These days, railways have become the center of attention, not only for their geographical function of forming land structure but also for their ecological function of high energy efficiency. But completion of the entire project including the third-phase Shinkansen lines seems hopeless.

1.3 Intercity Railway Policies in Europe

Recently many countries have become more aware of reducing greenhouse gas emissions and have begun to switch their transportation policies to railways. EU has the Trans-European Network for Transport (TEN-T), a main project of continental unity (Anciaes 2000). In France or Germany, a high-speed rail network has been expanded for TGV or ICE.

In one of such countries, a large high-speed rail network has blossomed whose shape resembles an airline hub and spoke system. However, their high-speed rail networks have been built without consideration of changing trains at stations except some cases, and functions of the networks are different from an air hub system.

1.4 Intercity Railway Policy in Switzerland: Rail 2000

On the other hand, high-speed lines in Switzerland are very short, but a significant effort has been expended to improve intercity rail transportation by the National government. Such policy may serve as a reference case for future policy in Japan.

Switzerland has the most characteristic rail policy in Europe. It is determined by the Swiss constitution, which preserves and utilizes the environment, protects the Alps from traffic pollution, and taxes automobile fuel for railway construction. For example, the government invested 30.5 billion Swiss francs to modernize old railways, excavate two long tunnels of 37 and 57 km long, reduce running noise, connect to European high-speed rail networks, and improve trunk rail networks (RJ 1999; Aoki 1999; SBB [1]; SBB [2]).

An improvement plan for intercity trunk railways is a part of the Swiss rail policy, named “Rail 2000,” that has been in effect since 1987. The country constructed a high-speed line between Olten and Bern, reformed existing rail tracks, introduced high-performance trains, and installed safety equipment to improve transfer conditions at major stations, which is Rail 2000’s main purpose. Due to these works a substantial hub system has been set up, and traveling time has been reduced in wide areas. Passengers have increased in number.

In Japan, constructing new high-speed tracks is the only method to improve our trunk railway network, but it may be time to consider alternatives. We believe that introducing a hub system like Switzerland may be an effective scheme to improve transportation convenience.

2. Measurement Method of Convenience of Intercity Transportation

2.1 Integrated Index for Intercity Transportation

Intercity transportations usually have lower frequencies than urban transportations, and each train or flight often has different traveling time, path, and transit condition. Therefore, simply totaling riding hours does not reflect actual convenience level. For example, transit conditions on Swiss rail network were improved by shrinking block times or by raising train frequencies. An ordinary indicator of required time could not reflect such changes of transportation convenience as above, so a policy like Rail 2000 cannot be suitably evaluated.

Expected Value of Traveling Time (EVTT) is an integrated index that considers traveling times, transit conditions, and operation schedules. In this paper, transportation improvements will be evaluated by using this indicator, whose measurement method is described below (Amano et al. 1991).

Figure 1 shows the EVTT concept. Vertical and horizontal axes denote traveling time between two places and travel starting time, respectively. Intercity transportation operated with intermittent departures, and traveling time of each train is displayed as a large black dot in Figure 1. For example, when using train 2, if the starting time is earlier than the departure of train 2, waiting time will increase the traveling time, and the relationship between starting and traveling times is drawn as an oblique line from the dot of the train. If passengers always use the earliest train for him, the relationship chart resembles the edge of a saw. Slower trains, shown as dotted lines in Figure 1, will not be used. EVTT is the average value of this saw-shaped chart.

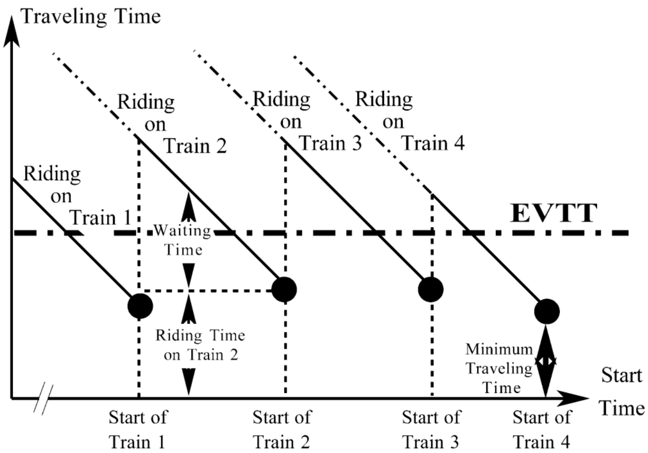

Figure 1 Expected Value of Traveling Time

EVTT is reduced by shorter traveling time or higher train frequency; however the indicator is increased by low convenience, for example, numerous unevenly operated rapid trains. Moreover, transit conditions can be reflected in EVTT by considering actual sequential rides. Expected Value of Generalized Cost (EVGC) (Nakagawa et al. 2005) is defined by replacing the traveling time with the generalized cost in Figure 1.

2.2 Loss Time of Transit or Waiting

Swiss Rail 2000 policy is characterized by improvement of transit conditions at stations. This feature can be evaluated by an index as below. In Figure 1, which explains EVTT, train 4 has the minimum riding time among the four trains. If a passenger rides every fastest train on his route, the virtual traveling time can be named "Virtual Fastest Traveling Time (VFTT)", which must be smaller than EVTT. The difference between EVTT and VFTT, which means loss time, can be named "Real Operation Loss Time (ROLTime)". It consists of the followings:

(1) Loss of prolonged traveling time caused by restrictions of a previous slower train, an oncoming train on a single truck line, detours, and full of station tracks

(2) Loss of average waiting time at initial station caused by train frequency

(3) Loss of waiting time at transit stations

Features of these indexes are summarized as Table 2.

Table 2 Features of indexes

Name	Length of boarding hours	Loss time caused by a previous slower train	Loss time caused by train frequency	Loss time caused by bad timing at stations
EVTT	Yes	Yes	Yes	Yes
VFTT	Yes	No	No	No
ROLTime	No	Yes	Yes	Yes

3. Comparison Study between Switzerland and Kyushu of Japan

3.1 Profile of Analysis Targets and Analysis Conditions

In this section, we compare Switzerland and Japan, even though the dimensions of these countries are very different. So, we only used the island of Kyushu of Japan because it has almost the same dimensions and area as Switzerland.

As shown in Table 3, despite being roughly the same size as Kyushu, Switzerland's population and density are almost half. 3,000 km national railways of SBB link a major city with another in Switzerland. On the other hand, trunk railways in Kyushu, operated by the Kyushu Railway Company (JR Kyushu), are only 2,100 km long, so railway density is higher in Switzerland than in Kyushu.

