Spatial Analysis of Urban Characteristics Based on Land Use Information along Tram Lines

Koji Yoshikawa, Fumiko Perry and Naoyuki Tsukamoto

Abstract

Urban public transportation networks have become an important tool to relieve traffic congestion and as a means to promote a sustainable society. Among the various public transportation systems, trams have developed their own status as an urban symbol in numerous cities. However, in Japan, tram projects have had difficulty introducing new methods with planners unaware of the merits of new technologies and management systems. It is important to analyze the urban, subjective factors by objective means related to tram systems and clarify the characteristics of recent successful European projects. In this paper, the authors focus on land use information and create the methodology to perform spatial analysis and to acquire quantitative information related to land use along the tramline. Results show the validity of tram projects integrated into large-scale development, even for small cities, so as to promote new ways to use trams and improve traffic conditions.

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1. Introduction

1.1 Background

Urban public transportation networks have become an important element not only as a solution to relieve traffic congestion but also as a means to promote a sustainable society. Among the various public transportation systems in Europe and America, the tram has developed its own status as an urban symbol in numerous cities that have developed new systems or enhanced older systems. However, in Japan, urban public transportation is principally based on an independent, economically self-supporting model and is treated separately from urban planning. Tram projects are evaluated by profitability based on revenue generated from the number of present or estimated passengers that will ride the line(s) separate from any concurrent urban development. Overall impact of an enhanced transportation system on development projects tied to public transportation is not considered. Because it is extremely difficult for tram systems to be profitable there are no new tram construction projects in Japan and it is quite difficult to introduce new operation systems to existing tram systems.

The authors have studied the effects that European tram projects have had on urban planning and design with the goal to develop new values for urban design in Japan. The authors suggest that tram adaption should be realized as an urban reactivation tool that accompanies new urban development projects that is evaluated as part of a larger scale urban framework and not evaluated as a single transportation tool. The authors' research approach over the past 3 years has included an analysis of effective factors for tram projects within a city-planning matrix. For example, the comparison of urban characteristics between 17 cities with tram systems to 40 similar population scale cities without trams was analyzed (Tsukamoto, et al., 2014). This research also includes analysis of the reasons for successful recent tram projects. The analysis of systems in operation were performed based on site surveys and interviews with tram system operational staff as well as interviews with planning offices that were involved in developing these new systems (Tsukamoto, et al., 2013 & 2014). In addition, urban landscape factors were cataloged and analyzed by identifying various design elements such as tram carriage design, tramway layout, tram stop and pedestrian space design among 30 European cities using data collected by site surveys (Perry, et al., 2013).

The interviews mentioned above were performed in the French cities of Angers, Le Mans, Montpellier, Le Havre, Orléans and Tours. With the exception of Montpellier, the populations of these cities are less than 300,000 and it was generally considered that such low populations could not support tram systems. Ignoring professional advisers, these cities pushed forward and completed successful tramlines over the past 15 years. In most of these cities, trams pass through the city centers and reach out to surrounding suburbs. At the end of the lines, typically there are large-scale housing, commercial and public facilities such as hospitals and universities. Also, through interviews and site surveys, it became clear that tram construction enhanced the successful day-to-day functioning of the region based on links to the surrounding suburb developments. These results suggest that new factors should be considered when tram systems are proposed in Japan with an economically self-supported system not the only metric. Such considerations about new factors can be grasped quantitatively by land use analysis along the tramlines. Land use along tramlines contains important information that clarifies the effect that tram construction has on urban activities and it is the key parameter to measure the impact of transportation improvement upon urban activities. However, detailed spatial information such as land use along tramlines has not been organized by any of the cities or national governments surveyed and it has been difficult to gain such information in general. To fill this gap has been part of the research focus of the team over the past few years.

1.2 Purpose

In this paper, the authors focus on land use information along tramlines. The major goal is to create a methodology to organize information that includes quantitative spatial factors so as to be able to analyze land use in cities anywhere in the world.

Previously, a method to input tram related information such as the characteristics of tramways, tram stops, tram stops' locations and tram carriage design had been collected in studies conducted over the past 3 years by the authors via Google Earth and for this paper land use information has been layered in. The authors have attempted to construct in a detailed manner a way to input polygon data of two city blocks along various tram lines according to separate land use categories so as to process the data within different statistical models. This method can enhance the system's multiplicity and applicability by integrating all tram information onto Google Earth as front-end using the KML data format. Also, such a single system may be applicable for research in various urban planning projects around the world.

For this paper a methodology has been created to process data related to land use analysis. Versatile applications such as ArcGIS and Excel are utilize to integrate procedures and a ratio of land use categories can be calculated based on collected land use information related to a tram stop's sphere of influence. This data allows for a quantitative visualization of changes in land use from the urban centers out to the suburbs.

