Analysis of Land Use along Urban Rail Transit Based on POI Data

Lirong Zeng[1] and Hangfei Lin[2]

[1]Postgraduate of Traffic and Transportation Engineering, The Key Laboratory of Road and Traffic Engineering, Ministry of Education, Tongji Univ., Shanghai 201804, China. E-mail: zlr_hust@163.com
[2]Professor of Traffic and Transportation Engineering, The Key Laboratory of Road and Traffic Engineering, Ministry of Education, Tongji Univ., Shanghai 201804, China. E-mail: linhangfei@126.com

Abstract

The land use pattern of the areas along urban rail transit is crucial for the efficiency of transportation system and city sustainable development. This paper analyzes the characteristics of land use along urban rail transit in Shanghai, China from three levels: rail network, lines, and stations by taking advantage of the POI data collected from open source map. The indicators we propose to measure are the land use characteristics including the land use density, degree of concentration, and the entropy of land use structure. The results show that the land use density declines as the distance from rail line increases and the rail transit attracts commercial facilities significantly, keeping away from residential facilities. The result also reveals that the intensity of land use along the rail transit is related to the relative location of the line in the city.

INTRODUCTION

Traffic capacity of a city depends not only on the scale of the infrastructure, but also on the transport development mode. Urban rail transit has now been the most important mode of public transit in large cities, at the same time, a feasible land development mode for the areas along the rail lines is quite necessary to ensure smooth city development and avoid awful traffic impacts. Therefore, the analysis of the land use along urban rail and the evaluation of land use density are essential to the coordination of transportation and land use development.

Rail transit and land use along the route are influenced by each other. More demand for public transit could be generated by high density, mixed land use and pedestrian friendly street design (*Tumlin and Millard-Ball, 2003; Chatman, 2009*). On the other hand, rail transit may change the urban space form (*Lin and Zeng, 2007; Chen et al., 2007*) and consequently affect land value along the rail route (*Bajic, 1983*).

There have been numerous studies on the analysis of land use characteristics along urban rail lines, however, they are mostly based on the traditional land use survey data, which is quite difficult obtain. *Roukouni et al.* (2012) selected a station from Thessaloniki Metro as a study case, conducted a lot field work to survey the land use within a buffer zone of 500 m away from the station, and achieved some corresponding thematic maps. *Zhou and Xu* (2002) and *Zeng* (2006) both took the Shanghai rail transit for case studies, and analyzed the spatial layout of land use along rail route using the GIS technology. They concluded that the attraction of rail transportation to urban residential land appears most obvious, whereas not obvious to public construction land and keep away from industry land. *Pan* et al. (2007) selected 48 stations from Line 1 and Line 2 of Shanghai Metro, and analyzed the land use characteristics along each rail line in detail and the reason of the formulation further. *Liu et al.* (2014) achieved the land use situation around three metro stations within 2000 m in Beijing, and calculated several indicators including land use structure, land use rate, entropy, balance degree, revealing the spatial distribution characteristics around different stations.

POI is the abbreviation for point of interest. A POI is usually a position of the electronic map which people are interested in. Each POI describes a space point object, and usually contains information as name, address, latitude and longitude, category, etc. POI data from open source map can be achieved to reflect land use situation. *Wang* (2014) estimated the land use mix level for Beijing with 200,000 poi through information entropy model, which represents city vitality and system structure of built up area. *Long and Liu* (2013) made use of road network and POI data, identified and classified the land type. He eventually found out the land use type, development density, land use mix degree and current built up areas of 297 cities in China. *Jiang and Alves* (2015) proposed the use of Web Mining and machine learning technique to automatically collect and classify the multi-source POI data in accordance with the unified standards. Besides, they developed methods to utilize POI data to estimate disaggregated land use at a very high spatial resolution.

Based on the existing researches, this paper puts forward a method to analyze the land use characteristics and to evaluate the degree of land use agglomeration based on POI data from open source map. The author analyzed the POI data for the land areas along the urban rail lines using ArcGIS, and calculated development density, agglomeration degree, and land use mix degree to characterize the land use. This evaluation method can make full use of the existing data resources, effectively reduce the workload of the survey, and the evaluation results can be used to guide the land use development along the rail transit.

