A Population Analysis Study of Hokkaido Railway

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Abstract: We analyze population data along all of Hokkaido railway network by quantitative method. Results of analysis are considered to be objective and correct enough, because it is based on 500 meter mesh population data.

On this study, we focus Hakodate line between Hakodate and Osyamanbe (HO-Rail), and Esashi line between Goryokaku and Kikonai (DI-Rail). HO-Rail and DI-Rail have been important main line for not only passenger trains but also freight trains. However, it is questionable that HO-Rail and DI-Rail have sustainability or not after Hokkaido Shinkansen opening/expansion.

This study is the first achievement about population analysis of all Hokkaido railway network, and we convince this achievement have enormous significance for regional science of Hokkaido.

Keywords: Population Analysis, 500 meter mesh population data, Railway Planning, Railway Management, Railway Network in Hokkaido

1. INTRODUCTION

The length of railways in Hokkaido, the second largest island in Japan, had amounted more than 4,000 kilometers about half century ago. Most of the network belonged to former Japanese National Railways (JNR). At that time, business condition of JNR was going to worse, especially in Hokkaido due to a decline of some kind of industries including coal, forestry, fishery, and so on. At the end of fiscal year of 1986, JNR was separated and privatized.

Hokkaido Railway Company (JR-H) is one of succeeded organizations of JNR. At the beginning of the fiscal year of 1987, about 2,500 kilometers of JR-H railway network were remained. So that means about 1,500 kilometers were closed.

It is said that almost all railway network of JR-H are still not profitable. Therefore, huge fund was prepared to JR-H for their financial support. JR-H has gotten investment profit from the fund and covered losses from railway commercial. This scheme is regarded as a kind of "Cross Subsidy".

Nevertheless, JR-H can hardly keep their network, and close some lines as below;

1) Hakodate Line Kami-Sunagawa branch (7.3 kilometer, 1994)
2) Shinmei line (121.8 kilometer, 1995)
3) Esashi line between Kikonai and Esahi (42.1 kilometer, 2014)
4) Esashi line between Goryokaku and Kikonai (37.8 kilometer, 2016)
   -> transferred to Donan Isaribi Railway (DI-rail)
5) Rumoi line between Rumoi and Mashike (16.7 kilometer, 2016)

The total length of closed line/section of JR-H is 225.7 kilometer.

After fire and derailment accident of Sekisho line (at 27 May 2011), many accidents and

natural disasters struck JR-H. In recent years, JR-H announced their financing difficulties, various problems, including very small transport density, and suggested more closing their railway commercial.

On the other side, Hokkaido Shinkansen will be expanded to Sapporo till the end of fiscal year of 2030. At the same time of Hokkaido Shinkansen expansion opening, Hakotade line between Hakodate and Otaru (252.5 kilometer) will be separated from JR-H. The section between Hakodate and Oshamanbe (147.6 kilometer, HO-Rail) will be remained by transferring to the third sector company due to its important role for freight trains.

It is easily observed that JR-H is in challenging state with unprofitable trunk lines and it is hard to keep their commercial of those lines. JR-H announced official statement of difficulty to keep their railway commercial on 18 November 2016. According to this statement, JR-H can keep their railway service less than half length of current network.