Up to now these results have been gained by qualitative analysis, however, this new statistical methodology confirms quantitatively important factors concerning large scale suburb developments linked to urban centers by tram lines as well as the type of facilities along the tram lines.

2. Paper Outline

This paper consists of 8 chapters and the research background is described in chapter 1. Chapter 3 contains notes about the cities surveyed in France. Chapters 4 and 5, explain methodology development. Chapter 4 details the input method using Google Earth regarding tram related information and land use information. Data processing methodology is described in chapter 5. Chapters 6 and 7 analyze land use information: the ratio of each category of land use and the changes of ratio due to Location. Chapter 8 summarizes the research findings and problems encountered.

3. Case Study Cities

Figure 1 shows 24 cities where French tram line construction has taken place from 1985. Five cities were eliminated because Google Earth data has not yet been updated since the completion of construction. The 19 case study cities are noted by filled in black circles in figure 1. After 2000, new tram systems were created for cities with population less than 400,000, and in the last 5 years, new tram system began to operate in cities with populations of approximately 200,000 (refer figure 1).

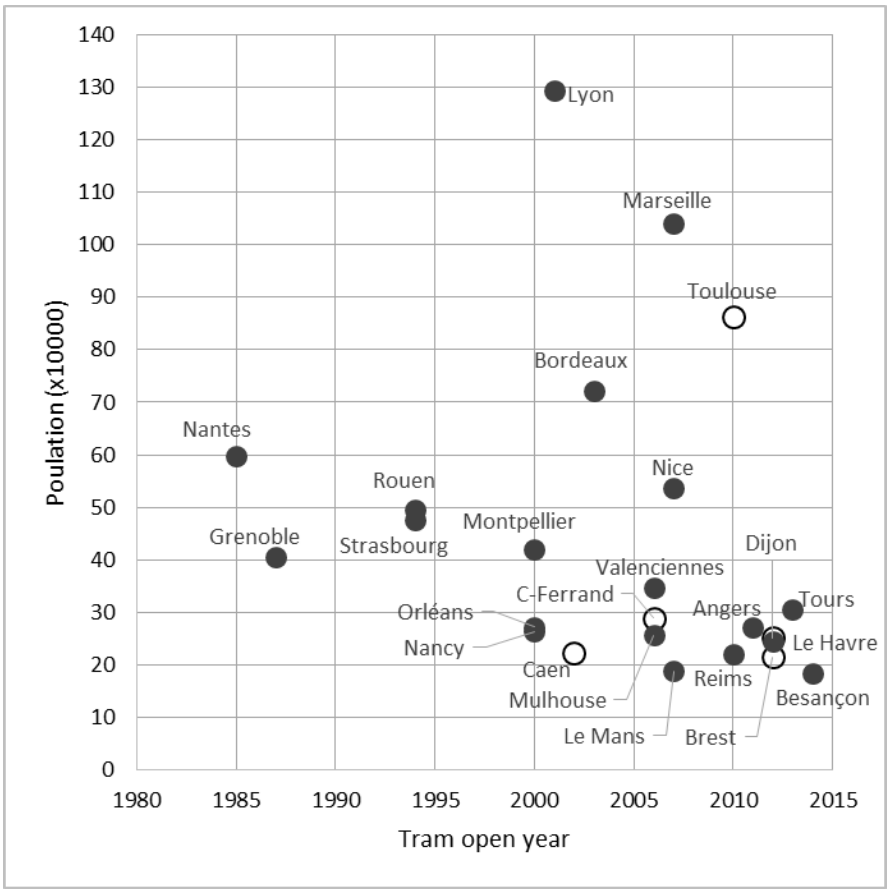


Fig. 1. City population and tram open year

4. Input Method of Tram and Land Use Data

Upon the assumption of effective utilization of Google Earth, all information such as tram position information, tram attribute information and land use information has been integrated into one system as KML data. In regards to attribute information, "KML editor" was created to organize and visualize the information as reported previously in CUPUM 2013 published paper (Perry, et al., 2013).

4.1 Position information of tramways and stops

Position information such as the location of tramlines, tram stops and facilities along the tramlines are entered into Google Earth referring aerial/satellite photographs. Each tramline is classified into one of three types: a tramline without greenery, a tramline with greenery, a tramline located in a transit mall with the data entered into Google Earth by line form. Tram stops and facilities data are entered by point form (see figure 2).