Table 3 Profiles of Switzerland and Kyushu

	Population	Gross Area	Population Density	Railway Length	Divisions
Unit	1,000 persons	km^2	persons/km^2	km	
Switzerland	7,390	41,000	180	3,000	26 cantons
Kyushu (Japan)	13,450	42,200	318	2,100	25 wide-area communities [7 prefectures]

The rail network in Switzerland is analyzed under the conditions of Table 4 and Figure 2. The network in Kyushu is also analyzed under the conditions of Table 5 and Figure 3. The year of 2005 was chosen as a target year because Swiss Rail 2000 projects have basically been completed at that time.

Table 4 Measurement Conditions of Swiss Intercity Railway

Year	1987 (Rail 2000started) and 2005 (now)
Source	1987: Thomas Cook Continental Timetable August 1987 2005: Thomas Cook European Timetable '05 Summer (Japanese edition)
Network	Considered Line: All trunk railway, some connected bus routes, some lines in next countries Considered Train: All trains operated on weekdays in Autumn Not Considered: Sightseeing, seasonal operation, dead-end, and international lines
City	Capitals of Cantons, larger cities than capitals of Canton, and hub cities of railway with more than three lines
Time	EVTT measurement: 6 a.m. – 9 p.m. Minimum transit time: Two minutes (train to train) and five minutes (train to bus)

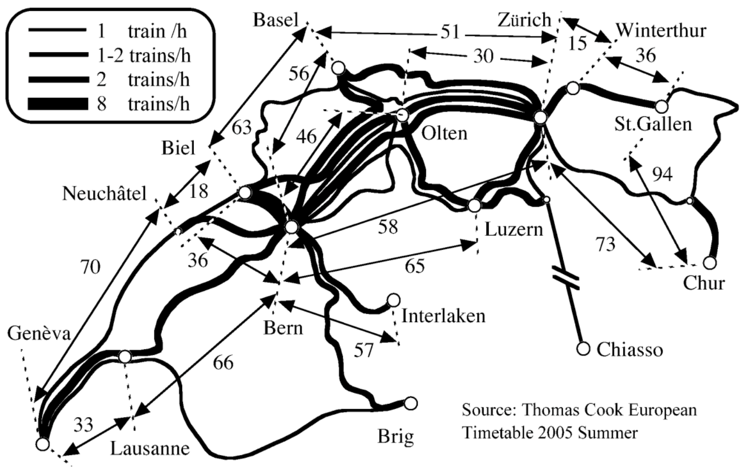

Figure 2 Train Frequency and Block Time in Switzerland

Table 5 Measurement Conditions of Kyushu Railway Network (Japan)

Year	2005 (now)
Source	Digital Timetable (Shirabe-Tarou) 2005 Autumn
Network	Considered Line: All trunk railways Considered Train: All trains operated on weekdays in autumn Not Considered: Sightseeing, seasonal operation, and dead-end lines
City	Capitals of Prefectures, central cities of wide-area communities, and hub cities of railway with more than three lines
Time	EVTT measurement: 6 a.m. – 9 p.m. Minimum transit time: Two minutes (train to train) and seven minutes (train to Shinkansen, except Shin-Yatsushiro)

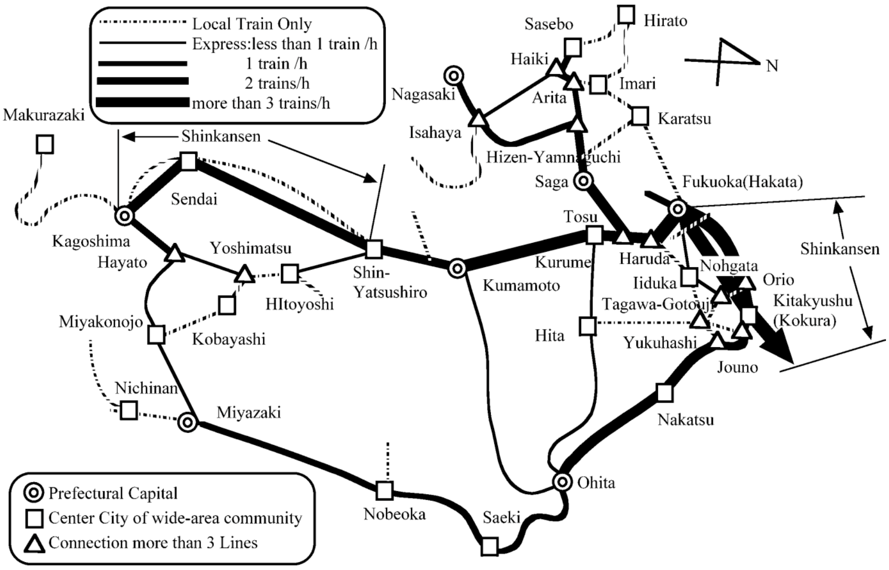

Figure 3 Railway Network and Cities in Kyushu

3.2 Comparison EVTT Study

The Expected Value of Traveling Times (EVTT) of every OD on both 2005 networks were measured. The results of Switzerland are shown in Table 6 and Kyushu's are in Table 7. Departure cities (stations) are shown on the left side columns of both tables and arrival cities in the top row.

Table 6 EVTT of Switzerland (2005)

