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A Population Analysis for Regional Railway Commercial Sustainability

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Abstract: In this paper, the authors examined the relationship between passenger volume and number of residentials along each line on Shikoku Railway Company (JR-S) in Shikoku District in Japan. In addition, the authors tried to indicate sustainability of railway systems coping with population decreasing and potential market contraction.
Therefore the authors analyzed population using mesh data to identify population along each line for observation of different decrease level among the characteristics of each areas. In addition, we analyzed we indicated a certain degree of correlation between population and traffic density.
In conclusion, to keep railway network, population along the route is one of the important factor: Transit-oriented development (TOD) and Compact and network policy is one of the solution.

Keywords: Regional Science, Regional Planning, Railway Planning, Population Analysis, 500 meter mesh population data,

1. INTRODUCTION

The total population of Japan turned to decrease since 2008.~ Especially, population except metropolitan regions (especially far from metropolitan) is going to decrease. Japanese inter-regional railway commercial sustainability should be affected by this population trend. Then passenger of railway seems to be decreasing due to population decreasing, however, the reason is not clear.

Then In this study, we focus on Shikoku region. Shikoku is the fourth largest island in Japan. Shikoku has four prefectures and has several large cities. In general, Shikoku is regarded as one of not metropolitan regions, in addition population trend seems to be clearly indicated.

The length of railways in Shikoku used to amount to about 1,100 kilometers. Most of the network belonged to former Japanese National Railways (JNR). At the end of fiscal year of 1986, JNR was separated and privatized.

Shikoku Railway Company (JR-S) is one of successor organizations of JNR. Undergo the opening event of Honshi Bisan Ohashi Bridge, about 855 kilometers of JR-S railway network were remained. As well, some local railway lines in Shikoku were abolished, or

reconstructed to so-called third sector company (Figure 1.).

It is said that almost all railway services of JR-S are still not profitable. Therefore, huge fund was prepared to JR-S for their financial support. JR-S has gotten investment profit from this fund and covered losses from railway commercial. We can regard this scheme as a kind of "Cross Subsidy". This subsidy named "Stable business foundation" was founded by the Government of Japan and has been manipulating the fund to cover the loss, which has been dedicated for sustain intercity railway network operated by JNR. The foundation was applied to other local JR companies with weak corporate strength when privatization of JNR.

In recent years, some JR companies announced their financing difficulties. One of the reasons about background of this difficulties, population of some regions along this JR is going to decrease significantly. Their railway network includes small transport density sections, so they suggested closing some part of their railway commercial.

JR-S started to implicate that they (going to) face financing difficulties too. On this study, we analyze population data along of Shikoku railway network by well-established quantitative method. Those results can help us to evaluate those difficulties.