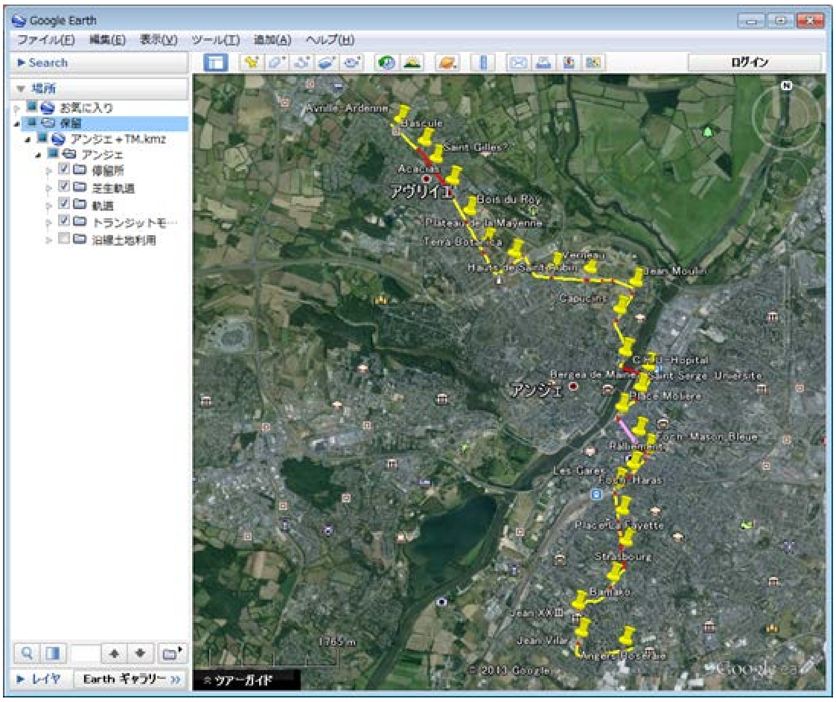


Fig. 2. Position information of tramlines

4.2 Attribute information of facilities related to trams

The authors created a KML editor program that creates attribute information such as detailed design of tram carriages and tram stops as well as general urban information including photos and texts and the data is organized in Excel format and linked to Google Earth. With this tool such information becomes possible to open on web sites as visual pop-up balloons (see figure 3).

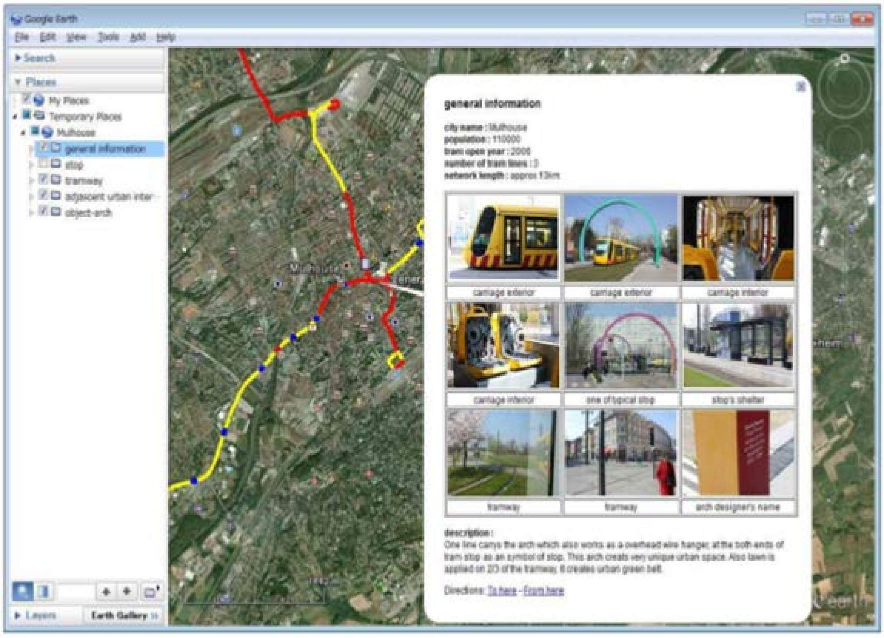


Fig. 3. Attribute information of facilities related to trams

4.3 Land use information along tram lines

The code for land use classification using ‘Numerical Value Map 5000’ from the Geographical Survey Institute is applied. Since the target of this study is about urban land use, the gray colored categories in table 1 are applied. Land use categories are articulated spanning a 2 blocks range along both sides of a tramline and each category’s polygon data is then entered into Google Earth as shown in figure 4. A street view function is used to confirm a land use category when difficult to identify by aerial photos.