DATA COLLECTION AND PREPROCESSING

Data required for study come from the Baidu map, which was grabbed through API online. The data capture procedure are as follows: (1) setting study area and laying out sample points according to certain density, (2) searching POI within certain area around the sample point, (3) using reverse address resolution and coordinate transformation.

As the search area decided by the sample point must cover the study area completely, tough computer work is still possible. To avoid such work, the search area was set as 120 m and sample point interval was 0.001 degrees. According to this procedure, the search area overlaps, causing the POI data to repeat. We thus deleted the duplicate records in the pretreatment process. Collected data contains attributes such as longitude, latitude, type, address and name.

The points contain 20 types, removing administrative landmarks and natural features, and reclassify the rest into five types, as shown in Table 1.

Table 1. Reclassification of POI Data

Reclassification	Original Classification
Residential (RE)	Real Estate
Companies(CO)	Companies
Commercial and Business (BE)	Shopping, Finance, Hotels, Beauty, Food, Tourist Attractions, Entertainment
Administration and Public Services (AD)	Education And Training, Car Service, Service Life, Culture Media, Health, Sports Fitness, Government Agencies, Tourist Attractions
Street and Transportation(ST)	Roads, Traffic Facilities

117797 records were obtained in total within land area in Shanghai. Among all the POI, commercial facilities account for the most part, up to 47.92%, and the type of public management and service follows, as shown in Figure 1.

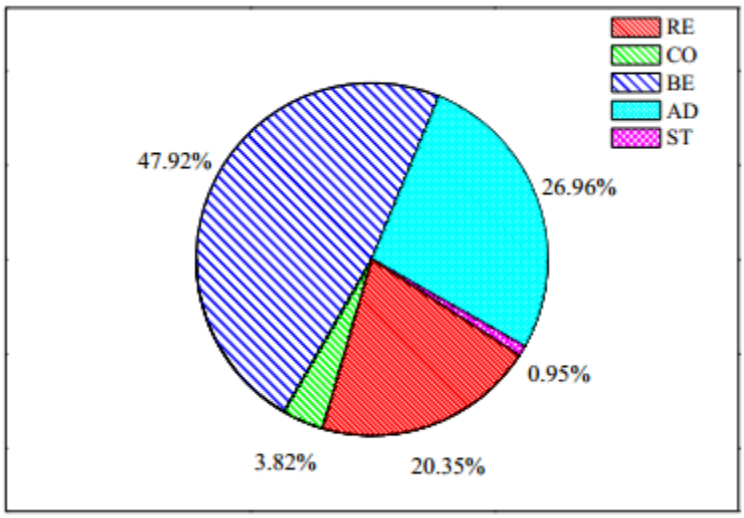

Figure 1. Types and Proportion of POI Data

ANALYSIS OF CHARACTERISTICS OF LAND USE ALONG THE RAIL TRANSIT IN SHANGHAI

Shanghai is one of the earliest cities building urban rail transit in China and has constructed a relatively complete system of rail transit network. By the end of 2014, Shanghai already have had 15 rail transit lines in operation in total (including the maglev line), and the total lengths of the operating lines have been to 577.6 kilometers, with 339 stations. In this section, we use the POI data of Shanghai City, and analyze the characteristics of land use along the track from three levels of rail transit network, line and station.

The range needs to be clearly identified when land use characteristics along the rail track is decided to be analyzed. For rail transit lines, the scope of its influence is the region within certain distance away from the track on both sides, while for a station, the impact region is usually defined as a circle, with the station as the center. Some scholars defined the influence zone as areas can be reached by different transport mode within 10 minutes respectively, as shown in Table 2.

Table 2. Zone Influenced by Urban Rail Transit (*Tian, 1999*)

Mode	Speed (km/h)	Maximum radius of influence zone (km)	Maximum area of influence zone (km^2)
Walk	4	0.6	1.1
Bicycle	11~14	1.8~2.3	10.2~16.6
Bus	16~25	2.6~4.1	21.2~52.8
Car	40~60	6.6~10	136.8~314.2

In fact, the station cannot be always reached from a certain place by a straight line, so the influence zones listed in Table 2 are larger. In this paper, the maximum influence area of rail transit is determined within 2000 meters. In this region, the main traffic modes are walking, bicycle and bus. The area within 500 meters from the station is referred as the directly impacted area.