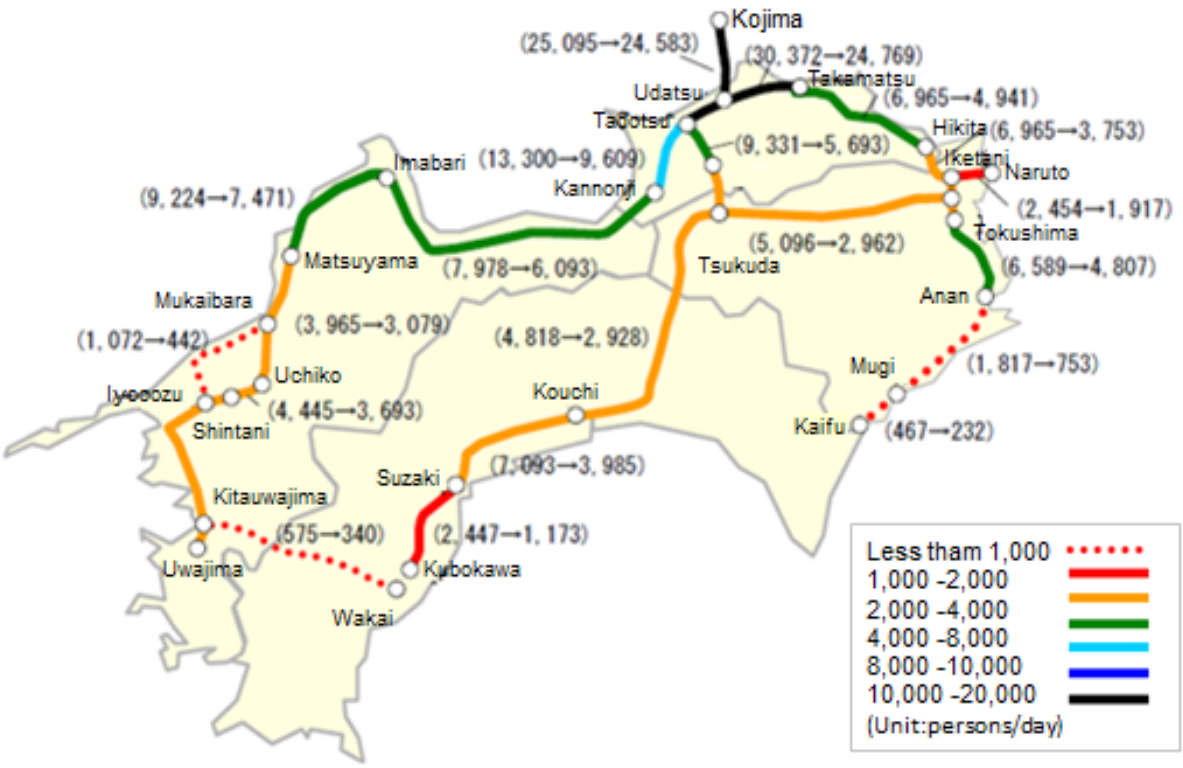

Figure 1. Current railway network map of Shikoku Railway Company (JR-S)

* This map is a part of official statement of JR-S on the web site at the beginning Fiscal year 2018. This map implicate the status of commercial sustainability of each section as color.

2. REVIEW and METHOD

2.1 Review of Existing Studies

It is considered that former population analyses method for railway planning based on the statistical data in each municipal or prefecture were correct enough. In recent years, thanks to advancement of GIS, more accurate methods are needed.

Table 1. Existing Studies for Railway Planning with GIS based population analyses

Author	Minimum unit of population	Radius of station area	Analysis year(s)	Target Railway
Oda et al.	1 km mesh	2 km	1980-2005 (every haif-decades)	Urban railway lines on Tokyo metropolitan region
Makimura et al.	500 meter mesh	1 km	1980-2005 (every haif-decades)	Urban railway lines nearby Tokyo metropolitan region central
Takeuchi et al.	500 meter mesh	750 meter	2010	Regional Railway
Ito et al.	500 meter mesh	750 meter	2000-2015 (every haif-decades)	Railway lines on Tokyo metropolitan region
Shibahara et al.	500 meter mesh	NA	2010	Regional
Asami et al.	100 meter mesh	500 meter	2000-2010 (every haif-decades)	Regional Railway (Reconstruction case)
Omino et al.	100 meter mesh	500 meter	2000-2010 (every haif-decades)	Regional Railway and Bus
Ochiai et al. **Tanaka et al.**	100 meter mesh	300, 500, 750 and 1,000 meter	2000-2015 (every haif-decades)	Recent Developed Urban Railway lines on region

＊ Shibahara et al. defined that station area is "core mesh" only.
※ with population allocation process from 500meter mesh (population) to 100 meter mesh (land use data).

Japanese government has developed and published various GIS data during these two decades for population, land use, etc. Concerning to the railway planning, several studies marked valuable achievements by applying GIS (population mesh data). Table.1 shows existing studies for railway planning with GIS based population analyses.

Asami et al, Omino et al, Ochiai et al, and Tanaka et al. applied same analyze method, population allocation process from one 500 meter mesh (population data) to twenty-five 100 meter meshes (land use data). This method is highly precise and suitable enough for urban railway planning. Of course, this method can be applied for Shikoku railway cases, but analyze data size may be mammoth. We need more simple and correct enough method.