Table 1. Correspondence list with details and the codes of the land use classification

code	Land use groups			
	large	medium	small	
1	forest, farmland, etc.	forest, waste land		
2		farmland	rice field	
3			other fields	
4	preparation land	**under development area**		
5		**vacant lot**		
6	residential area	**industrial area**		
7		**residential area**	**Low -rise**	**normal**
8				**dense**
9			**mid-to-high-rise**	
10		**commercial and business area**		
11	public and commonwealth service area	land for road construction		
12		**parks / green land**		
13		**(others)**		
14	river, lake, etc.			
15	others			
16	sea			
17	(not covered)			

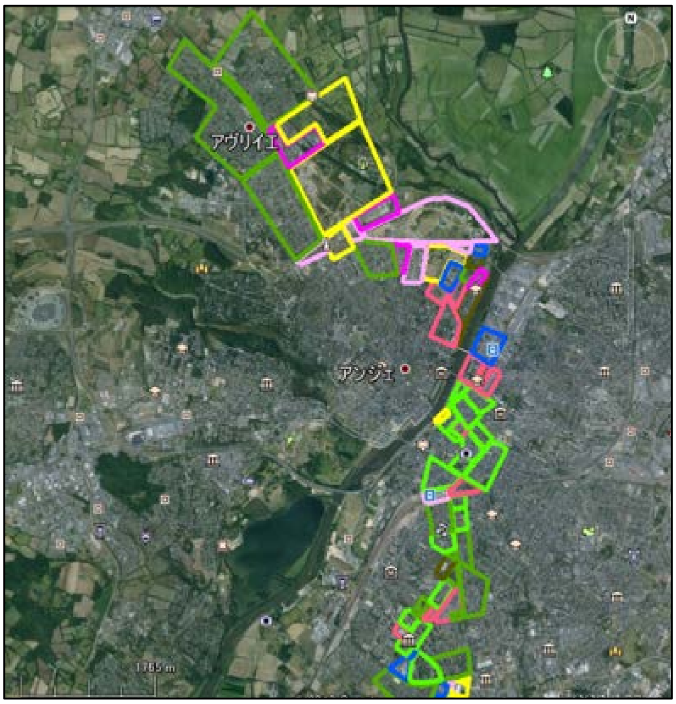


Fig. 4. Land use information along tramlines

5. Calculation Method of Land Use Ratio

This chapter describes the calculation method used to quantify land use conditions. As mentioned in chapter 4, land use information was acquired as the form of categorized polygon data, considering easiness of data input. Such data is needed to convert and form as some indices suitable for analysis. In this study, land use ratio of each category is employed as the quantitative index which shows land use condition along tram lines. The position of tram stops were set as the center points to collect land use information with a 200 meter radius proscribing each sphere of influence. A 200 meter radius was chosen since Japan's aging population has a limitation to how far people will walk beyond a center path.

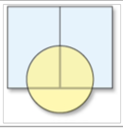
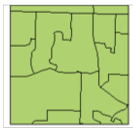
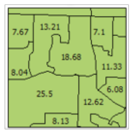
To acquire land use ratios, calculation steps are configured as the combination of spatial functions of ArcGIS after importing KML data which is created and exported using Google Earth. Concrete procedures are as follows:

- Create 200 meter radius buffers around tram stops to indicate stops' spheres of influence.
- Clip land use data by buffers using "intersect" function.
- Calculate square meters of each land use category according to the categories listed in table 1.

Also, measure the distance between tram stops using a "measurement" tool (refer table 2). Figure 5 shows an example of the ArcGIS procedure.

Then export the number of square meters of each land use category to an Excel file so as to generate a land use ratio. Figure 6 indicates an example of a land use ratio of each tram stop sphere of influence.

Table 2. Spatial calculation steps

Process			Spatial Function	Input	Output
Calculate areas of each land-use classification (by each sphere of tram stops)	Step1	Create 200m-radius buffers around tram stops	Buffer		
	Step2	Clip land-use polygon by buffers	Intersect		
	Step3	Calculate areas of each clipped zone	Calculate Areas		
Measure distances between stops			Measurement tool		