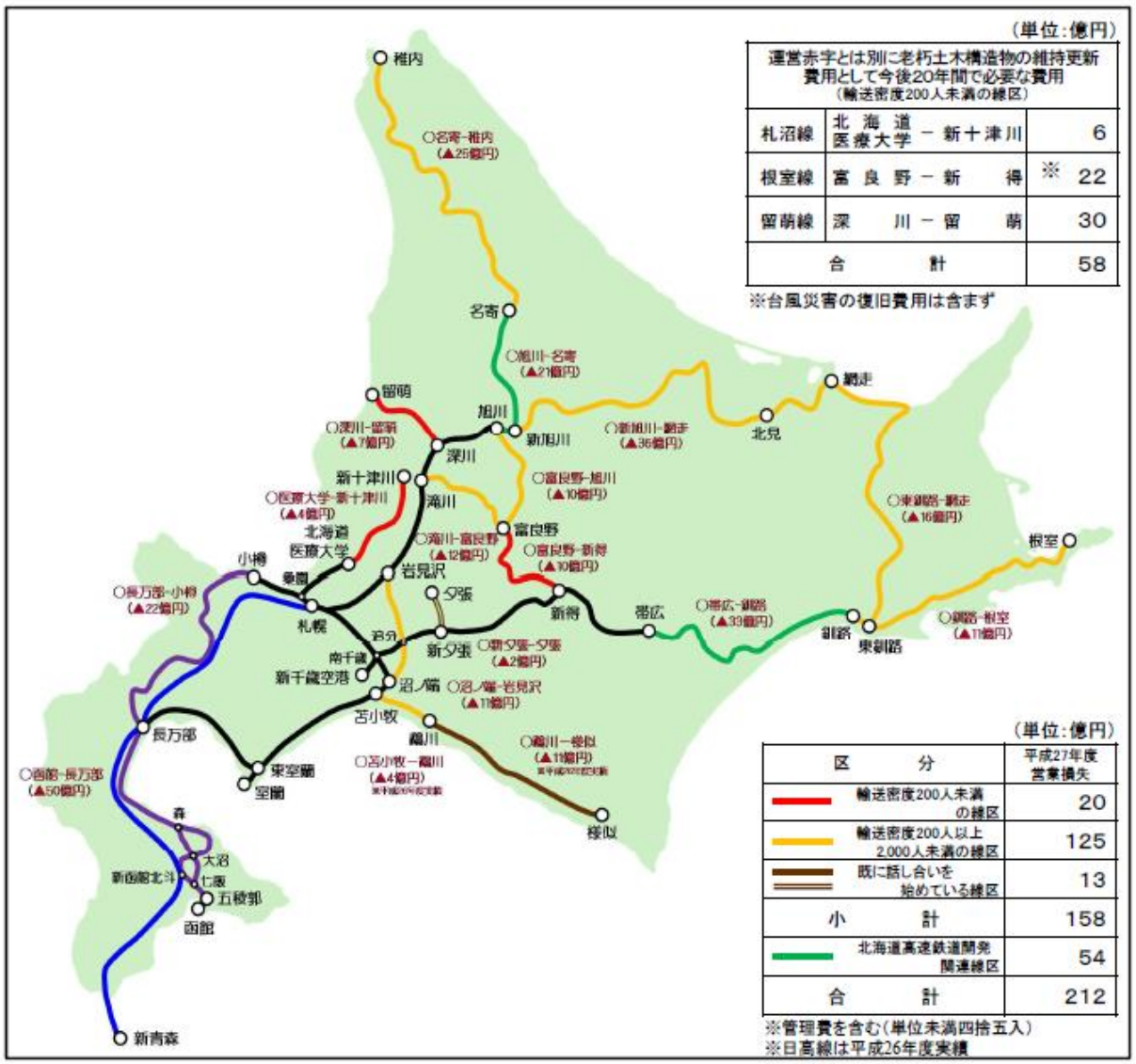

Figure 1. Current railway network map of Hokkaido Railway Company (JR-H)

* This map is a part of official statement at JR-H on 10 February 2016. According to this statement, they can keep their railway service themselves only blue/black/green lines.

On this study, we analyze population data along all of Hokkaido railway network by quantitative method. Results of analysis are considered to be objective and correct enough, because it is based on 500 meter mesh population data.

2. REVIEW and METHOD

2.1 Review of Existing Population Analysis for Railway Planning

In general, population analysis for railway planning is based on the surveyed data in each municipal or urban/metropolitan area. This method is practical for inter-regional railway planning.

But HO-Rail and DI-Rail are not considered as an inter-regional railway. Because most passengers of HO-Rail and DI-Rail may be commuters, students, hospital visitor, etc., their trip distance may be shorter than typical inter-regional passengers. And their access distance (from their residence to railway station) may be shorter too. Although we need detail analysis method for those passengers in this study, population analysis based on municipal or urban/metropolitan area is not enough for HO-rail and DI-Rail case.

Japanese central government has developed and published various GIS data during these two decades for population, land use, and so on. These data are applicable enough to this study. Uchiyama and Hibino (2000) proposed and established population analysis based on 500 meter mesh population data and 100 meter mesh land use data. Asami and Omino applied this method for case studies of regional railway revitalization. Although it is considered that this method is suitable for HO-Rail and DI-Rail case, this method needs an immense amount of time and effort, including population allocation process from 500 meter mesh to 100 meter mesh.