From / To	StGallen	Herisau	Appenzell	Sargans	Glarus	Thalwil	Zurich	Weinfelden	Winterthur	Schaffhausen	Chur	Schwyz	ArthGoldau	Fluelen	Zug	Luzern	Stans	Sarnen	Brugg	Aarau	Olten	Liestal	BaselSBB	Delemont	Solothurn	Biel	Bern	Spiez	Thun	Fribourg	LaChauxDeFonds	Neuchatel	Lausanne	Geneve	Sion	Bellinzona	Lugano	Brig
StGallen	–	##	##	&	x	&	##	##	##	&	&	&	&	x	&	&	x	x	&	&	&	&	&	x	&	&	&	x	&	&	x	x	x	x		x		
Herisau	##	–	##	&	x	&	&	&	##	&	&	&	&	&	&	&	x	x	&	&	&	&	&	x	&	&	&	x	x	x	x	x	x			x	x	
Appenzell	##	##	–	&	x	&	&	&	&	&	x	x	&	x	&	x	x	x	&	&	&	x	x		x	x	x	x	x	x		x						
Sargans	&	&	&	–	##	##	##	&	&	&	##	x	&	x	&	&	&	x	&	&	&	&	&	x	&	&	&	x	x	x	x	x	x			x		
Glarus	&	&	x	##	–	##	&	&	&	&	&	x	&	x	&	&	&	x	&	&	&	&	&	x	&	x	&	x	x	x	x	x	x			x		
Thalwil	&	&	&	##	##	–	##	##	##	&	&	&	##	&	##	##	&	&	##	##	##	##	##	&	##	&	##	&	&	&	&	&	&	x	x	&	x	x
Zurich	##	&	&	##	&	##	–	##	##	##	&	&	##	&	##	##	&	&	##	##	##	##	##	&	##	##	##	&	&	&	&	&	&	&	x	&	x	x
Weinfelden	##	&	&	&	x	&	##	–	##	&	&	x	&	x	&	&	&	&	&	&	&	&	&	x	&	&	&	&	&	&	x	&	x	x		x		
Winterthur	##	##	&	&	&	##	##	##	–	##	&	&	&	x	##	&	&	&	##	##	##	&	&	&	&	&	&	&	&	&	&	&	&	x	x	x	x	x
Schaffhausen	&	&	&	&	x	&	##	##	##	–	x	x	&	x	&	&	&	&	&	&	&	&	&	&	&	&	&	&	&	&	x	&	x	x		x	x	
Chur	&	&	x	##	&	&	&	&	&	x	–	x	&	x	&	&	x	x	&	&	&	&	&	x	&	x	&	x	x	x	x	x	x			x	x	
Schwyz	&	&	x	&	x	##	##	&	&	&	x	–	##	##	##	##	&	&	&	&	&	&	&	x	&	&	&	x	x	x	x	x	x	x		&	x	x
ArthGoldau	&	&	&	&	&	##	##	&	&	&	&	##	–	##	##	##	##	&	&	&	&	&	&	&	&	&	&	&	&	&	x	&	x	x		&	&	x
Fluelen	&	&	x	x	x	&	&	&	&	&	x	##	##	–	##	##	&	&	&	&	&	&	&	x	&	x	&	x	x	x	x	x	x			&	&	x
Zug	&	&	&	&	&	##	##	&	##	&	&	##	##	##	–	##	##	##	##	##	##	&	&	&	&	&	&	&	&	&	&	&	&	x	x	&	&	x
Luzern	&	&	x	&	&	##	##	&	&	&	&	##	##	##	##	–	##	##	&	##	##	&	##	&	&	&	##	&	&	&	&	&	&	x	x	&	x	x
Stans	x	x	x	&	x	&	&	&	&	&	x	&	##	&	##	##	–	##	&	&	&	&	&	x	&	&	&	&	&	&	x	&	x	x	x	x	x	x
Sarnen	x	x	x	x	x	&	&	&	&	&	x	&	&	&	##	##	##	–	&	&	&	&	&	x	&	&	&	&	&	&	x	&	x	x		x	x	x
Brugg	&	&	&	&	&	##	##	&	##	&	&	&	&	x	##	&	&	&	–	##	##	##	##	&	##	&	##	&	&	&	&	&	&	x	x	x	x	x
Aarau	&	&	&	&	&	##	##	&	##	&	&	&	&	&	##	##	&	&	##	–	##	##	##	&	##	##	##	&	&	&	&	##	&	&	x	x	x	x
Olten	&	&	&	&	&	##	##	&	##	&	&	&	&	&	##	##	&	&	##	##	–	##	##	##	##	##	##	##	##	##	&	##	&	&	x	x	x	&
Liestal	&	&	x	&	x	##	##	&	&	&	&	x	&	x	&	&	&	&	##	##	##	–	##	&	##	##	##	&	&	&	&	&	&	x	x	x		x
BaselSBB	&	&	x	&	x	##	##	&	&	&	&	&	&	x	&	##	&	&	##	##	##	##	–	##	##	##	##	&	&	&	&	&	&	x	x	x	x	x
Delemont	x	x	x	x	x	&	&	x	&	&	x	x	x	x	&	&	x	x	&	&	##	&	##	–	##	##	&	&	&	&	&	##	&	&	x			x
Solothurn	&	&	x	&	x	##	##	&	&	&	&	&	&	x	&	##	&	&	##	##	##	##	##	##	–	##	##	&	##	##	##	##	&	&	&	x		&
Biel	&	&	x	&	x	&	##	&	&	&	x	x	&	x	&	&	&	&	&	##	##	##	##	##	##	–	##	##	##	##	##	##	##	&	&	x		&
Bern	&	&	x	&	x	##	##	&	&	&	&	&	&	x	&	##	&	&	##	##	##	##	##	&	##	##	–	##	##	##	&	##	##	&	&	x		&
Spiez	x	x	x	x	x	&	&	&	&	&	x	x	&	x	&	&	&	&	&	&	##	&	&	&	&	&	##	–	##	##	&	&	&	&	&			##
Thun	&	x	x	x	x	&	&	&	&	&	x	x	&	x	&	&	&	&	&	&	##	&	&	&	##	##	##	##	–	##	&	&	&	&	&			&
Fribourg	&	x	x	x	x	&	&	&	&	&	x	x	&	x	&	&	&	&	&	&	##	&	&	&	##	##	##	##	##	–	&	##	##	&	&			&
LaChauxDeFonds	x	x		x		&	&	x	&	x	x	x	x		&	&	x	x	&	&	&	&	&	&	##	##	&	&	&	&	–	##	&	&	&			x
Neuchatel	x	x	x	x	x	&	&	&	&	&	x	x	&	x	&	&	&	&	&	##	##	&	&	##	##	##	##	&	&	##	##	–	##	&	&			&
Lausanne	x	x		x		&	&	x	x	x	x		x		&	&	x	x	&	&	&	&	&	&	&	##	##	&	&	##	&	##	–	##	##			&
Geneve	x					x	&	x	x	x			x		x	x	x	x	x	&	&	x	&	x	&	&	&	&	&	&	&	&	##	–	&			&
Sion						x	x		x						x	x			x	x	x	x	x	x	&	&	&	&	&	&	&	&	##	&	–			##
Bellinzona	x	x		x		&	&	x	x	x	x	&	&	&	&	&	x	x	x	x	x	x	x		x		x									–	##	
Lugano						x	x		x			x	&	x	x	x	x	x	x	x	x															##	–	
Brig	x					x	x	x	x	x			x		x	x	x	x	x	x	&	x	x	x	&	&	&	##	&	&	x	&	&	&	##	x		–

##: less than 90 minutes &: less than 180 minutes x: less than 270 minutes blank: over 270 minutes

Table 7 EVTT of Kyushu Japan(2005)