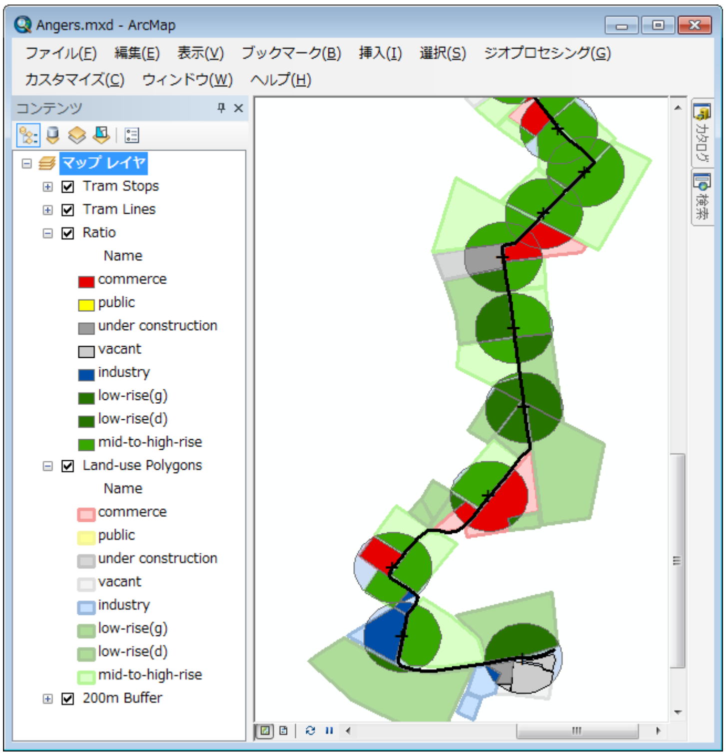


Fig. 5. Results of GIS procedure

#	name of stop	distance (m)	total distance (m)	residential district (low-rise)	residential district (mid-to-high-rise)	commercial and business district	public and common wealth service facilities	industrial districts	parks / green land	under development area	vacant lots	total
N11	AVRILLE-ARDENNE	0	8,693	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
N10	Bascule	681	8,012	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
N09	St Gilles	433	7,579	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
N08	Acacias	576	7,003	49.1%	0.0%	0.0%	39.7%	0.0%	0.0%	0.0%	11.2%	100.0%
N07	Bois du Roy	747	6,256	53.2%	0.0%	0.0%	5.6%	0.0%	0.0%	0.0%	41.3%	100.0%
N06	Plateau Mayenne	740	5,516	52.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	47.3%	100.0%
N05	Terra Botanica	899	4,617	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	18.3%	81.7%	100.0%
N04	Verneau	1,106	3,511	7.1%	0.0%	0.0%	4.3%	0.0%	0.0%	88.6%	0.0%	100.0%
N03	Hauts de St Aubin	743	2,768	0.0%	0.0%	0.0%	5.7%	0.0%	0.0%	82.9%	11.4%	100.0%
N02	Jean Moulin	1,099	1,669	43.4%	0.0%	0.0%	0.0%	17.8%	0.0%	12.4%	26.4%	100.0%
N01	Capucins	673	996	0.0%	0.0%	74.0%	0.0%	25.2%	0.0%	0.0%	0.8%	100.0%
C	CHU-Hopital	996	0	20.0%	0.0%	80.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
S01	Berges de Maine	626	626	0.0%	0.0%	46.7%	0.0%	53.3%	0.0%	0.0%	0.0%	100.0%
S02	St.Serge-Universite	543	1,169	0.0%	40.5%	59.5%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
S03	Moliere	608	1,777	0.0%	88.5%	2.1%	0.0%	0.0%	0.0%	0.0%	9.4%	100.0%
S04	Ralliement	612	2,389	0.0%	83.7%	16.3%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
S05	Foch-Mason Bleue	487	2,876	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
S06	Foch-Haras	476	3,352	0.0%	77.0%	23.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
S07	Les Gares	506	3,858	15.2%	44.8%	13.6%	0.0%	0.0%	0.0%	26.4%	0.0%	100.0%
S08	Pl. La Fayette	608	4,466	51.1%	48.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
S09	Strasbourg	673	5,139	98.5%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
S10	Jean XXIII	854	5,993	5.2%	38.8%	56.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
S11	Bamako	1,017	7,010	0.0%	71.6%	25.9%	0.0%	2.6%	0.0%	0.0%	0.0%	100.0%
S12	Jean Vilar	716	7,726	7.1%	49.6%	0.0%	0.0%	43.3%	0.0%	0.0%	0.0%	100.0%
S13	Angers-Roseraie	1,185	8,911	51.2%	0.0%	0.0%	0.0%	2.4%	0.0%	9.8%	36.6%	100.0%