Hokkaido railway cases need more simple way, because residential areas are tend to be located in city center, and population of pastoral/rural area are relatively very small.

Shibahara, Kishi, and Takada (2016) defined “railway accessible population”. It means that if a 500 meter mesh includes a railway station, they define population of this 500 meter mesh as “railway accessible population”. This method, without population allocation process, is very simple but not correct, because residents living in neighbor 500 meter meshes can also access to the railway station. Therefore, we propose a revised method.

2.2 Method to analyze

We propose a revised method as follows;

1) Pick out a 500 meter mesh located center coordinate point of each railway station. We define this 500 meter mesh as “core mesh”.
2) Check eight 500 meter meshes around the core mesh. These eight 500 meter meshes are candidate of “primary meshes”.
   “Primary Meshes” are 500 meter meshes whose center coordinate point locate within 750 meters from a center coordinate point of railway station. If the two (railway station and core mesh) center ordinate points are same, primary meshes locate 5-15 minute walk distance of the station.
3) Sum up total amount of population of the core mesh and the surrounding primary meshes. We define this population as “population direct belonging to station” (DP).
4) In case of overlapping of the primary meshes, this mesh is considered to be a primary mesh of the closest station to the center coordinate point.

Residents living in core mesh or primary meshes can access railway station easily by walking. This revised method provides approximation of Asami and Omino's method, even as application of Shibahara, Kishi, and Takada's method.

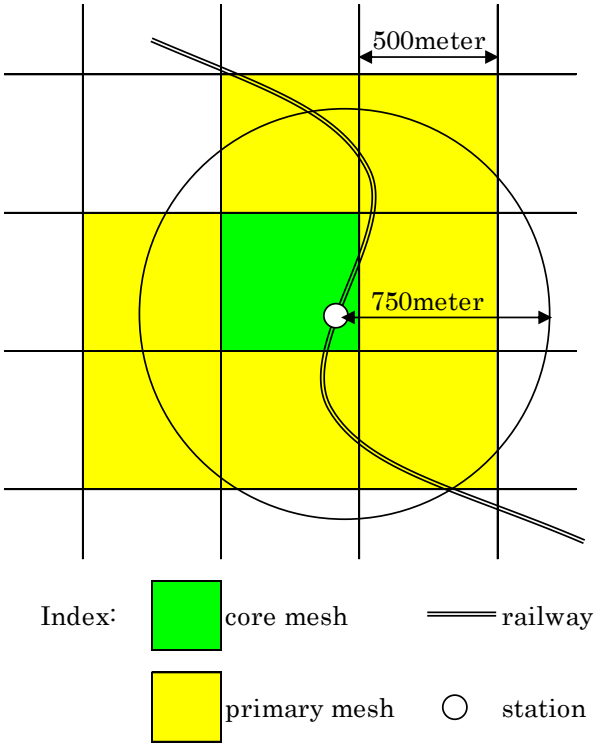

Figure 2. Location map of 500 meter meshes nearby railway station

Location map of those meshes are indicated in Figure 2. The main topic of this study is to collect each population data for relative comparison between each railway line/section.

The maximum number of primary meshes is eight. Figure 2 indicates seven primary meshes pattern.

In this study, there is no case that two railway stations locate in the same 500 meter mesh.

3. SURVEYED RAILWAY

3.1 Main Surveyed Railway

Main surveyed railways are HO-Rail and DI-Rail. But, both railways are too long to analyze. Therefore, we separate the lines into five sections.

HO-Rail
Section 1: from Hakodate to Shin-Hakodate-Hokuto, 17.9 kilometer, 6 stations
Section 2: from Shin-Hakodate-Hokuto to Mori, 66.9 kilometer, 17 stations (without Shin-Hakodate-Hokuto)
Section 3: from Mori to Oshamanbe, 62.8 kilometer, 15 stations (without Mori)
DI-Rail
Section 4: from Goryokaku to Kamiiso, 8.8 kilometer, 5 stations (without Goryokaku)
Section 5: from Kamiiso to Kikonai, 29.0 kilometer, 6 stations (without Kamiiso)

3.2 Comparison Surveyed Railway

Targeted railways of comparison analysis are all of JR-H railway lines. Comparison surveyed railway are sectioned to refer JR-H publication at 10 February 2016 (JR-H published transportation density of 30 sections).

