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Population Analysis along newly developed Urban Rails in the North East area of Tokyo Metropolitan Region

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Abstract

In Tokyo metropolitan region, many urban railway lines have been developed for a long time. On this study, we analyze population data along newly developed urban railway lines by quantitative method. Results of analysis are considered to be objective and correct enough, because it is based on Statistical GIS data, 500 meter mesh population data and 100 meter mesh land use data. We applied for this study an established population analysis method with population allocation process from 500 meter mesh population data to 100 meter mesh by 100 meter mesh land use data.
This study is the first achievement of population analysis belonging to railway station area to focus on several new urban railway lines developed in the latest three decades in Tokyo metropolitan region.

Keywords: population analysis for urban railway, 500 meter mesh population data, 100 meter mesh land use data, population allocation process;

1. Introduction

In three great metropolitan regions in Japan, rail transport has had a great role as a main public transportation mode. We can see that the modal split of railway has been over 70%, especially commuter to urban center in Tokyo metropolitan region.

It is undoubtable that this prosperity of railway has been supported by a large number of passengers, mainly residents along the rail. Adversely, population along the rail is a critical key to the success of the rails, especially for newly developed rails.

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In this study, we aimed to analyze population data along three newly developed urban railway routes in the north east area of Tokyo Metropolitan region by a quantitative method. Results of analysis are considered to be objective and correct enough, thanks to detailed statistical GIS data, 500 meter mesh population data and 100 meter mesh land use data. By this method, to analyze with population allocation process, we could get a good result.

2. **Review and Method**

2.1. Review of ex-post evaluation for urban railway development

Before starting this study we summarized some existing studies of ex-post evaluation for urban railway development in Tokyo metropolitan region.

Study by Kaneko et al. was an overview of ex-post evaluation method for urban railway development. Their evaluation was based on 'the railway development project evaluation manual' established by MLIT (Ministry of Land, Infrastructure, Transport and Tourism). The targets in this study were new subway developments at that time.

Study by Takatsu focused on cooperation between rail developers and urban developers along the rail. Targeted railway lines were the Tokyo Waterfront Area Rapid Transit, the Yokohama Minato-Mirai Railway, and the Tsukuba Express. In this study, he focused on how to transfer of profit by the development from urban developers to rail developers.

Both Kaneko et al. and Takatsu marked great achievements. However, they didn't mention population index along new urban railway lines.

Akiyoshi et al. are successor as study of Takatsu. We can regard their study as a kind of ex-post evaluation for the Tokyo Waterfront Area Rapid Transit, the Yokohama Minato-Mirai Railway and the Tsukuba Express. They focused on population index along Tsukuba Express in Ibaraki Prefecture, but the number of targeted cities was only three and time span ranged only one decade (from 2004 to 2014).

As mentioned at the introduction the method in our study contains more detailed population data compared to these existing studies. We have a convince that population analysis may be a determinative index as a kind of ex-post evaluation for urban railway development. Our analysis is correct enough and applicable to other railway development cases ranged for longer term.

2.2. Review of existing population analysis for urban railway

Some decades ago, population analysis for railway planning was based on the statistical data in each municipal (for example Akiyoshi et al.). However more detailed data have been available now and old data are not enough to describe current status of passengers' movement of not only urban railway lines but also inter-regional railway lines.

Along with the development of statistical data, there had been appeared many studies of population analysis of urban railway. These studies provided social significant achievements and knowledge. And some of these studies are based on published GIS mesh data, defined population belonging to railway station area.

Population study by Oda et al. focused on radiated railway lines in Tokyo metropolitan region. Base data of this study consist of 1 kilometer mesh. Oda et al. defined railway station area in case of distance between 1 kilometer mesh central coordinate point and railway station central coordination point is shorter than 2 kilometers.