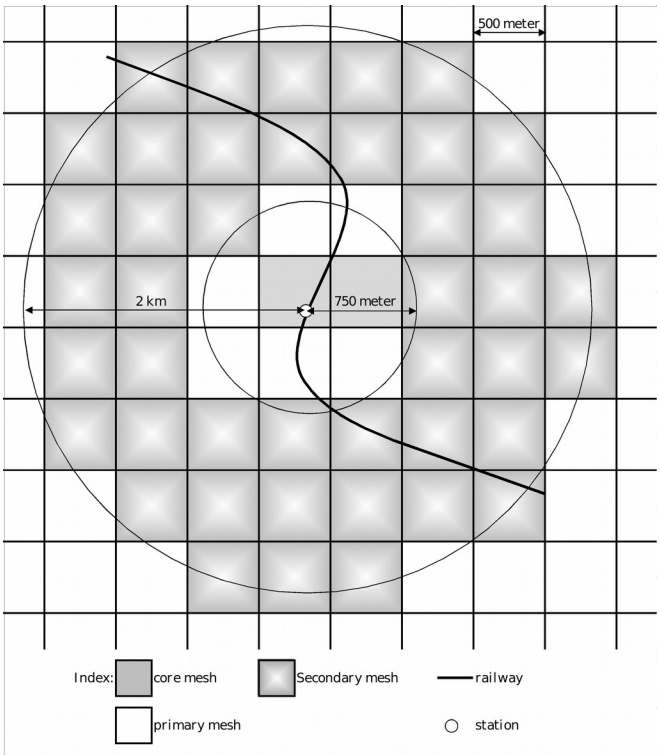

Figure 2. Location map of 500 meter meshes nearby railway station

2.2 Method to analyze

On this study, we apply a revised method based on Takeuchi et al. 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 500 meter meshes around the core mesh. If distance between central point of railway station and central point of 500 meter mesh is equal to or shorter than 750 meter, we define this 500 meter mesh as "primary mesh".
3) Check 500 meter meshes around the primary meshes. If distance between central point of railway station and central point of 500 meter mesh is equal to or shorter than 2 kilometer, we define this 500 meter mesh as "secondary mesh".
4) Sum up total amount of population of core mesh and all primary meshes. We define this population as DP_{750m}.
   DP: Population Direct belonging to railway station
5) Sum up total amount of population of core mesh, all primary meshes, and all secondary meshes. We define this population as DP_{2km}.
6) In case of overlapping of the primary/secondary meshes, this mesh is considered to be a primary/secondary mesh of the closest station.

Location map of those meshes are indicated in Figure 2. The mission of this study is to collect each population data for relative comparison.

2.3. Targeted Railway

Main targeted railways are belonging to JR-S. Moreover, we added three lines of third sector railways. We separate those railway lines into eight groups, prefectural capital city (PCC), and other municipals in the same prefecture.

3. RESULTS OF ANALYSIS

3.1 Main Analysis Results

Authors analyzed DP value by each region. Results of main analysis are showed from next pages.

Population trend of Shikoku is going to be polarized. Population of four “other municipals” is going to decrease significantly. On the other side, we can observe different population trend in four PCC. Population of Tokushima city (PCC of Tokushima prefecture) and Kochi city (PCC of Kochi prefecture) is going to decrease moderately. Especially, population of Takamatsu city (PCC of Kagawa prefecture) and Matsuyama city (PCC of Ehime prefecture) is going to increase, even in recent one half decades (Figure 3 to Figure 6).

Each DP values are going to decrease too, rather than each belonging region Even though station groups of Yosan and Kohtoku line in Takamatsu city, DP values are going to decrease.(Figure7 to 10) In addition population decrease seems to be large if lines is operated with mountain areas and few operation of inter-regional express service,

When we define N as the number of railway stations, DP/N value can be applied as an index, for example comparing with other regions.

During recent one half decades, each DP750m・PCC/N values are from 6,500 to 9,000. These absolute value are (medium) high, equal to or less than urban railway lines in sub-urban areas of Tokyo metropolitan region.

On the other side, DP750m・all Shikoku without PCC/N value are under 2,000, at least in recent one half decades. This absolute value is small, furthermore, going to be smaller.

Therefore, it is very difficult to regard JR-S (without PCC areas) as a blessed railway network with enough demand for their sustainable commercial.

In addition, authors described one more remark. Many DP2km・2015/ DP2km・2000 ratio are higher than DP750m・2015/ DP750m・2000 ratio. This fact suggest that population decreasing ratio of core / primary meshes tend to be steeper than those of secondary meshes.-(3)

According to these evidences, we cannot regard population trend of Shikoku as a result following TOD (Transit Oriented Development) process. Total population of Shikoku is going to decrease, and residents nearby stations are going to leave.

These facts indicate it is probable that JR-S will face serious difficulties, especially demand steep decrease.