From / To	Fukuoka(Hakata)	Kurume	Iiduka	Nohgata	Tagawa-Gotouji	Orio	Kitakyushu(Kokura)	Jouno	Yukuhashi	Haruda	Tosu	Saga	Hizen-Yamaguchi	Arita	Karatsu	Imari	Hirato	Nagasaki	Isahaya	Haiki	Sasebo	Kumamoto	Shin-Yatsushiro	Hitoyoshi	Ohita	Nakatsu	Hita	Saeki	Nobeoka	Miyazaki	Miyakonojo	Kobayashi	Nichinan	Kagoshima	Hayato	Yoshimatsu	Makurazaki	Sendai
Fukuoka(Hakata)	--	##	##	##	&	##	##	##	##	##	##	##	##	&	&	&	x	&	&	&	&	&	&	x	&	##	&	x						&	x			&
Kurume	##	--	&	&	&	##	##	##	&	##	##	##	##	&	&	&	x	&	&	&	&	##	##	x	&	&	##							&	x			&
Iiduka	##	##	--	##	##	##	##	&	&	##	##	&	&	&	&	x		x	&	&	x	&	&		&	&	&							x				x
Nohgata	##	&	##	--	##	##	##	##	##	&	&	&	&	&	&	x		x	x	x	x	&	x		&	&	&	x						x				x
Tagawa-Gotouji	&	&	##	##	--	##	##	##	##	&	&	&	&	x	x			x	x	x	x	x	x		&	&	&											
Orio	##	##	##	##	##	--	##	##	##	##	##	&	&	&	&	x		x	&	&	&	&	&		&	##	&	x						x				x
Kitakyushu(Kokura)	##	##	##	##	##	##	--	##	##	##	##	##	&	&	&	x		&	&	&	&	&	&		&	##	&	x						x	x			x
Jouno	##	##	&	##	##	##	##	--	##	##	##	&	&	&	&	x		x	&	&	x	&	&		&	##	&	x						x				x
Yukuhashi	##	&	&	##	##	##	##	##	--	&	&	&	&	&	&	x		x	x	x	x	&	x		##	##	&	&						x				x
Haruda	##	##	##	&	&	##	##	##	&	--	##	##	##	&	&	&	x	&	&	&	&	##	&	x	&	&	&							&	x			&
Tosu	##	##	##	&	&	##	##	##	&	##	--	##	##	##	&	&	x	&	&	&	&	##	&	x	&	&	&	x						&	x			&
Saga	##	##	&	&	&	##	##	&	&	##	##	--	##	##	&	&	x	&	##	##	&	&	&	x	x	&	&							x	x			&
Hizen-Yamaguchi	##	##	&	&	&	&	&	&	&	##	##	##	--	##	&	&	x	&	##	##	##	&	&		x	&	&							x	x			x
Arita	&	&	&	&	x	&	&	&	&	&	##	##	##	--	&	##	&	&	&	##	##	&	x		x	x	x							x				x
Karatsu	&	&	&	&	x	&	&	&	&	&	&	&	&	&	--	##	x	x	x	&	&	x	x		x	x	x											
Imari	&	&	x	x		x	x	x	x	&	&	&	&	##	&	--	&	&	&	##	&	x	x			x	x											
Hirato	x	x								x	x	x	x	&	x	&	--	x	x	&	&																	
Nagasaki	&	&	x	x	x	&	&	x	x	&	&	&	##	&	x	x		--	##	&	&	x	x			x	x											
Isahaya	&	&	&	x	x	&	&	&	&	&	&	##	##	&	x	&	x	##	--	##	&	&	x		x	x	x											x
Haiki	&	&	&	x	x	&	&	&	x	&	&	##	##	##	&	##	&	&	##	--	##	&	x		x	x	x											
Sasebo	&	&	x	x	x	&	&	x	x	&	&	&	##	##	&	##	&	&	&	##	--	x	x		x	x	x											
Kumamoto	&	##	&	&	x	&	&	&	&	&	##	&	&	&	x	x		x	&	&	&	--	##	&	x	&	&							##	&			##
Shin-Yatsushiro	&	##	&	x	x	&	&	&	x	&	&	&	&	&	x	x		x	x	x	x	##	--	&	x	x	x				x			##	&	x		##
Hitoyoshi	x	x								x	x	x										&	&	--								x		x	x	x		x
Ohita	&	&	&	&	&	&	&	&	##	&	&	x	x	x	x							x	x		--	##	x	&	&	x								
Nakatsu	##	&	&	&	&	##	##	##	##	&	&	&	&	x	x			x	x	x	x	&	x		##	--	x	&	x					x				x
Hita	&	&	&	&	&	&	&	&	&	&	&	&	&	x	x	x		x	x	x	x	&	&		x	x	--							x				x
Saeki	x	x		x		x	x	x	&	x	x														##	&		--	&	&	x							
Nobeoka							x		x																&	x		&	--	&	&		x					
Miyazaki																									x			x	&	--	##	x	&	x	&	x		x
Miyakonojo																						x	x					x	&	##	--	&	x	&	&	&		&
Kobayashi																													x	&	&	--		x	&	##		x
Nichinan																													x	&	x		--					
Kagoshima	&	&	x	x		x	x	x	x	&	&	&	x	x					x	x	x	##	##	x		x	x			x	&	x		--	##	&		##
Hayato	x	x					x			x	x	x										&	&	x					x	&	&	&	x	##	--	&		##
Yoshimatsu																						x	x	x						x	&	##		&	##	--		&
Makurazaki																																					--	
Sendai	&	&	x	x	x	x	x	x	x	&	&	&	&	x	x				x	x	x	##	##	&		x	x			x	x			##	##	x		--

##: less than 90 minutes &: less than 180 minutes x: less than 270 minutes blank: over 270 minutes

Northeast Switzerland has higher density of cities and also northern Kyushu has the same tendency, while city location patterns are not so different from each other. Both countries have many mountainous regions and a few flat regions. Swiss ODs with more than 270 minutes of EVTT (shown as blank cells in Table 6) are small in number, while there are many such ODs in Table 7 for Kyushu. For example, all ODs from/to Makurazaki in Kyushu require more than 270 EVTT minutes.

In Switzerland, EVTT range of “less than 90 minutes” or “less than 180 minutes” appears in cells not only of short distance sections but also long distance sections, including improved lines by Rail 2000. An OD from/to a city along a line from Zürich to Bern by Olten only requires a smaller EVTT than others and rarely needs more than 270 minutes. On the other hand, for Kyushu, EVTT less than 180 minutes (range of “less than 90 minutes” or “less than 180 minutes”) appears only in cells of short distances between cities in northern Kyushu.

Figure 4 is a histogram of EVTT for Switzerland and Kyushu. The mode values of the both are not so different, but the maximum values are not same. The maximum value of the Swiss network is almost 450 minutes, while Kyushu’s distribution has a very long tail, whose end is up to fifteen hours (900 minutes).