We try comparison survey with closed lines. We focus four long closed lines; Chihoku, Tenboku, Nayoro, and Haboro (141.1km) line. These four lines are more than 100 kilometer in length. There are municipals along these four closed lines, once upon a time, these municipals are prosperous society based on primary activity. It is probable that HO-Rail, DI-Rail, and these four closed line have a common feature about geographical location.

Tenboku, Haboro, and Nayoro line have one more common feature with HO-Rail and DI-Rail. Those lines have long length seaside section.

Table 1. Results of Analysis (Main)

Line Name	Section		Section Length (L) kilometer	Number of Stations (N)	Population Direct belonging to Station (DP)			DP per unit		Traffic Density	Average passenger fare
	Start	End			Core Mesh	Primary Meshes	Total (DP)	DP/L	DP/N	number of passengers / day・kilometer	Yen / kilometer・person
Rumoi	Rumoi	Mashike	16.7	8	880	4,980	5,860	351	733	39	21.0
Sassho	Health Sciences Univercity	Shin-Totshkawa	47.6	17	954	4,883	5,837	123	343	81	11.4
Sekisho	Shin-Yubari	Yubari	16.1	5	1,009	3,540	4,549	283	910	117	20.4
Nemuro	Furano	Shintoku	81.7	8	879	4,677	5,556	68	695	155	13.0
Rumoi	Hukagawa	Rumoi	50.1	13	1,140	5,880	7,020	140	540	177	14.2
Hidaka	Mukawa	Samani	116.0	24	3,976	11,681	15,657	135	652	298	9.0
	Tomakomai	Mukawa	30.5	5	778	3,895	4,673	153	935		
Sohya	Nayoro	Wakkanai	183.2	38	2,431	11,667	14,098	77	371	487	15.0
Nemuro	Kushiro	Numuro	135.4	20	3,658	20,552	24,210	179	1,211	436	11.5
Nemuro	Takikawa	Furano	54.6	9	2,392	14,525	16,917	310	1,880	460	13.1
Senmoh	Higashi-Kushiro	Abashiri	166.2	25	2,924	13,454	16,378	99	655	466	11.8
		Subtotal	898.1	172						347	12.9
Muroran	Numanohata	Iwamizawa	67.0	11	2,968	9,993	12,961	193	1,178	516	9.8
Esashi	Kikonai	Esashi	42.1	9	1,255	4,057	5,312	126	590	618	24.1
Hakodate	Oshamanbe	Otaru	140.2	18	4,806	21,150	25,956	185	1,442	675	12.7
Sekihoku	Kamikawa	Abashiri	189.1	32	5,771		41,054	217	1,283	1,061	17.5
Muroran	Higashi-Muroran	Muroran	7.0	4	1,144	7,270	8,414	1,202	2,104	1,342	26.5
Furano	Asahikawa	Furano	54.8	17	5,680	25,527	31,207	569	1,836	1,406	12.0
Sekihoku	Shin-Asahikawa	Kamikawa	44.9	13	2,627	13,418	16,045	357	1,234	1,489	15.9
Sohya	Asahikawa	Nayoro	76.2	20	4,567	24,487	29,054	381	1,453	1,512	17.2
		Subtotal	621.3	124						1,027	14.6
Nemuro	Obihiro	Kushiro	128.3	22	5,732	23,933	29,665	231	1,348	2,259	21.0
Hakodate (HO-Rail)	Hakodate	Shin-Hakodate-Hokuto	17.6	6	3,712	24,878	28,590	1,624	4,765	3,765	22.6
	Shin-Hakodate-Hokuto	Mori	66.9	17	1,527	5,922	7,449	111	438		
	Mori	Oshamanbe	62.8	15	2,210	9,127	11,337	181	756		
Kaikyo	Kikonai	Nakaoguni	87.8	-	-	-	-	-	-	3,851	27.0
		Subtotal	363.7	60						3,255	23.4
Sekisho-Nemuro	Minami-Chitose	Obihiro	176.2	18	4,637	28,964	33,601	191	1,867	4,270	23.1
Esashi (DI-Rail)	Goryokaku	Kamiiso	8.8	5	5,693	20,229	25,922	2,946	5,184	4,377	20.9
	Kamiiso	Kikonai	29.0	6	1,371	3,493	4,864	168	811		
Muroran	Oshamanbe	Higashi-Muroran	77.2	14	8,838	40,895	49,733	644	3,552	5,022	20.0
Muroran	Higashi-Muroran	Tomakomai	58.0	16	4,319	22,848	27,167	468	1,698	7,736	19.0
		Subtotal	349.2	59						5,023	21.2
Hakodate	Iwamizawa	Asahikawa	96.2	15	4,919	27,402	32,321	336	2,155	9,320	18.0
Sassho	Souen	Health Sciences Univercity	28.9	12	15,561	84,023	99,584	3,446	8,299	16,873	16.3
Hakodate	Sapporo	Iwamizawa	40.6	12	13,945	80,566	94,511	2,328	7,876	43,025	
Chitose-Muroran	Shiroishi	Tomakomai	68.0	16	9,309	66,208	75,517	1,111	4,720	43,433	
Hakodate	Otaru	Sapporo	33.8	14	19,113	121,927	141,040	4,173	10,074	44,099	
		Subtotal	267.5	268						28,519	16.4
		Total	2499.8	683						4,791	17.0