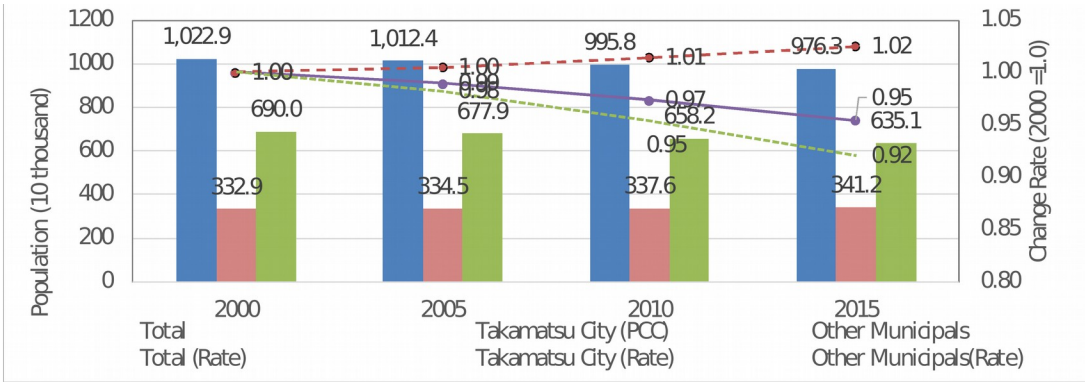

Figure 3 Total Population (Kagawa Prefecture)

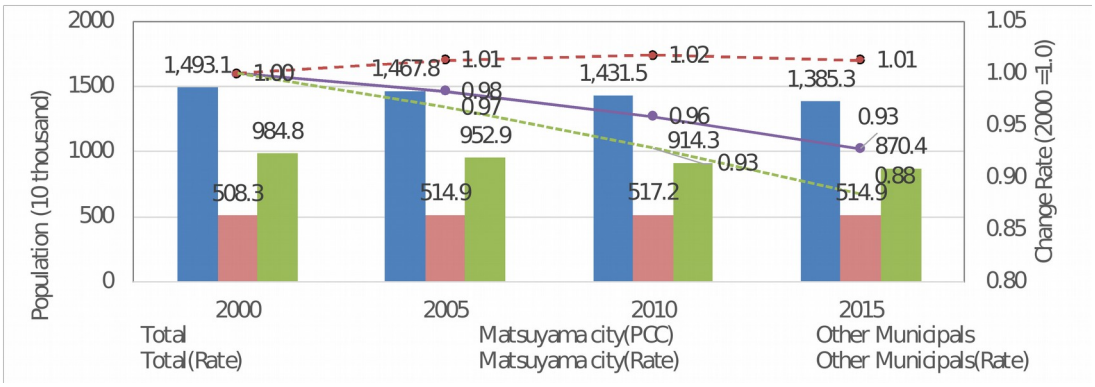

Figure 4 Total Population (Ehime Prefecture)

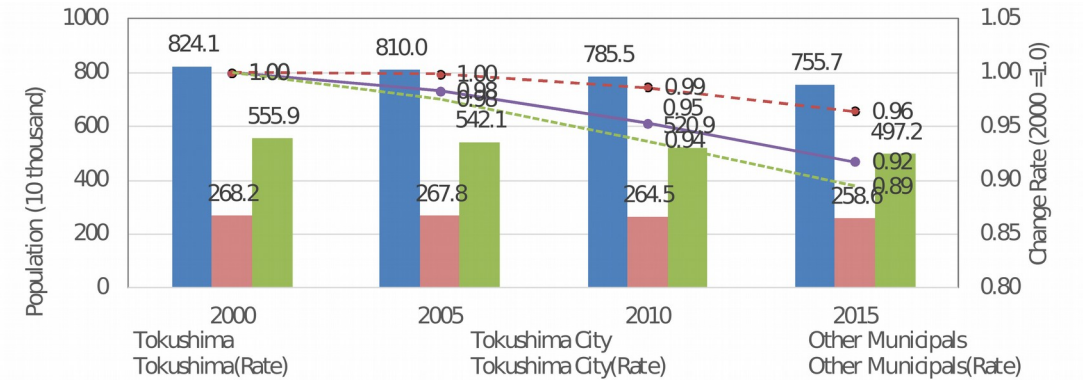

Figure 5 Total Population (Tokusihma Prefecture)