Land use characteristics of the areas around urban rail network. Up to now, a total of fourteen rail lines have been in operation in Shanghai city. The lines mainly concentrated in the central city, a network system has been formed. With the continuous expansion of the scale of rail transit network, the main body position of rail transit in public transportation is increasingly prominent.

In this section, first, the buffer zone of 500 m, 1500 m, 1000 m and 2000 m from rail lines are obtained by using GIS buffer. Second, we calculate the quantities and proportions of each POI type within certain buffer zone. The number of POIs reflects the land use density of a zone, and the proportions of each type of POI reflect the difference of land use mix.

The total number of POIs obtained in the range of 2000 m from rail lines is 96387, accounting for 81.82% of the total number of POI in Shanghai land area. As we can see, most of the points in Shanghai are located in the impacted area of rail transit. Also, we calculated the number of POIs within the range of 500 m, 500 m - 1000 m, 1000 m -1500 m and 1500 m – 2000 m, as shown in Figure 2.

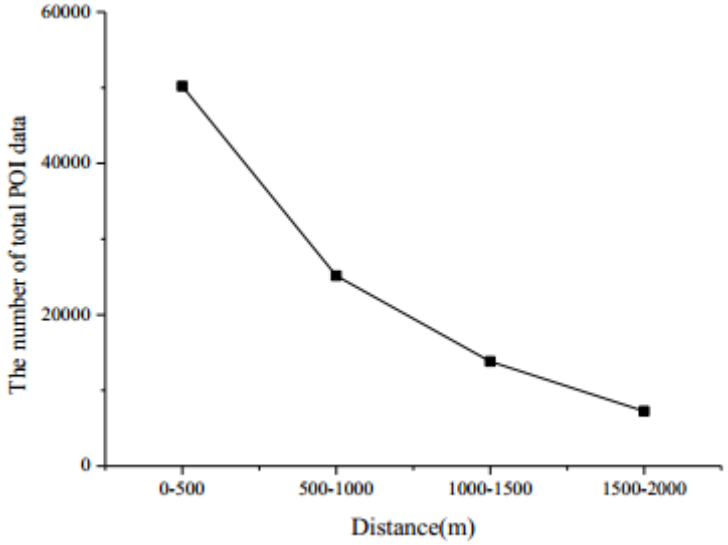

Figure 2. Relationship between Number of POI and Distance

From Figure 2, it can be clearly seen that with the increase of the distance, the number of points of interest gradually reduces. We must notice that the number of interest points within the range from 500 m to 500 m – 1000 m reduces sharply, and then become slower, which is the corridor effect of rail transit. Corridor area includes corridor itself and its radiation area, which can be referred to as the corridor effect field. The corridor effect gradually decreases from the center to the outside and follows the distance decay rate, which can be expressed by the logarithmic decay function.

There are two reasons for this phenomenon. First, in advance, urban rail lines are planned to go through the high-density developed area, in order to serve larger population and make sure the operation of urban rail normally itself. Second, the accessibility of the region close to urban rail lines is higher, so more land development may usually be attracted to.

Next, proportions of each POI type for different distance from rail lines are calculated, and the results are presented by the curves in Figure 3.