Population study by Makimura et al. focused on railway lines in Tokyo metropolitan central 23 districts. Base data of this study consist of 500 meter mesh. Makimura et al. defined railway station area in case of distance between 500 meter mesh central coordinate point and railway station central coordination point is shorter than 1 kilometer.

Each method is suitable for each study's object and achievement. But the situation of the transportation in Tokyo has been more complicated. Many urban railway lines have been developed in Tokyo metropolitan area in these decades and some strange situations have been occurred. For example, some commuters choose farther railway station (ex. by bus & rail ride activity) rather than the closest railway station. It is considered that this behaviour is the result of comparison result of total transportation service level (between origin and destination) including travel time, fare, time of transfer, access and egress conditions, congestion rate, etc. Therefore new analytical method and statistical data are indispensable to the analyses for this current transportation situation.

In this study we define railway station area as 0-10 minutes walking distance from the station, 500 meter mesh is enough large. And we also applied the GRAPE (GIS for RAilway Planning Evaluation) method which was established and developed by the Japan Railway Construction, Transport and Technology Agency (JRTT). Population study of GRAPE method is suitable for urban railway development planning, correct enough for this study.

2.3. Method to analyze

The typical feature of the GRAPE method is population allocation process from 500 meter mesh to 100 meter mesh. Asami et al. and Ochiai et al. described this population allocation process as follows;

1) In Japan, minimum population data size is 500 meter mesh, published by central government.
2) There are 100 meter mesh land use data, published by central government too.
3) Classifications of 100 meter mesh land use are 11 types.
4) We define one of the types “7: Buildings/Occupancy” as the unique land use for residence.
5) Population is allocated from 500 meter mesh to “7: Buildings/Occupancy” 100 meter meshes.
   This allocation function is described as follow.

$$NP_{100m,i} = \frac{1}{n} NP_{500m} \quad (n \neq 0, \quad i = 7)$$

$$= 0 \quad (n \neq 0, \quad i \neq 7)$$

NP_{500m} : Population of 500 meter mesh
$NP_{100m,i}$:Population of each 100 meter meshes belonging to 500 meter mesh
i :Land use classifications code of each 100 meter mesh
n : The number of 100 meter meshes ($i = 7$) belonging to 500 meter mesh

6) Select a 100 meter mesh located central coordinate point of each Railway station.
7) Check all 100 meter meshes distance between mesh central coordinate point and railway central coordination point is shorter than 300/500/750/1,000meters.
8) Sum up total amount of population of these 100meters meshes. We define this population as “population belongings to station directly” ($PD_{300/500/750/1,000}$)
9) In case of some 100 meter mesh belonging to several stations, this mesh is considered belonging to the closest station.

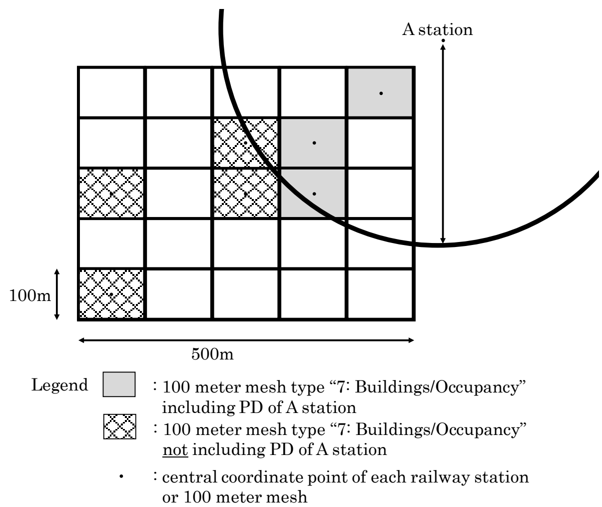

Fig. 1 Location map of 100 meter meshes including PD

Location map of 100meter meshes including PD are indicated in Fig. 1. The main object of this study is to collect PD value along each new urban railway lines. We analyze PD value of all stations at 2000, 2005, 2010 and 2015.