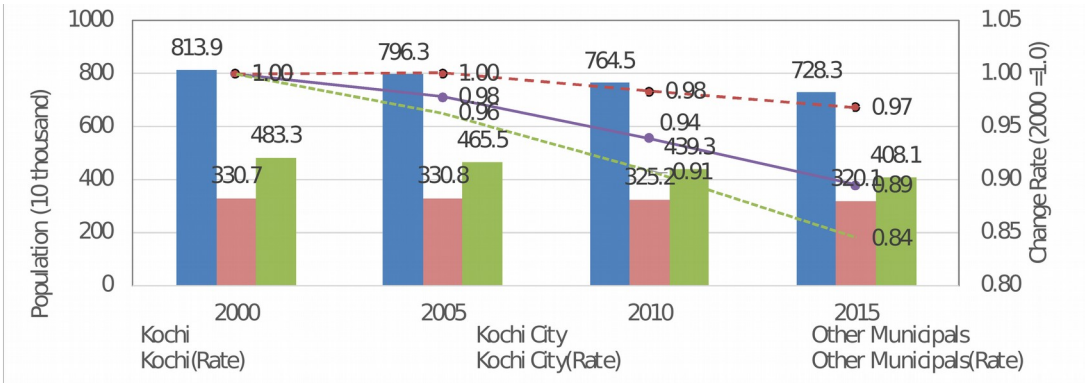

Figure 6 Total Population (Kochi Prefecture)

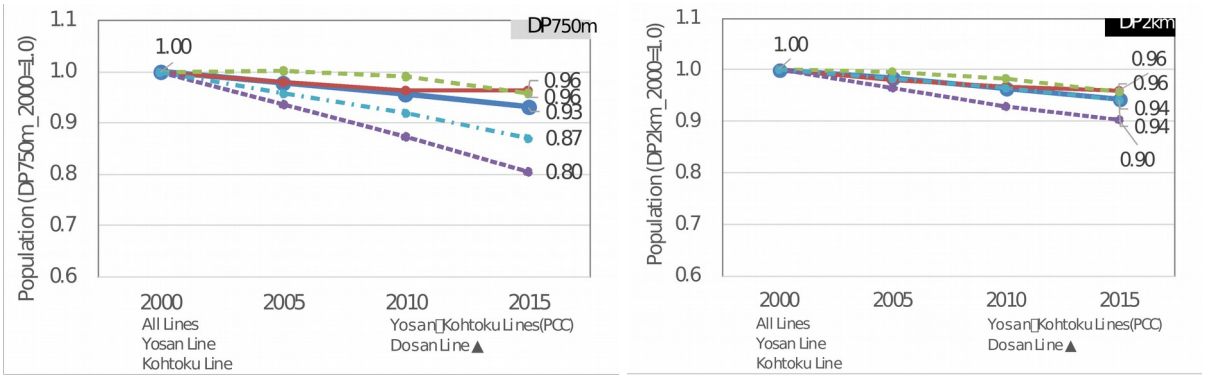

Figure 7 Population Change Along Each Line (Kagawa Prefecture)

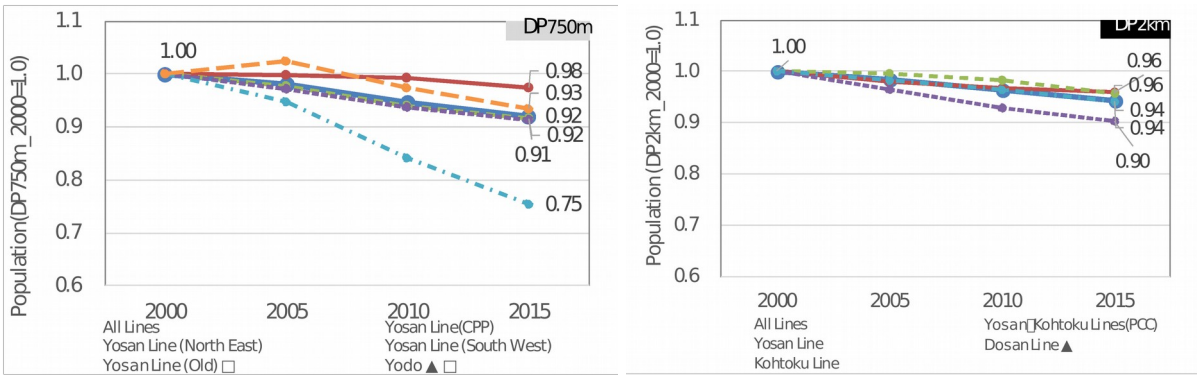

Figure 8 Population Change Along Each Line (Ehime Prefecture)