4. RESULTS OF ANALYSIS

4.1 Remarks of Analysis

Authors analyzed DP value by each line/section, based on official statement at JR-H at 10 February 2016. Results of main analysis are indicated as Table 1.

Average passenger fare was estimated by authors as follow;

average passenger fare = Revenue / passenger kilometer

passenger kilometer = Traffic density * Section length

Number of stations does not include start stations in Table 1(exception Hakodate et. al). Number of stations is based on the data in 2016 and includes abandoned stations after 1985.

Population data is based on national population census on 2010, analyzed by authors.

Traffic density is calculated from the data in 2014 published by JR-H.

Commercial of yellow hatched line/section was closed. Esashi line between Goryokaku and Kikonai was transferred from JR-H to DI-Rail, which is a third sector company. HO-Rail will be separated from JR-H's commercial when Hokkaido Shinkansen will be expanded to Sapporo.

Kaikyo line was upgraded to Hokkaido Shinkansen, exception this analysis.

4.2 Main Analysis Results

The policy/strategy of JR-H has been not concrete, but the latest willingness of JR-H is very clear and determinate. According to the official statement of JR-H on 18 November 2016, JR-H can keep their railway service on only green hatching lines/sections. Common features of those lines/sections are as follows; traffic density is more than 2,000 (number of passengers / day･kilometer) and average passenger fare is high enough (exception Sohya line between Asahikawa and Nayoro, Muroran line between Higashi-Muroran and Muroran).

DP/L values of green hatching lines/sections are not always large. It is considered that main passengers of green hatching lines/sections may be inter-regional passengers (≒ passengers of express trains). The access transportation mode to contact railway station of such inter-regional passengers may be not only walking but also another mode (subway, bus, private owned car, taxi, etc.). It is considered that origin/destination area of such inter-regional passengers may be farther than primary/core meshes.

On the other side, DP/L values of other lines/sections are almost all small. DP/N values, traffic density, and average passenger fare are too. In generally, these values are not enough to keep train operation commercial. We can regard that JR-H should face difficulty to keep their sustainable commercial.

But this condition does not mean financial difficulty of JR-H, because they were prepared huge fund for their financial support. There is little information about financial matter concerning to JR-H, it is necessary to analyze detail financial scheme of JR-H.

In addition, the authors examined to indicate the relationship DP/N and railway productivity (shown by traffic density and average passenger fare). Figure 3 clearly indicates correlation between DP/N and traffic density. If DP/N and traffic density are less than 2000, target lines have planned to be abolish, which is same indication for indices for give up operating lines. In addition, figure 4 indicates correlation between DP/N and revenue (passenger fare), which shows revenue level is less than 15.0 yen/km, target lines have planned to be abolish. Therefore, the policy of JR-H mentions the direct productivity of each line.