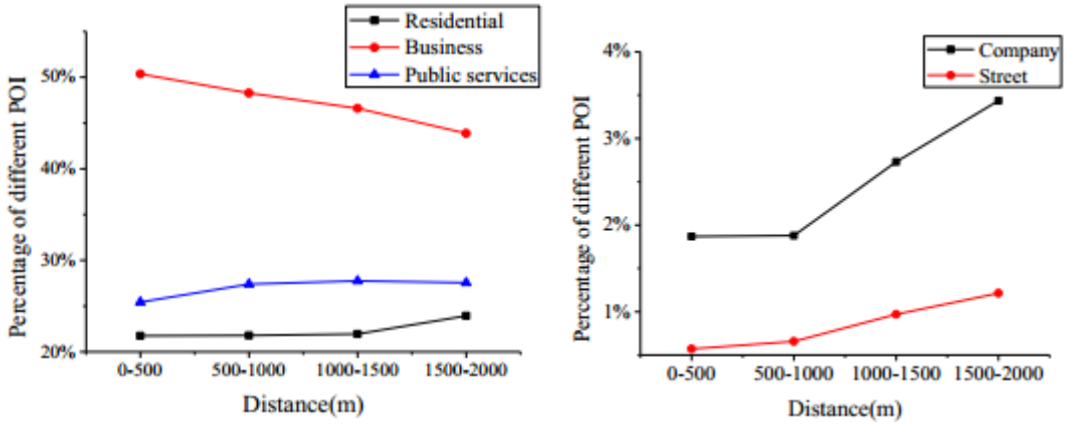

Figure 3. Percentage of different type of POI

It can be seen the commercial facilities account for the largest proportion, while the proportion decreases as the distance from rail lines increases. However, the proportions of residential land use and public services part increase when the distance grows. The proportions of company and street account for the least part, but grow when distance grows. We may infer that urban rail transit attracts commercial facilities, while keeps away to other land use types.

Characteristics of land use along Shanghai Metro Line 1. Shanghai Metro Line 1 is the earliest subway in Shanghai City, running from south to north as the main artery of the rail transit network. The total length of Metro Line 1 is 36.89 kilometers, with 28 stations. Following the analysis method of the rail network section, the different densities of land use and proportions of each POI type are obtained, as shown in Figure 4.

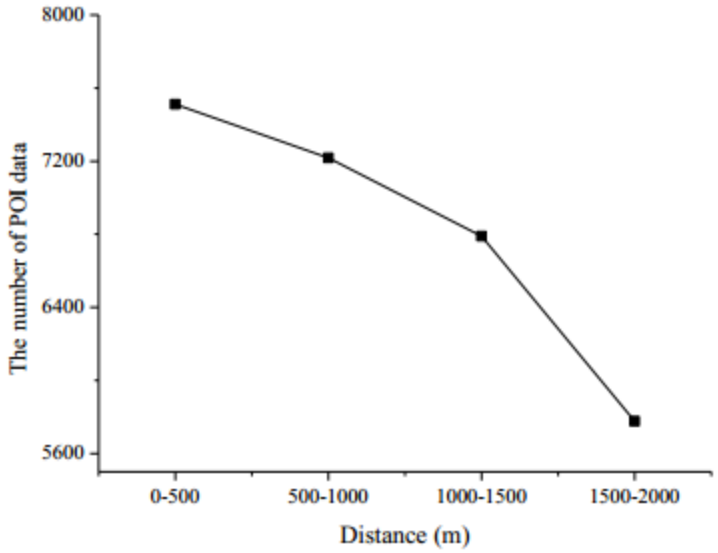

Figure 4. Relationship between Number of POI and Distance

For Metro Line 1, the density of land use decreases as distance from rail line increases, similar with the rail network analysis. However, what is not quite same with the phenomenon in rail network section is the declining rate, which is smoother when the POI is closer to rail line, opposite with the rail network section. This is because the land development is combined influenced by city structure and other corridors apart from Metro Line 1, so the corridor effect from Line 1 is not obvious.

As shown in Figure 5, similar with the entire rail network, the proportion of commercial facilities along Line 1 accounts for the most part and decreases with the distance from the track growing, while the residential facilities are the opposite. Different from the rail network, the variation of proportions of public facilities, street and company with the distance from rail line growing is not monotonous, without clear trends.