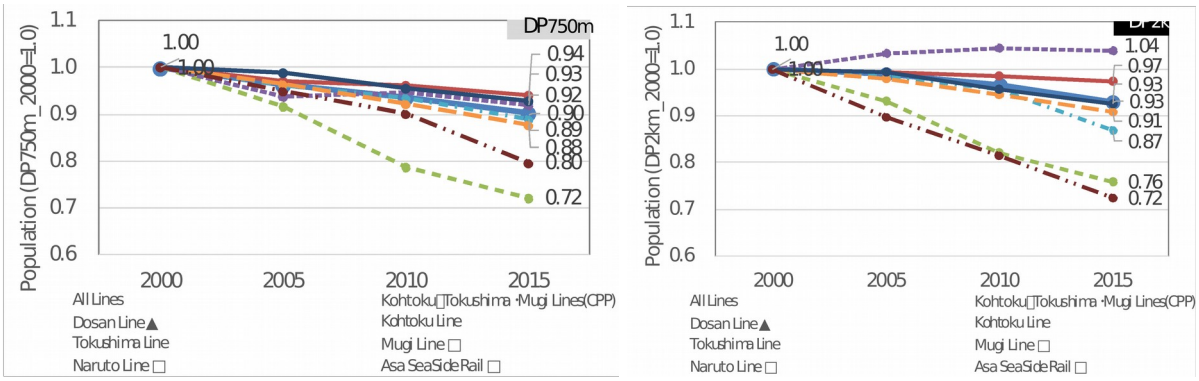

Figure 9 Population Change Along Each Line (Tokushima Prefecture)

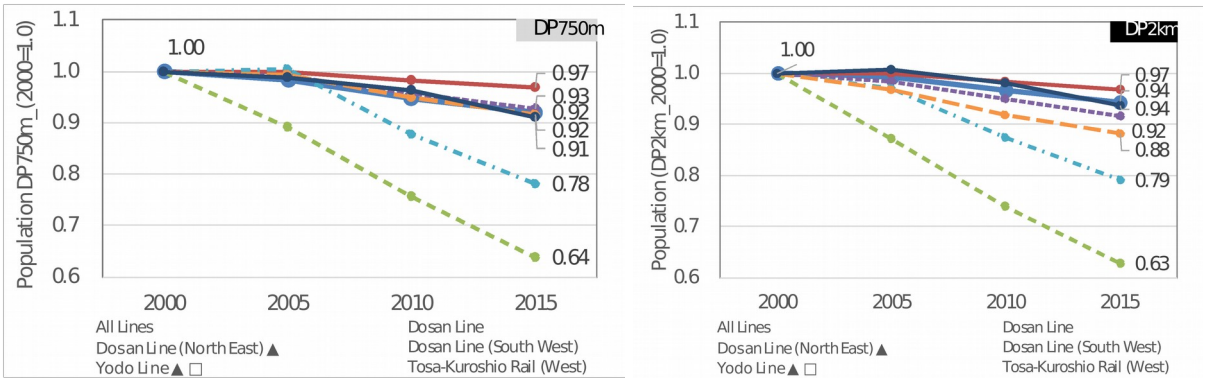

Figure 10 Population Change Along Each Line (Kouchi Prefecture)

Notes: ▲ : Lines operated on the inland mountain area
□ : Local line (Without or with a few inter-regional express service)

3.2 Correlation between DP/N value and traffic density

In recent years, JR-S published traffic density of their railway network by each section. Authors evaluated the correlation between DP/N value and traffic density. Results of this analysis is showed as Figure 11.

At first glance, Figure 11 is indicated co-relationship between $DP/N2_{km}$ and traffic density to some degree (R^2 = 0.52 between DP/N_{2km} and traffic density). In addition, coefficient of result of regression indicates elasticity of traffic density responding to population variation. From this result, if population is increase by 1 person, 0.68 passenger increase is shown.

. On the other hand, we can observe stronger correlation in the double logarithmic chart as Figure 12 (R^2 = 0.75 between DP/N_{2km} and traffic density). Correlation between DP/N value and traffic density (local trains only) is a little bit stronger.

We confirm similar correlation in the former study, population analysis for Hokkaido Railway commercial sustainability. We can understand this correlation as follows; traffic density of small DP/N value railway may be smaller, traffic density of large DP/N value railway may be larger.