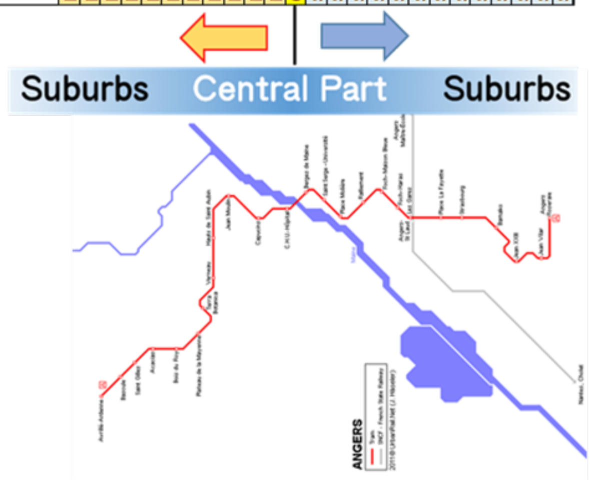


Fig. 6. Results of generating land use ratio

6. Difference of Urban Characteristics

6.1 Comparison of land use ratio along tram lines

Figure 7 shows the land use ratio of 19 cities listed by its population order. In this figure, (a) shows the land use ratio of all stops, (b) indicates the average land use ratio of only 3 stops from a suburb terminal. Numbers inside of ( ) shows population (x10,000), also that of [ ] shows tram open year.

The following tendency of overall land use ratio for the 19 cities was found (refer figure 7):

- there are various combinations of land use, however, for most of the cities, residential districts ratio is more than 50%, and the highest ratio is over 80 % at Nice.
- parks/green land exists in most cities.
- the ratio of commercial and business districts is 10 to 20 % in many cities, the ratio rises to approximately 40 % in Reims.
- the ratio of public and common wealth service facilities is approximately 10 to 20 % in most cities.
- under development areas and vacant lots are found more in suburban areas, for example in the suburbs of Tours, Le Havre, Le Man, Besançon.

6.2 Relation between land use ratio and tram open year

To examine potential near future development, figure 8 shows the ratio of vacant lots and under development areas according to the tram open year. Cities with higher ratio of these categories are especially found when tramlines were opened from 2005 onward. Under development areas and vacant lots are both classified as preparation land that has the potential for new development to take place with higher value created by the new presence of a tramline. These preparation lands point to possible plans for urban development.