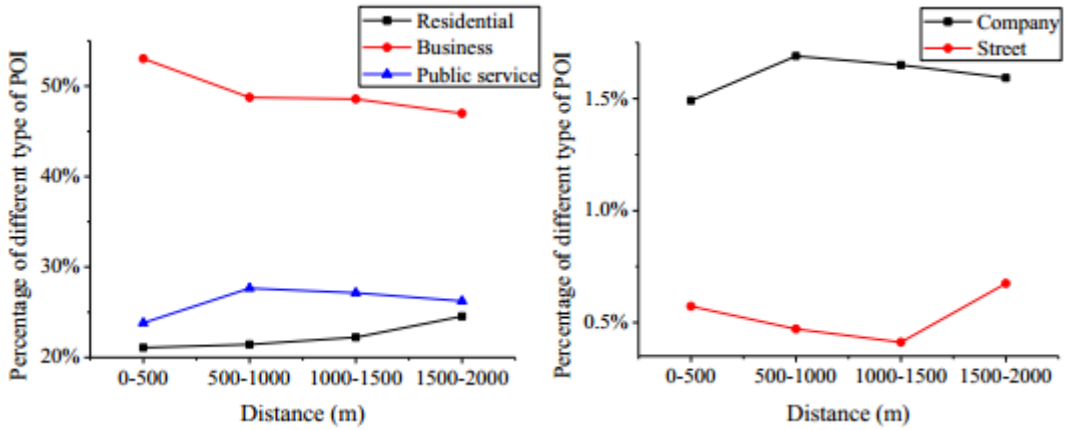

Figure 5. Percentage of different type of POI

Characteristics of land use around the stations on Shanghai Metro Line 1. There are 28 stations on Shanghai Metro Line 1, located in both city center and outer areas. In this section, we analyze the characteristics of the land use around all the stations within 500 m away from the rail line. The numbers of POIs around each station are presented in Figure 6.

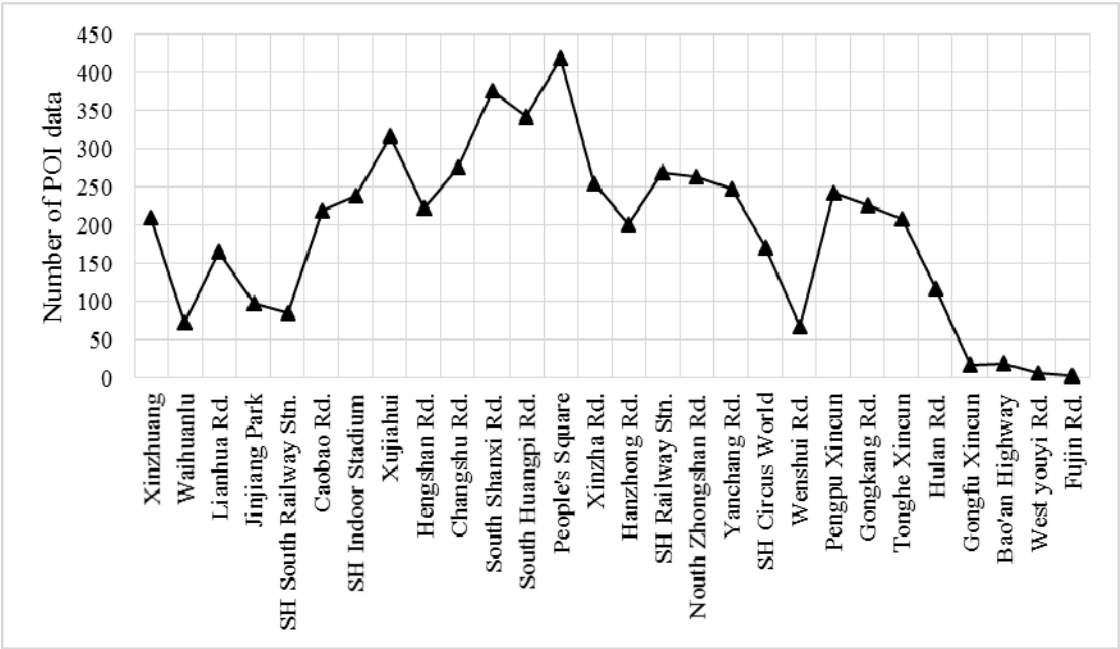

Figure 6. The number of POI around each station within 500m

As can be seen from the figure, the density of land development declines from city center to outer area. In which, the region around People's Square Station reached the highest developed density, while regions around Bao'an Highway Station, West Youyi Road Station and Fujin Road Station were barely developed. In addition, Waihuanlu Station, Jinjiang Park Station, Wenshuilu Station and Gongfu Xincun Station are located right in the place of road interchange, and the areas within 500 meters from the stations still belongs to the road infrastructure, so the numbers of POIs are rather small.