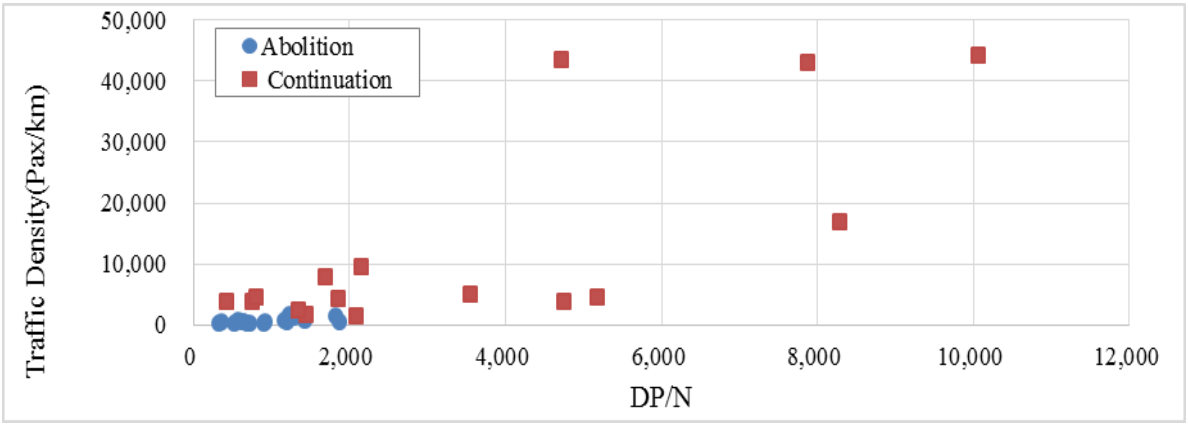

Figure 3. Results of Analysis (Correlation between DP/N and Traffic Density)

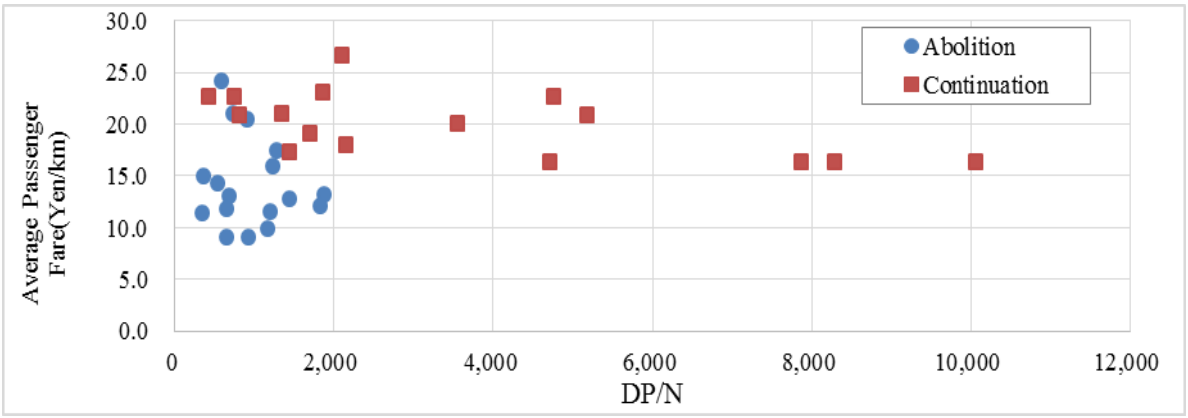

Figure 4. Results of Analysis (Correlation between DP/N and Average Passenger Fare)

4.3 Comparison Analysis Results

Table-2 shows more typical features of Hokkaido railway network. Even though we must consider there are about two decades between population data year and railway commercial closing year, DP/L and DP/N values of closed lines/sections are very small. Especially, DP/L value of Shinmei line is only 13, extremely small value. It should be right for JR-H to give up these lines/sections commercial.

The maximum DP/L value of closed lines/sections is 496, and the maximum DP/N value of closed lines/sections is 906 (both Hakodate line Kamisunagawa Branch). If DP/L value is smaller than 496, or DP/N value is smaller than 906, it is justified for JR-H to decide closing such railway's commercial.

This analysis suggests a future condition. Now some lines/sections have enough traffic density, but if inter-regional passengers shift to another transportation mode (including Hokkaido Shinkansen) and DP/L or DP/N values are small, it should be considered that commercial of such line/section is not sustainable.

We can find one another typical example, Chihoku line case. Commercial of Chihoku line, between Ikeda and Kitami, was transferred from JR-H to Hokkaido Chihoku Highland railway (CH-Rail) in 1989. CH-Rail was a third sector company, succeeded commercial of Chihoku line. Even though fund was prepared to CH-Rail for their financial support, CH-Rail could not keep their sustainable commercial. CH-Rail was closed in 2006.