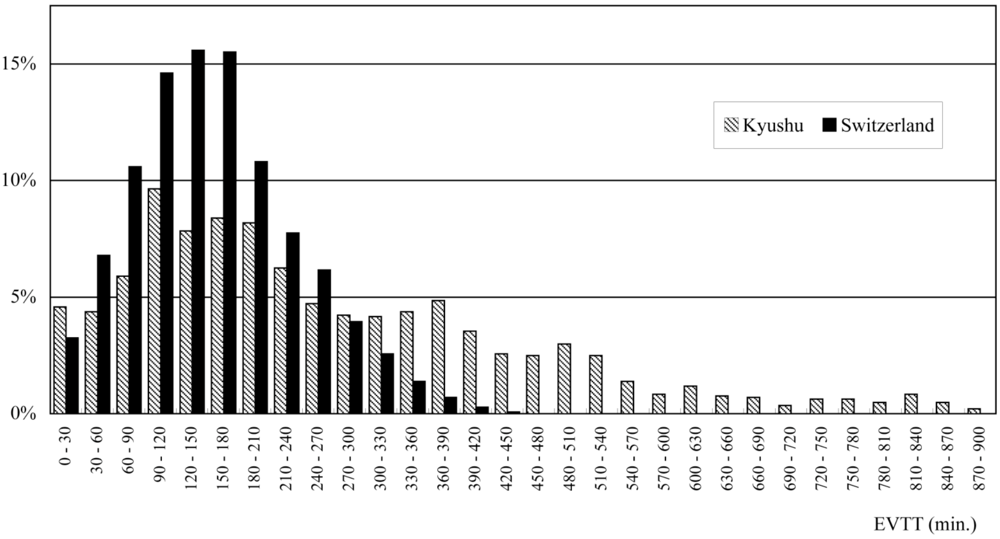

Figure 4 Distribution of EVTT

3.3 Comparison VFTT Study

Figure 5 is a histogram of Virtual Fastest Traveling Time (VFTT) for Switzerland and Kyushu. The mode values of the both distributions are not so different. The maximum VFTT is up to 270 minutes in Switzerland and more than 390 minutes in Kyushu. The difference is not as large as EVTT, but it is one of the factors that increases Kyushu's EVTT. Trains have to run on alternative routes to avoid the mountainous regions in central Kyushu. Some lines across mountainous regions are not improved, so trains have to run slowly.

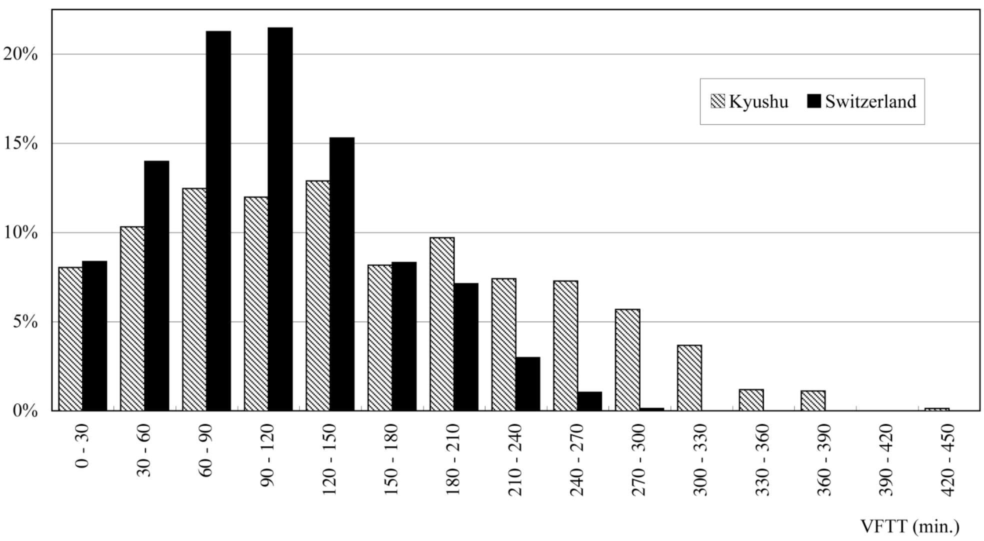

Figure 5 Distribution of Virtual Fastest Traveling Time (VFTT)

3.4 Comparison ROLTime Study

Figure 6 is a histogram of Real Operation Loss Time (ROLTime) for Switzerland and Kyushu. Half of all ODs in Switzerland belong in a range of “30 - 60 minutes,” and the ROLTime of the Swiss OD are less than most 210 minutes. On the other hand, the mode value of Kyushu’s OD falls in the range of “30 - 60 minutes,” while the ROLTime of Kyushu’s OD reaches 570 minutes, which may be a main factor of increasing Kyushu’s EVTT. This might be caused by low train frequency in Kyushu except in the northern area.

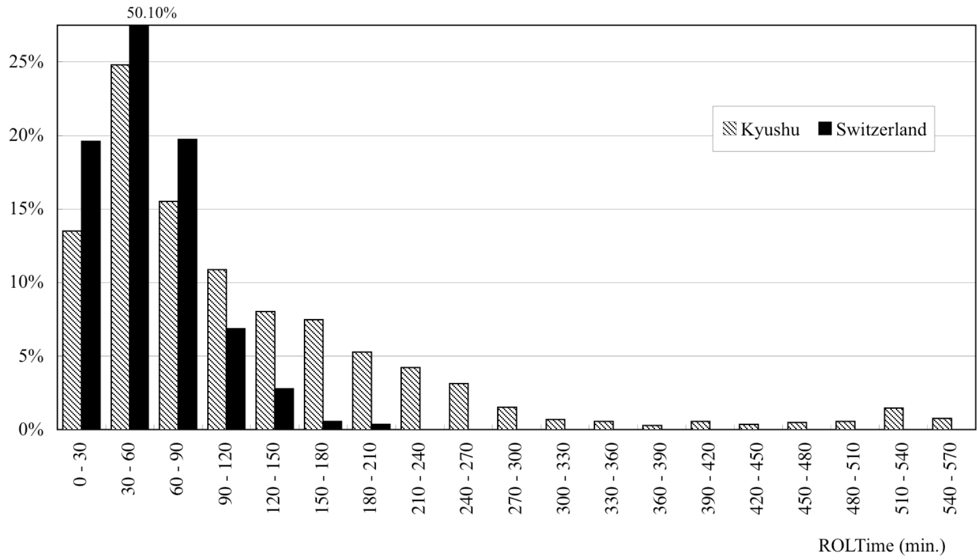

Figure 6 Distribution of Real Operation Loss Time (ROLTime)

3.5 Summary of Comparison Study in This Chapter

The results in this chapter are summarized as Table 8. Switzerland is as large as Kyushu island of Japan. But the maximum value of EVTT of Switzerland is almost half of Kyushu’s as shown in Figure 4, namely trunk railway network in Switzerland is more convenient than Kyushu. The maximum value of VFTT of Switzerland is smaller than Kyushu’s as shown in Figure 5, while the difference is not so large. The maximum value of ROLTime of Switzerland is much shorter than Kyushu’s. In other words, trains of Japan Railway Kyushu run not so slower than SBB, but train frequency or train schedule of JR Kyushu is much worse than SBB.

We think these differences between Switzerland and Japan are caused by the difference of railway policy, especially by introduction of a hub system onto the railway network in Switzerland.

Table 8 Summary of Comparison Study

Index	EVTT	VFTT	ROLTime
Meaning	Integrated Index of Intercity Transportation Convenience	Length of boarding hours (Train Speed)	Loss Time (caused by train frequency or bad timing of train schedule)
Switzerland	< 450 minutes	< 300 minutes	< 210 minutes
Kyushu (Japan)	< 900 minutes	< 400 minutes	< 570 minutes

4. Role of Hub Systems on Transportation Networks

4.1 Features of Airline Hub Systems

Air transportation is often described as hub systems on transportation networks (Chujo et al. 1995; Ohashi et al. 1999; Hino et al. 2004). Appropriate aircraft must be selected in proportion to carrying volume, because low carrying efficiency only produces scant benefit. Such multi-stop operations as railways result in low efficiency. Larger aircraft can provide cheaper service, and thus gathering air passengers to large aircraft is more profitable.