EVALUATION OF THE GATHERING EFFECTS IN LAND DEVELOPING BY URBAN RAIL TRANSIT

Land use characteristics are usually described by density and structure, but both of these two indictors barely illustrate the gathering phenomenon of land use along the urban rail, therefore the indictor of land use concentration degree is added. In the following part, the land use density, degree of concentration and the entropy of land use structure are calculated.

Density of Land Use. Traditionally, the evaluation of the density of land use requires the indicators of living population, population density, number of job position, employment density, volume ratio of building and building density. However, the achievement of all these indicators is quite tough and a lot of work is needed. Now, the density of land use can be estimated conveniently by taking advantage of the collected POI data.

$$d = \frac{N}{S}$$

where d is the intensity of land use, N is the number of POI in the study region, and the area of the study region is S.

Degree of Concentration. The impact area has been defined within 2000 m from urban rail line, and area within 500 m is the focus part. When the number of POI in 500 m area accounts for larger proportion in total number of POI, more concentrated the land developed, and vice versa. The definition of degree of Degree of Concentration is given as follows.

$$c = \frac{N_{500}}{N_{2000}}$$

where c is the Degree of Concentration, N_{500} represents the number of POIs within the range of 500 m, N_{2000} represents the number of POIs within the range of 2000 m.

Entropy of Land Use Structure. The Entropy Value from information science is used to reflect the complexity and diversity of the land use structure in the section. The more ordered a system is, the lower the entropy of information is. On the other hand, higher entropy represents a disordered system.

$$H = -\sum_{i=1}^{n} p_i \times ln\, p_i$$

where H is the Entropy, p_i represents the percentage of different types of POI within 500 m from rail line.

Evaluation on the Degree of Agglomeration of Land Use along Urban Rail Lines in Shanghai. With the support of ArcGIS, the POI data of the areas of 500 meters and 2000 meters from the track line of Shanghai city are analyzed respectively, and the evaluating indicators have been calculated. The results are shown as follows:

Seen from Table 3, after analyzing and comparing the characteristics and evaluating indicators of the land use along each rail transit line, results can be obtained as follows.

The proportion of commercial facilities is the highest, staying around 50%, while the proportion of the transport facilities accounts for the lowest, within 1%. For the lines mainly located in suburb, like Line 5 and Line 16, the proportion of real estate is lower, but the proportion of company is higher.

The areas highly developed are along Line 4, Line 10 and Line 1. Among which, Line 4 is a loop line, located entirely within the inner ring of Shanghai; Line 10 and Line 1 are both located in the west side of Huangpu River, within the outer ring of Shanghai. Regions along Line 16, Line 5 and Line 11 are insufficiently

developed. Line 16 is almost located outside the outer ring of Shanghai, connecting Shanghai city and the suburb, therefore the land development intensity is quite low.

Areas along Line 2, Line 6 and Line 8 have higher degree of concentration of land use. However, the degrees of concentration of land use of the areas along Line 3, Line 12, Line13 and Line 16 are lower, specifically, the proportion of POI within 500 m of these areas account for less than 25%. That is, few facilities could be reached within walking distance and the area needs to be further developed.

The entropies of land use of regions along Line 16 and Line 11 are higher than others, indicating they have been developed and more disordered.

Table 3. Evaluation Result

Line	Percentage of different type of POI					Evaluation indicator		
	RE	CO	BE	AD	ST	d	c	H
1	21.09%	1.49%	53.04%	23.81%	0.57%	203.55	0.2752	1.0985
2	21.94%	2.31%	52.17%	23.09%	0.49%	121.98	0.3160	1.1236
3	22.22%	2.05%	50.07%	24.91%	0.75%	168.26	0.2383	1.1433
4	21.45%	1.76%	51.73%	24.42%	0.64%	249.88	0.2720	1.1191
5	12.13%	6.01%	53.59%	27.74%	0.53%	55.12	0.2741	1.1426
6	17.60%	1.12%	53.48%	27.53%	0.27%	111.30	0.3153	1.0620
7	19.73%	1.04%	51.27%	27.51%	0.46%	117.52	0.2708	1.0900
8	23.92%	1.67%	48.68%	25.31%	0.43%	181.10	0.2901	1.1320
9	19.64%	2.35%	52.13%	25.36%	0.52%	126.63	0.2782	1.1226
10	23.11%	1.32%	49.98%	25.17%	0.42%	210.75	0.2552	1.1125
11	21.63%	2.54%	47.99%	27.11%	0.73%	67.21	0.2588	1.1666
12	20.58%	2.37%	52.69%	23.60%	0.76%	144.53	0.2153	1.1295
13	19.93%	2.25%	51.15%	26.34%	0.34%	188.64	0.2457	1.1204
16	14.02%	3.97%	46.96%	34.11%	0.93%	7.24	0.1743	1.1691