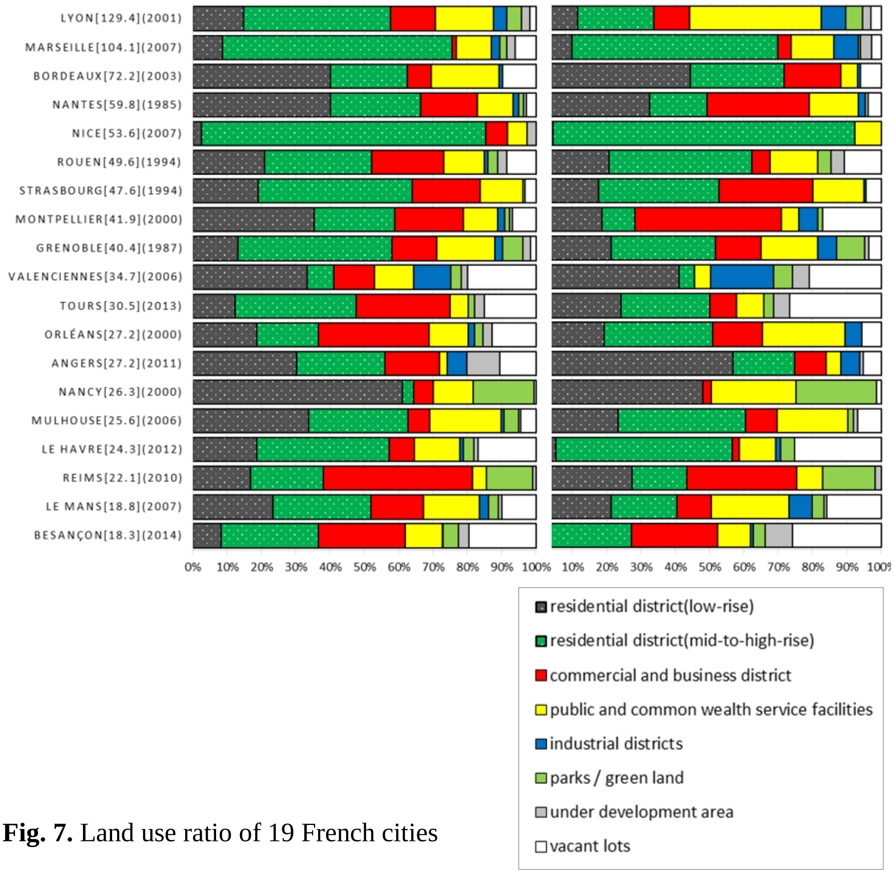


Fig. 7. Land use ratio of 19 French cities

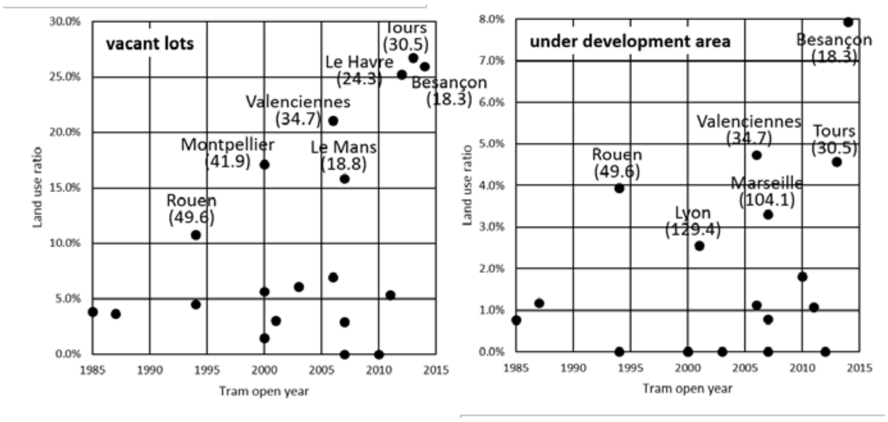


Fig. 8. Relation between land use ratio and tram open year

7. Changes of Land Use Ratio from City Center to Suburbs

Figure 9 shows the changes of land use ratio along the tramlines from city centers toward the suburbs for six cities where the authors performed interviews or site surveys. Since the population of these cities is less than 300,000, it is assumed that they should have a specific strategy to connect the city centers to the suburbs or to plan large-scale facility development project in cooperation. The analysis on the changes of land use ratio along the tramline can verify actual site conditions.

For each city the authors selected a tram stop within the central district as the city's center point. The following three reasons were used to make the selection: a crossing point of tram lines allowing for passengers to transfer lines, next to the SNCF, next to the city hall. In all the graphs in figure 9, the left is center city and the right is the outer terminal. When there are more than two lines in a city, only line 1 (T1) is used for analysis. Although the distances between the stops were measured, the graphs show the same interval between stops for a cleaner appearance of ratio changes.

The following is descriptive text of fig. 9. An overall tendency for a high commercial ratio in central areas with increasing residential ratios as the lines go towards the suburbs. At terminal areas various other land uses other than residential increases. The west line of Besançon and the north line of Tours, there are commercial facilities around the terminal area. The south line of Orléans runs through two local commercial areas and passes a university a few stops before the terminal with a hospital at the terminal. The industrial district indicated at the terminal at Le Mans and Orléans is a tram depot. The north line of Angers shows an exceptionally high residential ratio at the terminal because the purpose of this line is to connect the center city and relatively large outlying suburban towns. The terminal area of the western line at Besançon, the middle area of the southern line at Tours and the north line at Angers has a high ratio of vacant and under development areas. Since trams in these cities opened quite recently, these preparation lands seems to be apart of large urban development plans based on trams.