All 500 meter mesh population data have never been given any information about transportation activity of residents, especially transportation mode choice or station choice. Therefore on this study, population belongings to station are analyzed in increments of each station and several stations group.

3. Surveyed Railways

We focused on three new urban railway lines, Tsukuba Express, Saitama Railway, and Toyo Rapid Railway, developed in the north east area of Tokyo metropolitan region. These three new urban railway lines have provided high quality service, especially to shorten travel time between origin and destination for commuters/students. Location map of Tsukuba Express, Saitama Railway, and Toyo Rapid Railway are indicated in Fig. 2.

These urban railways were constructed by JRTT, and are owned and operated by third sector companies. Main stockholder of each third sector companies are prefecture(s) and municipals.

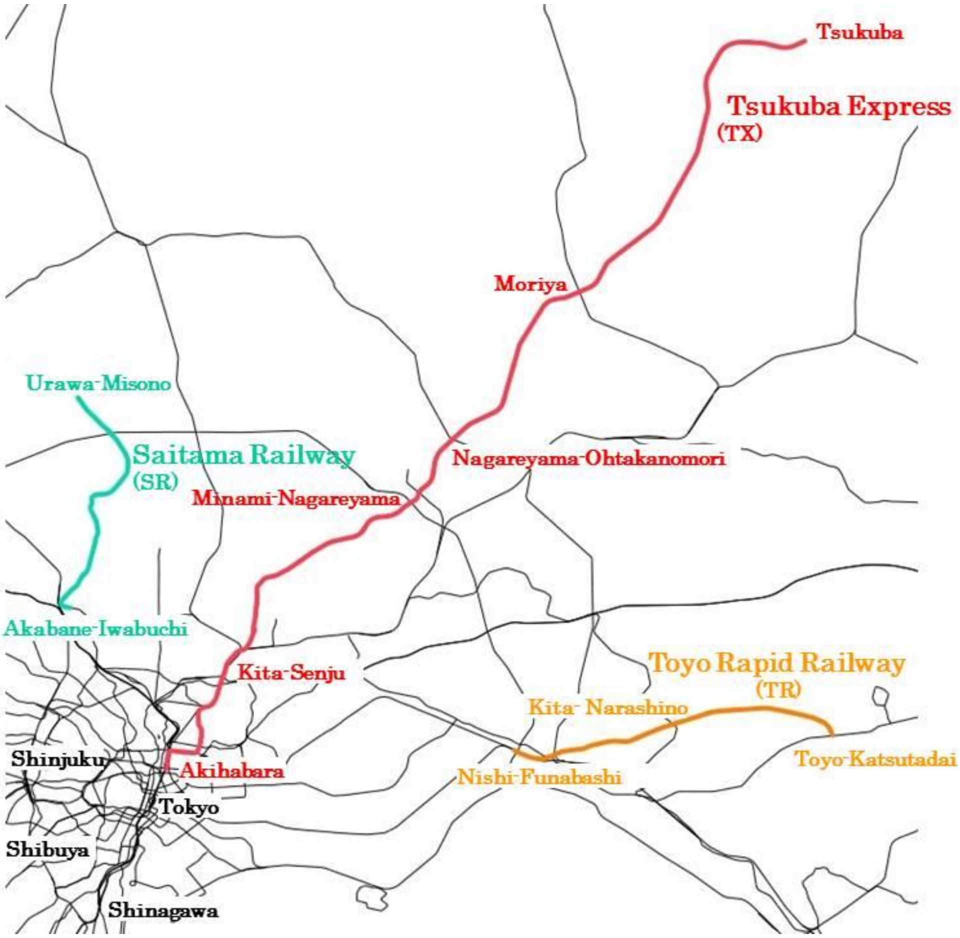

Fig. 2 Location Map of Surveyed Railways

3.1. Tsukuba Express

Tsukuba Express (TX) was opened on August 2005, between Akihabara and Tsukuba. The specifications of TX are as follows;