The left half of Figure 7 is a basic style that links two airports, and the right half shows a new type of network without direct links among B, C, and D. By abolishing air links, operation cost can be kept at low level, while all airports are linked by airport A. If a hub system is introduced to a transportation network, traveling times might be lengthened, and fares may also be increased. So, it is important that passengers can transit smoothly at hub airports and may pay almost the same fare as before.

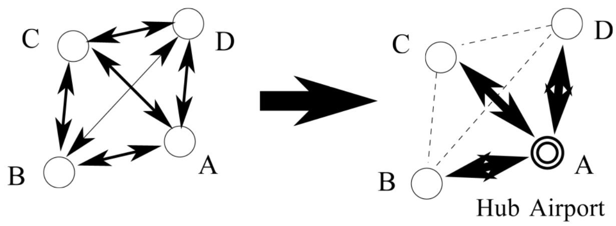

Figure 7 Hub System of Airline Network

4.2 Features of an Urban Transportation Hub System

Hub systems are also used in urban transportation networks. For example, a bus terminal is a kind of hub on a bus network, because passengers can start their travel there and transfer from one bus to another. Moreover, introducing such a system can help sustain unprofitable bus lines. If all bus stops are linked by direct bus lines, every bus line may be unprofitable, while introduction of a hub system makes feeder lines and trunk lines more efficient. This system can be installed onto urban railway networks, too.

4.3 Conditions of Trunk Railway Network Hub System in Today's Japan

Today in Japan small-scale hubs exist on trunk railway network. For example, Okayama Station is a terminal of seven trunk lines as shown in Figure 8. Passengers of these seven lines can transfer to other lines there except some cases. Travelers from Shinkansen to conventional trains (or reverse) only need a short time; however, travelers on conventional trains need a long time (Table 9). Okayama Station is not a perfect hub station because in some cases, travelers must wait for more than one hour.

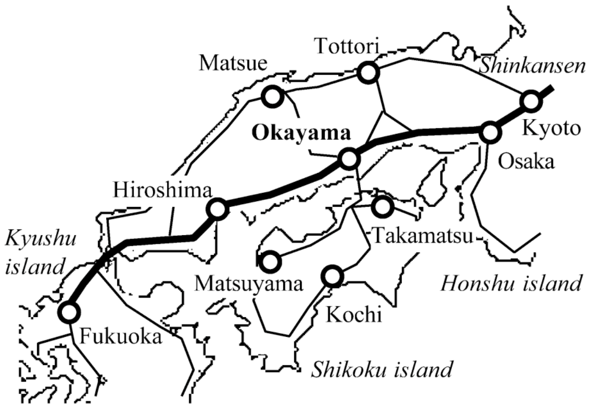

Figure 8 Major Cities in West Japan

Table 9 Transfer Time at Okayama Station [min.] (nearly noon, 2005)

To/From	Osaka	Fukuoka	Tottori	Matsue	Matsuyama	Kochi	Takamatsu
Osaka	---	*1*	12	8	9	15	7
Fukuoka	*1*	---	10	17	18	11	16
Tottori	*	*	---	*	*	*	*
Matsue	9	18	18	---	26	56	18
Matsuyama	8	17	17	24	---	---	---
Kochi	15	12	47	54	---	---	---
Takamatsu	7	8	8	15	---	---	---

*: Transit time is more than one hour, ---: Same direction, *italics: Through train*

5. Necessary Conditions for a Trunk Railway Hub System

5.1 Comparison of Airlines and Railways Features

Figure 9 indicates the relationship between journey distance and required time for express trains on conventional railways, Shinkansen, and airlines. For both express trains and Shinkansens, required time is simply proportional to journey distance. On the other hand, the proportionality factor of air transportation is smaller than railways, but air transportation always needs certain fixed time.

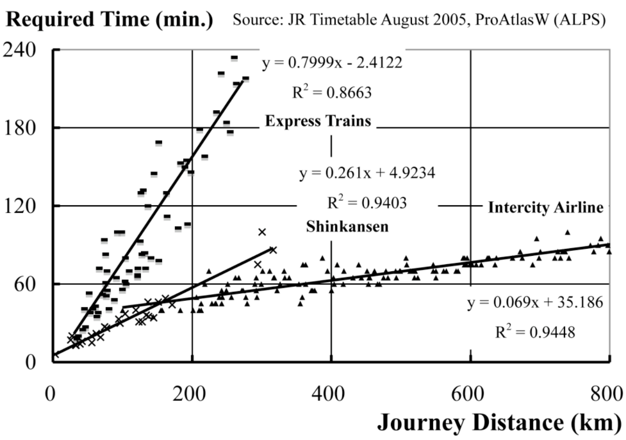

Figure 9 Journey Distance and Required Time

This feature of air transportation may influence its structure of the hub system. Distance is not a problem for air transportation, but transfer time at a hub airport is crucial. If many airlines are gathered at one hub airport despite following a roundabout way, passengers can transit from any line to other line at the hub airport. The network shape may resemble the hub and spokes of a wheel. The larger the hub airport is, the more useful the network is, because many airlines may connect there.

Since Figure 9 illustrates network shape, access times to airports are not included, and therefore the figure does not mean the most useful transportation changes from Shinkansen to airline at journey distances of 200 km.

5.2 Necessary Conditions for a Trunk Railway Hub System

On the other hand, due to slower speeds especially on conventional lines, since journey distance directly affects required time, the logical shape is not "hub and spoke" but rather a "mesh" network. Passengers must transit at many small hub stations (base stations). It is unnecessary to gather many rail lines with detours at certain stations.

Since Shinkansen trains can run three times faster than express trains on conventional slow rails (Figure 9), they seem to inhabit a middle mode between conventional trains and airlines. But the Japan's Shinkansen network has not been completed yet; if a hub and spoke system is introduced to a rail network, conventional slow rail must function as spokes. But in Japan, slow express trains might require one or two hours to cross a mountain range and reach a Shinkansen, so they cannot be spokes.

For example, if a person travels by Shinkansen or conventional slow rail from Toyama to Akita (both are on the Sea of Japan coast, see Figure 10), it takes almost the same time as Table 10. But the journey's distance by Shinkansen is as twice as slow rail. Even if backbone lines are provided as Shinkansens and rib lines are equipped as slow rails, a mesh network with a minimum journey distance may be an excellent choice.