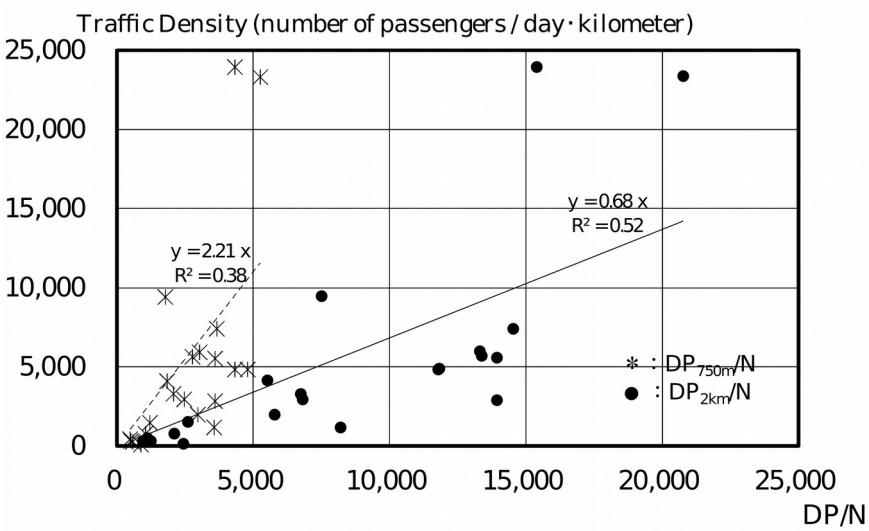

Figure 11 Correlation between DP/N value and traffic density

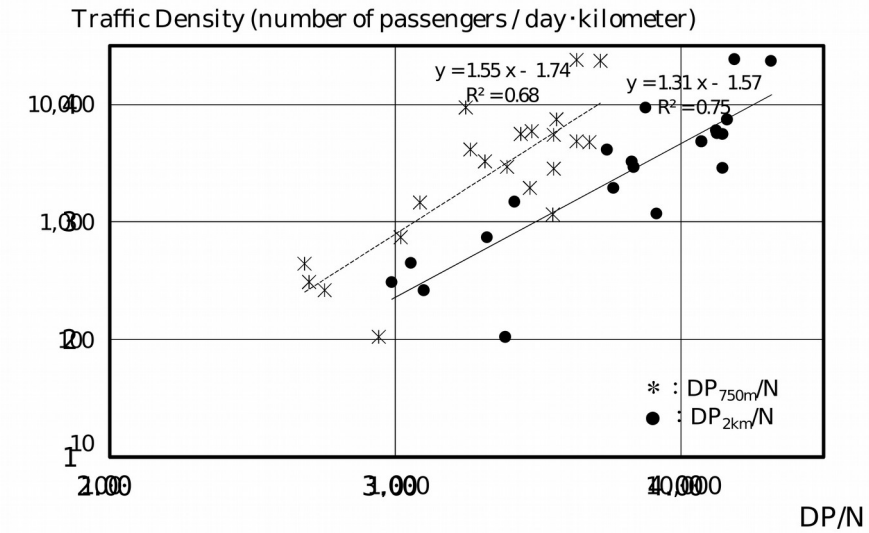

Figure 12 Correlation between DP/N value and traffic density
(Double logarithmic chart)

5. SUMMARY

As analyzed above, DP/N values of Shikoku railway network are small, and are going to be smaller. It is considered that traffic density of Shikoku railway is closely linked with these population trend. Therefore, JR-S might face great difficulty in near future according to DP/N values trend. If current "Cross Subsidy" scheme is well-suited, JR-S should need to add extra fund for their sustainability railway commercial.

The most important achievement of this study is the results of population analysis of all Shikoku railway network, by well-established quantitative method, based on authorized and correct enough statistical population mesh data. We convince this achievement have enormous significance for regional science of Shikoku.

One more important achievement, we can observe that strong correlation between DP/N values and traffic density in the double logarithmic chart. If these correlations are general phenomenon, we can provide as a new finding.

In addition, these findings of this paper have two aspects. The one is evaluation indices for commercial sustainability of conventional railway, as potential passenger is indicated by population. However, generalization has under-discussion as this result has been still the one case in Japan, then we need to analyses some other case. The other is evaluation of countermeasure the policies for the vitalization of railway network One of the strength of Japanese railway systems has Transit Oriented Development (TOD) , corridor housing development along the railway enhance the railway use. The result can evaluate TOD policy with quantitively indices on feasibility level.

We hope our achievements can be valuable to help for regional science, regional planning, railway planning, TOD policies, and so on.

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