Total length: 58.3 kilometers
Number of station: 20
Prefectures: Tokyo, Saitama, Chiba and Ibaraki
Traffic density: indicated in Fig. 3
Traffic volume: indicated in Fig. 4

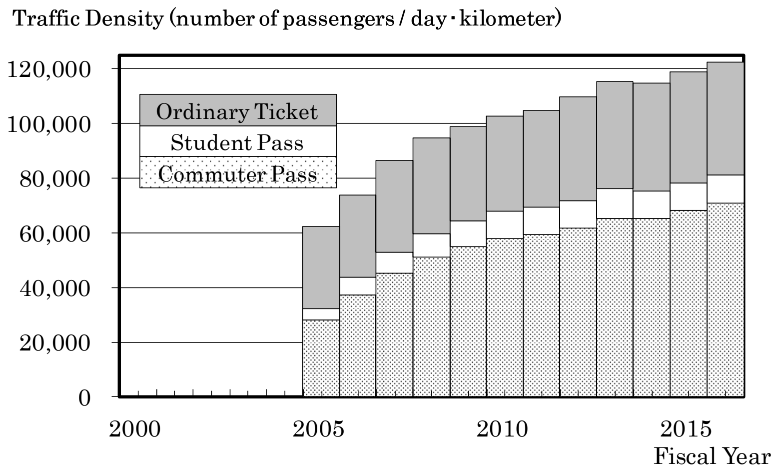

Fig. 3 Traffic Density of TX

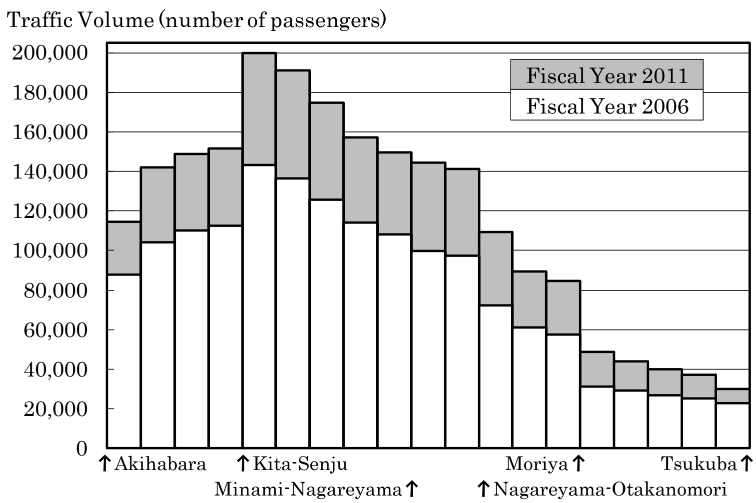

Fig. 4 Traffic Volume of TX

3.2. Saitama Railway

Saitama Railway (SR) was opened on March 2001, between Akabane-Iwabuchi and Urawa-Misono. The specifications of SR are as follows;

Total length: 14.6 kilometers
Number of station: 8
Through operation: Tokyo Metro Namboku Line and Tokyu Meguro Line
Prefectures: Tokyo and Saitama
Traffic density: indicated in Fig. 5
Traffic volume: indicated in Fig. 6