Table 10 Toyama to Akita by Rail

	Shinkansen	Slow Rail
Journey Distance	1,003 km	511 km
Toyama Echigo-Yuzawa	Express (Hakutaka 11) 12:04 | 14:00	Express (Nihonkai 1) 22:23 | |
Echigo-Yuzawa Ohmiya	Shinkansen (Max-Toki 320) 14:08 | 15:02	| | | |
Ohmiya (via Morioka) Akita	Shinkansen (Komachi 1) 15:22 | 19:01	| | | 5:28
Time Distance	6:57	7:08

Source: JR Timetable, March 2005

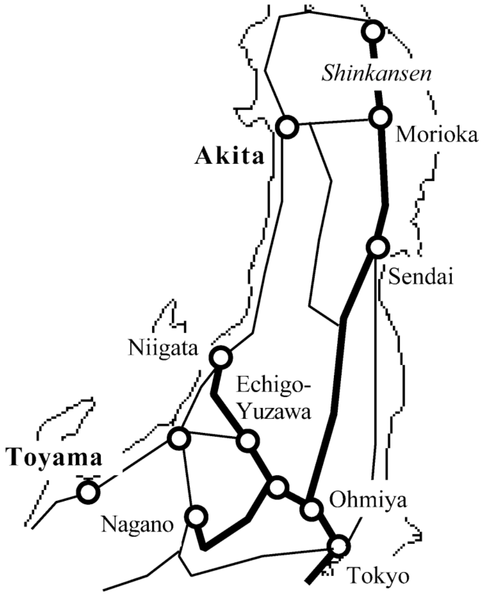

Figure 10 Major Cities in North Japan

6. Changes of Intercity Transportation Convenience by Swiss Rail 2000

6.1 Building Policy of Hub System in Rail 2000

Even though a mesh type hub system has been built in the Swiss trunk rail network, the basic concept is different from a hub and spoke airline system.

Intercity trains in Switzerland arrive at base stations on the hour and half hour (or quarter to/past), and passengers can transit there. Accordingly, total traveling time is reduced by this mesh type system. Intercity trains have to run between base stations in times shorter than multiples of 15, 30, or 60 minutes (SBB [1]; SBB [2]). Constructing high-speed lines, introducing high-performance cars, and installing safety equipments, achieve this objective of block time.

6.2 Transition of Block Time of Intercity Transportation

Figure 12 shows intercity block times in 1987 when Rail 2000 started and as recently as 2005. The construction of high-speed lines and the introduction of high-performance cars were carried out in this period. Block times of many sections are shrunk so they can run in multiples of 15, 30, or 60 minutes.

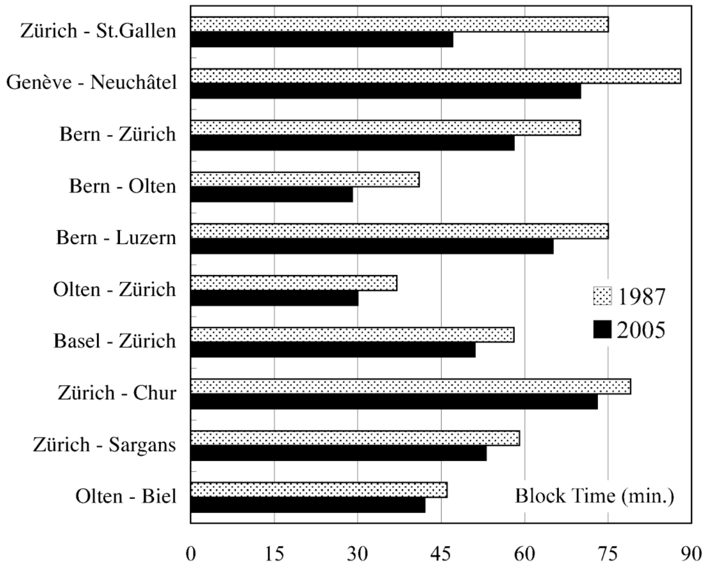

Figure 12 Comparison of Intercity Block Time

6.3 Changes of Transit Conditions

Transit conditions at base stations were improved by Rail 2000 by establishing block times less than certain times. For example, Figure 13 indicates train arrivals and departures in 1987 and 2005 for two hours from 11 a.m. to 1 p.m. at Bern Central Station. A short horizontal line means a train arrival or departure.

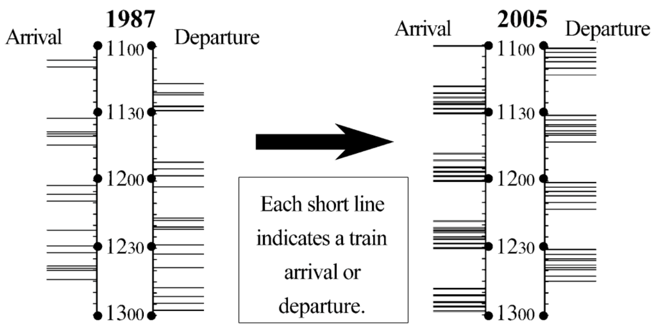

Figure 13 Comparison of Arrival and Departure Timing at Noon (Bern Station)

The number of trains increased during this period. In 1987 there was an uneven pattern, and average times from arrivals to departures were longer than in 2005. Transit conditions in 1987 were not always good. On the other hand, in 2005 arrivals and departures are clearly separated (Figure 13). All trains are just making stops every 30 minutes, and passengers can easily transit at this station. The maximum transfer time is almost 30 minutes, but it is unnecessary to transit in such cases due to reverse trains. Since the average transit time is 9.1 minutes, and the maximum is 16 minutes, Bern Central Station works as a substantial hub of a railway network.

6.4 Transition of Expected Value of Traveling Time

We measured EVTT in Switzerland under the same conditions shown in Table 4 and Figure 2. EVTT was calculated for all combinations of target cities in 1987 or 2005 and displayed in Figure 14. It shows an overall shrinkage tendency of EVTT, which is an integrated transportation convenience indicator. Shrinkage is less than 30 minutes at the EVTT range of 0 - 180 minutes in 1987 and also less than 60 minutes at the EVTT range over 180 minutes in 1987. Some OD's EVTTs have increased.