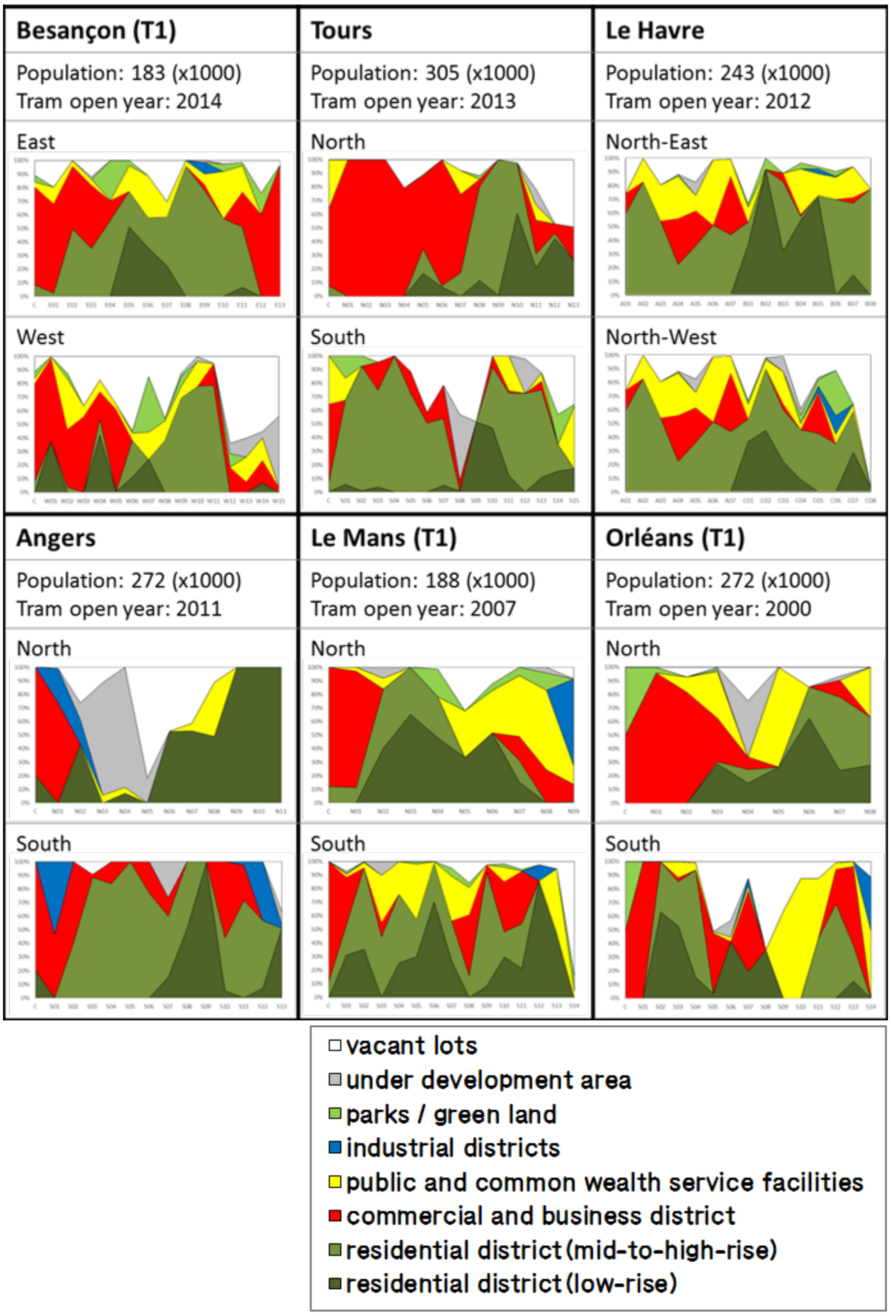


Fig. 9. Changes of land use ratio from city centers toward the suburbs

8. Conclusion

8.1 Result of the study

In this study a methodology focused on land use information was created to organize spatial information and to analyze it quantitatively. The methodological approach allows land use information data to be integrated into Google Earth. Previous tram related information as well as various information regarding worldwide tram projects can then access such information through this integrated system so as to study the impact of future projects. With additional processing, spatial information can be visualized in an appropriate format to suit various analytical purposes. The combining of common applications has created a methodology with a flexible, broad range of analytical functions.

The major purpose of this study is to create the methodology, however, the authors also attempted to confirm its effectiveness by performing actual analysis. The results of the analysis are listed below:

- Ratio of land use varies for each city, but there is a tendency that commercial and/or public facilities to accumulate at the terminal ends of tramlines. In cities where a tram system opened recently, more vacant lot and/or under development areas remain near the terminal ends of the lines.
- In regards to a change of land use ratios along tramlines, which was examined for only six cities, analysis shows high commercial ratios in the central areas with residential ratios increasing as the lines go towards the suburbs. As the lines approach the suburban terminals, non-residential use such as commercial and/or vacant lot, under development areas, increase.

Summary noted above indicates that land use conditions along tramlines that were previously analyzed by qualitative knowledge was confirmed quantitatively through the methodology created in this study.

8.2 Concurrent problem

As a method to quantify land use information along tramlines, this study was limited to a point buffer using tram stops as locus points. As a continuation of this study, the authors plan to expand the buffer range by creating a line buffer along continuous areas next to tramlines so that the researcher can chose the most appropriate buffer for each type of spatial information analysis.

Also, Google Earth was an important factor to integrate various spatial information in this study, however one problem is that Google Earth cannot offer chronological analysis. To clarify the effects of tram construction quantitatively, it is necessary to perform time sequential analysis of land use. In this study, as Google Earth is used only as a 'front-end' for land use data input and ArcGIS is employed to calculate land use ratios, calculations using past data can be easily executed by importing the data directly to ArcGIS when we acquire them from municipalities and so on. Such data are normally provided in the form of shape file or other GIS readable formats. With/without analysis comparing areas with tramlines and others along trunk roads at the same city is needed as well. They are high priorities as research continues.

Because the major purpose of this study was to create the methodology and confirm its effectiveness, actual analysis has been performed in a limited fashion. By changing variables, such as the buffer diameter bordering tram stops and the range of suburbs, the results of spatial analysis for land use has the potential to become multifaceted. It is necessary to research further so as to enhance this methodology.

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