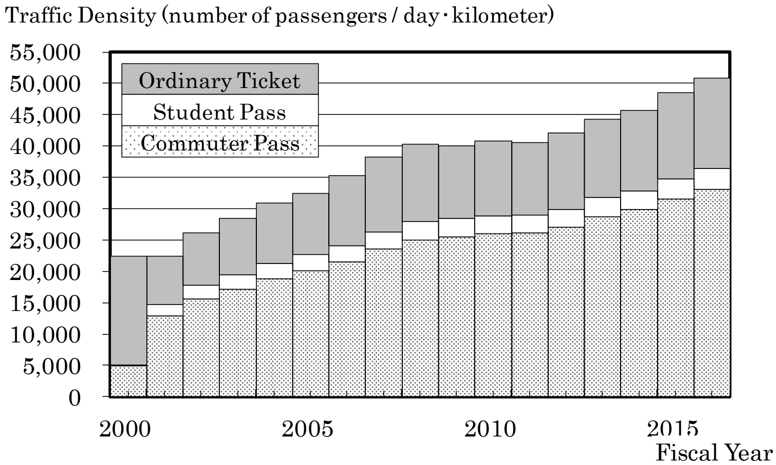

Fig. 5 Traffic Density of SR

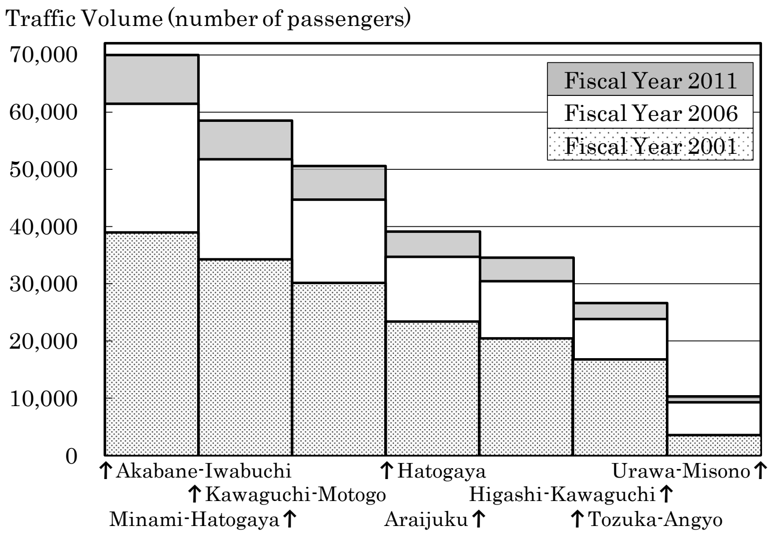

Fig. 6 Traffic Volume of SR

3.3. Toyo Rapid Railway

Toyo Rapid Railway (TR) was opened on April 1996, between Nishi-Funabashi and Toyo-Katsutadai. The specifications of TR are as follows;

Total length: 16.2 kilometers
Number of station: 9
Through operation: Tokyo Metro Tozai Line and JR East Chuo Line
Prefecture: Chiba
Traffic density: indicated in Fig. 7
Traffic volume: indicated in Fig. 8