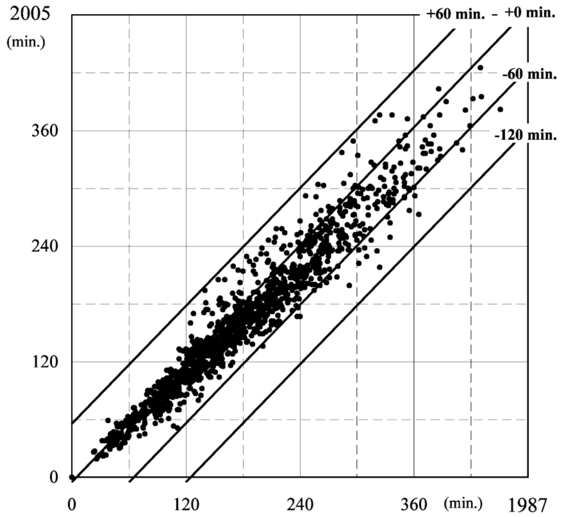

Figure 14 EVTT Transition (start time: $6_{a.m.}$-$9_{p.m.}$)

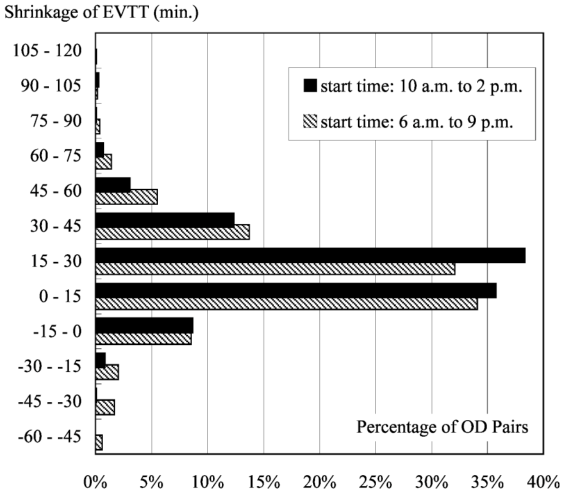

Figure 15 Distribution of EVTT Shrinkage

Figure 15 shows the distribution of EVTT shrinkage from 1987 to 2005. In the case of "$6_{a.m.}$ - $9_{p.m.}$" starting times, the ranges of "0 - 15 minutes" and "15 - 30 minutes" occupy almost 75% of all OD pairs, and the ranges of "30 - 45 minutes" and "45 - 60 minutes" occupy 15%. The largest shrinkage is 106 minutes.

On the other hand, OD pairs with enlarged EVTTs occupy 13%, but these sections may be under construction for improvement. For example, the mountainous line from Zurich to Italy by Lugarno in southern Switzerland may be improved for the opening of the 57 km long Gotthard Base Tunnel in near future.

Rail 2000 adopted a train diagram with repeated patterns, which appear most typically in daytime, as in the case of "$10_{a.m.}$ - $2_{p.m.}$" starting times in Figure 15, where OD pairs with enlarged EVTTs only occupy a small percentage.

6.5 Loss Time Changes during Transit or Waiting

In this section, we clarify the effects of increasing train frequency and improving transfer conditions by adopting an indicator of loss time that excludes riding time.

In Figure 16, the horizontal and vertical axes denote ROLTime and VFTT Shrinkage from 1987 to 2005. All ODs are dotted on this figure by ROLTime and VFTT. The downward-sloping thick line through the origin divides the plane into two areas. The dots on the upper right part are decreased in EVTT where transportation convenience has been upgraded. Those on the lower left part are increased, where convenience has been downgraded.

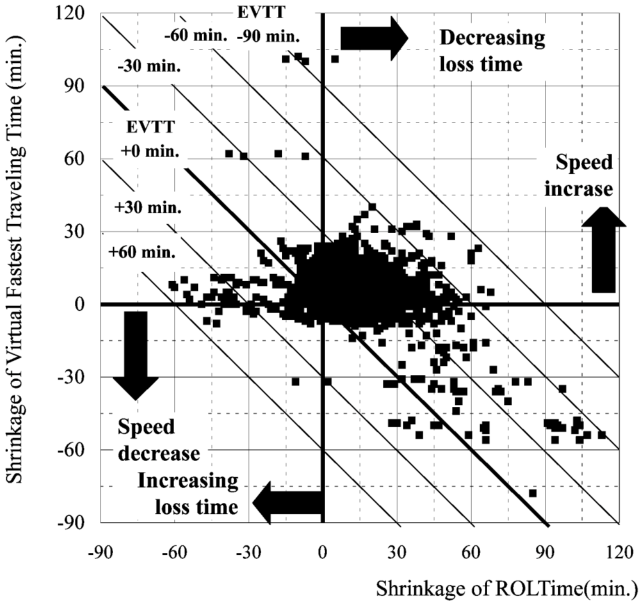

Figure 16 Component Analysis of EVTT Transition

56.4% of all ODs are dotted in the upper right square with shrinkage of both VFTT and ROLTime (speed increase and decreasing loss time), where EVTT has been improved. Conversely, only 3.7% are dotted in the opposite lower left square with enlargement of both VFTT and ROLTime (speed decrease and increasing loss time), where EVTT has deteriorated.

OD dotted in the upper left square with shrinkage of VFTT and enlargement of ROLTime (speed increase and increasing loss time) occupy 15.9% of the total, while half of the dots in this square are located in the upper of the downward-sloping thick line through the origin, where EVTT improved.

On the other hand, dots in the lower right square with VFTT enlargement and ROLTime shrinkage (speed decrease and decreasing loss time) occupy 24.0% of the total, and almost 90% of the dots in this square are located in the upper of the diagonal thick line, where EVTT improved.

In this way, shrinking ROLTime very effectively improves intercity transportation. Consequently, Rail 2000 with transit condition improvements is actually a useful policy for intercity railway.

7. Conclusion

7.1 Summary of Comparison Study between Switzerland and Kyushu Japan

We made it clear that overall convenience of railway network in Switzerland is better than Kyushu Japan. This is mainly caused by the difference not in train speed but in train frequency or train schedule. These were measured by special indexes: EVTT, VFTT, and ROLTime.

7.2 Trunk Railway Network Hub System

We considered that a fewer loss time on the railway network of Switzerland is a result of introduction of railway hub system. A rail network with many small hubs will make advantage against that with few large hubs, because even high-speed trains cannot run as fast as airplanes.

7.3 Swiss Policy: Rail 2000

We clarified that Rail 2000 policy had success in shrinkage of true traveling time. Half of this success was brought by increases of train speed and decreasing loss time, and the rest was mainly carried by only decreasing loss time even if train speed decreased. Increases of train speed without any decreases of loss time have brought almost nothing.

7.4 New Basic Rule for Trunk Railway Improvement in Japan

In Switzerland, the basic railway policy is decided in their constitution, while Japan has no integrated governmental policy for railway construction, improvement, or operation except a law for Shinkansen construction.

The Shinkansen was a principal tool of national land development legislation, which planned many Shinkansen projects. Some of these projects have been realized and opened, or are currently under construction. But many other Shinkansen plans may be hardly realized. The existing Shinkansen lines grew from megalopolises and function as the backbone of the trunk railway network. Conventional slow railways play the roles of branch lines for Shinkansens. But such Japanese trunk railway system does not as fully function as Swiss.

Railway improvement must discretely select not only the construction of high-speed rail but also other various methods. Currently, the construction of Shinkansen lines is the only national policy method for trunk railways in Japan, but conventional lines play roles in parts of nationwide trunk rail networks. Therefore policy for improving conventional lines also needs a position as clear as that for Shinkansens.

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