DP/L value of CH-Rail is 97, and DP/N value of CH-Rail is 438. Chihoku line case suggests marginal of sustainable railway commercial.

Table 2. Results of Analysis (Comparison)

Line Name	Section		Section Length (L) *kilometer*	Number of Stations (N)	Population Direct belonging to Station (DP)			DP per unit	
	Start	*End*			*Core Mesh*	*Primary Meshes*	*Total (DP)*	*DP/L*	*DP/N*
Chihoku	Ikeda	Kitami	140.0	31	2,985	10,606	13,591	97	438
Nayoro	Nayoro	Engaru	143.0	38	3,516	16,253	19,769	138	520
Tenboku	Otoineppu	Minami-Wakkanai	148.9	28	2,440	9,444	11,884	80	424
Haboro	Rumoi	Horonobe	141.1	34	2,829	8,841	11,670	83	343
Shinmei	Hukagawa	Nayoro	121.8	25	186	1,380	1,566	13	63
Hakodate Kamisunagawa Branch	Sunagawa	Kamisunagawa	7.3	4	1,443	2,179	3,622	496	906
Rumoi	Rumoi	Mashike	16.7	8	880	4,980	5,860	351	733
Esashi	Kikonai	Esashi	42.1	9	1,255	4,057	5,312	126	590
Hakodate (HO-Rail)	Hakodate	Shin-Hakodate-Hokuto	17.6	6	3,712	24,878	28,590	1,624	4,765
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	Kamiiso	Kikonai	29.0	6	1,371	3,493	4,864	168	811

*All of commercial of gray hatched lines/sections were closed on passed year.
* Population data is based on national population census on 2010, analyzed by authors too.

4.4 Analysis Results about HO-Rail and DI-Rail

Concerning HO-Rail section 1 and DI-Rail section 4, DP/L and DP/N values are seems to be enough. These two sections are located around Hakodate city area. It is considered these two sections can keep sustainable railway commercial.

At the same time, concerning HO-Rail section 2, 3 and DI-Rail section 5, DP/L and DP/N values are small. These values are equal or larger than those of CH-Rail, but smaller than Hakodate line Kamisunagawa Branch. There is no urban area along these three sections. Furthermore, total section length of HO-Rail section 2, 3 and DI-Rail section 5 is 158.7 kilometers, far longer than Hakodate city area.

There is another collateral evidence. Local trains of HO-Rail/DI-Rail contains less cars, sometimes only one car. On the other side, express trains are long, at least five cars. These (very) short trainsets indicate that the number of passengers of HO-Rail/DI-Rail local trains is (very) small.

At the present day, statistical data hasn't published yet, it is considered that major passengers of express train are shifting from DI-Rail to Hokkaido Shinkansen. In near future, passengers of express trains will be shifting from HO-Rail to Hokkaido Shinkansen too. Considering with traffic density and average passenger fare of express train, it should be serious damage for HO-Rail and DI-Rail to lost express train.


Photo 1. Trainsets example of HO-Rail
Left: Local Train (only one car) Right: Express Train (eight cars)

5. SUMMRY

As analyzed above, it is considered that HO-Rail and DI-Rail will face great difficulty, small traffic density caused by small DP/L and DP/N values. It is no wonder that commercial of HO-Rail and DI-Rail are closed, especially section 2, 3 and 5.

HO-Rail and DI-Rail need enough fund or subsidy scheme for their sustainability railway commercial. However, is it possible to define “enough”? JR-H with huge fund faces financial problems. CH-Rail with fund closed their railway commercial, and liquidated.

This study is the first achievement about population analysis of all Hokkaido railway network, including closed lines. We convince this achievement have enormous significance for regional science of Hokkaido. But we cannot propose good solution for sustainable railway commercial of HO-Rail and DI-Rail. We must find another way to resolve this problem.

For further study, the authors need to examine the scheme to maintain railway networks in Hokkaido District. Main passenger revenue seems to consist of long-distance trip and reservation tickets for express train. When considering the two-tier scheme, if railway infrastructure are maintained by public sector or administrative institution, internal aid scheme for local train and long express train is considered to maintain the railway. However it is difficult to maintain entire existing network because of budget restriction, the main lines for inter-regional has priority to maintain by using revenue from long-distance trip. In addition local trip is to be maintained by combination of internal aid scheme and two-tire scheme or transferred to bus system.

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