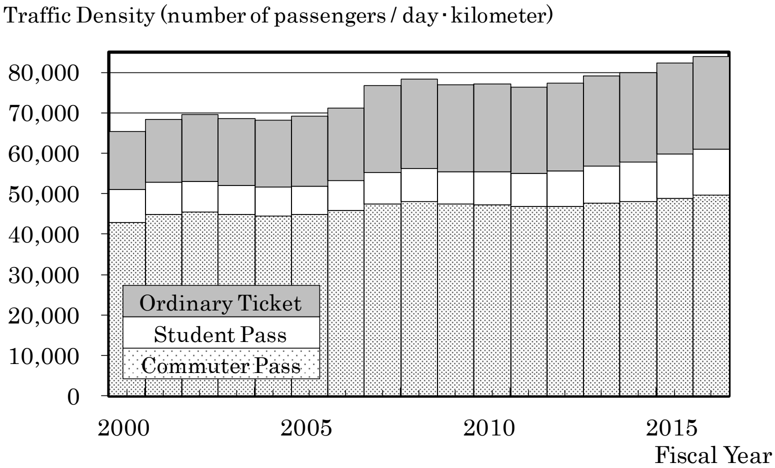

Fig. 7 Traffic Density of TR

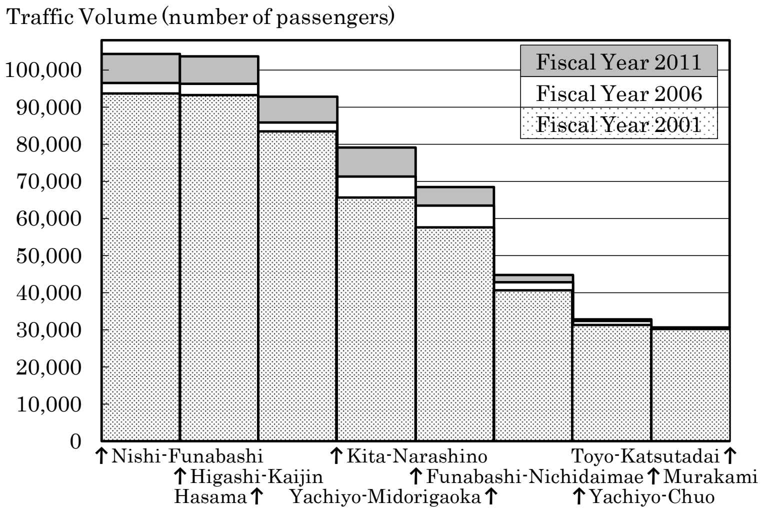

Fig. 8 Traffic Volume of TR

4. Results of Analysis

4.1. Overviews

Overviews of Japan and Tokyo metropolitan population trend are indicated in Table 1. The maximum total population of Japan was recorded in 2008, about 128 million of people. Total population of Japan has moderately decreased from 2008.

In recent years, population structure of Japan has been changed. Many residents have shifted from town/village to city, from country to metropolitan, and from suburban area to city center.

Though total population of Japan has decreased, that of Tokyo metropolitan region has increased, and it is said that this trend will continue.

And we define PR index, as population ratio index (from 2000 to 2005, 2010 and 2015).

Principal PR indexes of prefecture/municipal are indicated in Table 1. PR of Japan is flat. PR of Tokyo metropolitan prefecture (especially 23 districts) marks the highest value of Japan. PR of Saitama, Chiba, and Ibaraki is enough high in Japan.

Higher PR indexes tend to be marked on nearby Tokyo metropolitan center, new high-rise condominium buildings developed area. For example, those are observed along three new urban railways, nearby Urawa-Misono (SR, Saitama city, Saitama prefecture), Yashio-Chuo (TX, Yashio city, Saitama prefecture), Kashiwanoha-Campus (TX, Kashiwa city, Chiba prefecture), Yachiyo-Midorigaoka (TR, Yachiyo city, Chiba prefecture), etc.

On the other side, there are several negative PR meshes. Those meshes are featured as old high-rise condominium buildings (so called “Danchi”, the housing developments) area.

Table 1. Overview of Japan or Tokyo metropolitan population trend

Candidate Rail	Municipal ＼ Year	2000	2005		2010		2015	
	Japan	126,926	127,768		128,057		127,095	
			1.01	842	1.01	1,132	1.00	169
TX	***Tokyo Pref.***	***12,064***	***12,577***		***13,159***		***13,515***	
			1.04	***513***	***1.09***	***1,095***	***1.12***	***1,451***
	Tokyo 23 Districts	***8,135***	***8,490***		***8,946***		***9,273***	
			1.04	***355***	***1.10***	***811***	***1.14***	***1,138***
	Bunkyo District	176.0	189.6		206.6		219.7	
			1.08	13.6	1.17	30.6	1.25	43.7
	Taito District	156.3	165.2		175.9		198.1	
			1.06	8.9	1.13	19.6	1.27	41.7
	Arakawa District	180.5	191.2		203.3		212.3	
			1.06	10.7	1.13	22.8	1.18	31.8
	Adachi District	617.1	624.8		683.4		670.1	
			1.01	7.7	1.11	66.3	1.09	53.0
	Saitama Pref.	***6,938***	***7,054***		***7,195***		***7,267***	
			1.02	***116***	***1.04***	***257***	***1.05***	***329***
	Yashio City	75.0	75.5		83.0		86.7	
			1.01	0.6	1.11	8.0	1.16	11.8
	Misato City	131.0	128.3		131.4		136.5	
			0.98	-2.8	1.00	0.4	1.04	5.5
	Chiba Pref.	***5,926***	***6,056***		***6,216***		***6,223***	
			1.02	***130***	***1.05***	***290***	***1.05***	***296***
	Nagareyama City	150.5	152.6		164.0		174.4	
			1.01	2.1	1.09	13.5	1.16	23.8
	Kashiwa City	327.9	352.8		352.4		361.5	
			1.08	25.0	1.07	24.5	1.10	33.6
	Ibaraki Pref.	***2,986***	***2,975***		***2,970***		***2,917***	
			1.00	***-11***	***0.99***	***-16***	***0.98***	***-69***
	Moriya City	50.4	53.7		62.4		64.8	
			1.07	3.3	1.24	12.1	1.29	14.4
	Tsukuba-Mirai City	40.5	40.2		44.5		49.1	
			0.99	-0.4	1.10	3.9	1.21	8.6
	Tsukuba City	191.8	200.5		214.6		227.0	
			1.05	8.7	1.12	22.8	1.18	35.1
SR	***Saitama Pref.***	***6,938***	***7,054***		***7,195***		***7,267***	
			1.02	***116***	***1.04***	***257***	***1.05***	***329***
	Kawaguchi City (All)	514.5	538.4		561.5		578.1	
			1.05	23.9	1.09	47.0	1.12	63.6
	Kawaguchi City (East)	273.4	291.1		305.6		316.5	
			1.06	17.7	1.12	32.1	1.16	43.0
	Saitama City (Midori-District)	110.0	104.0		110.1		116.5	
			0.95	-6.0	1.00	0.1	1.06	6.5
TR	***Chiba Pref.***	***5,926***	***6,056***		***6,216***		***6,223***	
			1.02	***130***	***1.05***	***290***	***1.05***	***296***
	Funabashi City	550.1	569.8		609.0		622.9	
			1.04	19.8	1.11	59.0	1.13	72.8
	Yachiyo City	168.8	180.7		189.8		193.2	
			1.07	11.9	1.12	20.9	1.14	24.3

Unit of Population : * Thousand Persons

Legend:

Prefecture Name	***Population(A)***	***Population(B)***		***Population(C)***		***Population(D)***	
		$PR_{2000\text{-}2005}$ = B/A	***B-A***	***$PR_{2000\text{-}2010}$ = C/A***	***C-A***	***$PR_{2000\text{-}2015}$ = D/A***	***D-A***
City or District Name	Population(a)	Population(b)		Population(c)		Population(d)	
		b/a	b-a	c/a	c-a	d/a	d-a

4.2. PD and PR of each urban railways

PD values and PR indexes of each urban railway lines are indicated in Table 2 and 3.

Most of PR indexes of municipal along new urban railway are higher than PR of prefecture.

All PR of each urban railway is higher than PR of prefecture and municipal. Especially, PR of TX (Tokyo center, Saitama and Ibaraki) and SR (Saitama city Midori district) is extremely high.

It is considered that almost all PD of each urban railway station are high enough as urban railway. Therefore, we can regard TX, SR and TR as successful urban railway development cases.

Table 2. PD Value and PR Index of SR and TR

Station Name	Municipal	300 meter			500 meter			750 meter			1,000 meter		
		PD	PR	ΔPD	PD	PR	ΔPD	PD	PR	ΔPD	PD	PR	ΔPD
SR	Kawaguchi City	6,047	1.32	1,477	8,193	1.34	2,079	19,323	1.28	4,232	30,721	1.25	6,125
SR	Saitama City (Midori District)	3,747	8.08	3,283	3,379	6.83	2,885	5,347	4.89	4,253	7,881	3.27	5,474
TR	Funabashi City	2,765	1.33	689	8,148	1.31	1,934	19,040	1.22	3,458	33,163	1.17	4,772
TR	Yachiyo City	2,999	1.50	1,006	7,812	1.45	2,437	14,555	1.33	3,584	21,226	1.28	4,599

Table 3. PD Value and PR Index of TX

Station Name	Prefecture	300 meter			500 meter			750 meter			1,000 meter		
		PD	PR	ΔPD	PD	PR	ΔPD	PD	PR	ΔPD	PD	PR	ΔPD
TX	Tokyo (Central District)	4,886	1.40	1,406	14,963	1.40	4,262	31,102	1.41	9,059	45,570	1.42	13,587
TX	Tokyo (North-East District)	3,838	1.11	372	12,005	1.08	868	28,417	1.10	2,682	48,788	1.12	5,403
TX	Saitama	2,684	4.60	2,100	6,295	3.02	4,210	11,472	2.14	6,113	17,951	1.78	7,886
TX	Chiba	2,132	2.69	1,341	5,178	2.08	2,683	10,060	1.67	4,036	16,055	1.44	4,878
TX	Ibaraki	1,311	4.32	6,047	3,445	3.51	14,780	6,439	2.85	25,095	9,607	2.36	33,264

Legend:

PD(average)	
PR	Δ PD (PD2015-PD2000)

4.3. Feature of PD and PR

Almost all PR index relation of these urban railway stations are as follows;

$PR_{300} > PR_{500} > PR_{750} > PR_{1,000}$.

On the other side, all of PD_{300} remain small value. $PD_{1,000}$ values of all stations are at least more than double PD_{300} value. For example, $PD_{1,000}$ value of Aoi, Rokucho and Kashiwa-Tanaka station of TX are ten times more than PD_{300} value.

It is considered that PR_{300} index of all urban railway stations are higher, because of short access distance to station and high convenience location. And it is considered that $PD_{1,000}$ absolute value of all urban railway stations are larger, caused by broad area.

We can describe this feature in different terms. The personality of some 100 meter mesh may be determined according to the distance from the closest railway station and the closest bus stop. In recent decades, extreme high PR index tend to be marked on 100 meter meshes nearby (new) urban railway station. Higher PR index 100 meter meshes have potential to be “densely inhabited district” (DID).

4.4. Three new urban railway and bus & rail ride

Bus transportations around these new urban railway lines are well developed. And some of those bus lines are accessed another conventional railway station directly. According to this transportation condition, some residents can choose at least two ways as follows;

1) Home — walking → Station of new Urban Railway (TX, SR, TR)
2) Home — walking → Bus Stop → Bus → Station of another Urban Railway (JR, etc.)

→ So called “Bus & Rail Ride activity”

Almost all PR indexes of bus line are positive, and almost all PR indexes of three urban railways are higher than that of bus lines around them. It is considered that new residents tend to choice nearby unban railway station rather than bus stop.

5. Achievements

This study is the first achievement of population analysis belonging to railway station area to focus on several new urban railway lines developed in the latest three decades in Tokyo metropolitan region.

TX, SR and TR may be successful urban railway development case, because of enough PD value, indicated in this study. We can reconfirm social significance of three new urban railways (TX, SR, and TR) development, by population analysis. It is considered that almost all PD of each urban railway station are high enough as urban railway. As a result, the numbers of passengers of these railways increase.

We actualize to indicate feature of PR as follows;

$PR_{rail} > PR_{municipal} > PR_{prefecture}$

$PR_{300} > PR_{500} > PR_{750} > PR_{1,000}$

$PR_{rail} > PR_{bus}$

We can apply these achievements, not only for railway planning or traffic phenomenon analysis, but also urban planning, regional planning, or both. We convince these achievements have enormous significance for transportation / urban / regional policy of Tokyo metropolitan region.

And we can reconfirm that GRAPE method is valuable and suitable for population analysis, railway planning, etc.

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