CONCLUSIONS

The evaluation of land development along urban rail transit is of great significance for the construction of rail transportation and the overall development of the surrounding land. This paper used the POI data obtained from the open source map, avoiding the tough workload of traditional data collection process, having analyzed the characteristics of land use around urban rail transit on network, routes and stations respectively under the support of GIS. The results have been found that the land use density declines with the distance from rail line grows. The rail transit attracts commercial facilities significantly, while keep away from residential regions.

In the article, the Degree of Concentration has been proposed to depict the land use more precisely. It is found that the intensity of land use along the track is mainly related to the location of the line. The degrees of concentration of land use along Line 3, line 12, line 13 and line 16 are too low, which indicated that the area needs to be further developed.

Although POI data collected from open source maps has been demonstrated to depict the land use characteristics usefully, there remains a problem: POI data do not reflect the differences in the size of each point. We are unable to distinguish a small shop from a large scale shopping mall based on POI data only. Fortunately, with the popularity of social network, more and more consumers get used to check in online when arrive at one place, as a result, the online check-in data could be used to estimate the POI size to some extent. How to sufficiently take use of the open source POI data and online check-in data from social network is quite necessary to be for future research in this direction.

REFERENCES

Bajic, V. (1983). "The effects of a new subway line on housing prices in metropolitan Toronto." *Urban Studies*, 20:2, 147-158.

Chatman, D. G. (2009). "Residential choice, the built environment, and nonwork travel: evidence using new data and methods." *Environment and planning. A*, 41:5, 1072.

Chen, C., Xiao, L., and Zhang, Z. (2007). "The research of the impact on urban morphology by orbit traffic in Guangzhou." *Yunnan Geographic Environment Research*, 19:1, 92-95.

Jiang, S., Alves, A., Rodrigues, F., Ferreira, J., and Pereira, F. C. (2015). "Mining point-of-interest data from social networks for urban land use classification and disaggregation." *Computers, Environment and Urban Systems.*

Lin, F. and Zeng, Z. (2007). "Impact of Shanghai UMT line 1 on urban form diffusion." *Urban Mass Transit*, 10:6, 4-8.

Liu, S., Guo, J., Li, R., and Li, Q. (2014). "Analysis of land use around typical rail transport stations in Beijing." *Urban Development Studies,* 21(4), 66-71.

Long, Y. and Liu, X. (2013). "Automated identification and characterization of parcels (AICP) with OpenStreetMap and Points of Interest." *arXiv preprint arXiv*:1311.6165.

Pan, H., Ren, C., and Yang, T. (2007). "A study on the impact on the land use of station areas brought by urban rail transport in Shanghai." *Urban Planning Forum,* 4, 92-97.

Roukouni, A., Basbas, S., and Kokkalis, A. (2012). "Impacts of a metro station to the land use and transport system: the Thessaloniki metro case." *Procedia-Social and Behavioral Sciences*, 48, 1155-1163.

Tian, L. (1999). "Study on land use along high-speed railway transit." *Urban Research*, 3, 26-29.

Tumlin, J. and Millard-Ball, A. (2003). "How to make transit-oriented development work." *PLANNING-CHICAGO-*, 69:5, 14-19.

Wang, P. (2014). "The urban planning method supported by big data." *Urban and rural governance and the reform of planning-014 China's urban planning conference proceedings.*

Zeng, Z. (2006). *Post evaluation of integrated impact of urban rail transit on urban development and environment-case study of Shanghai*. Doctoral dissertation, East China Normal University.

Zhou, J. and Xu, J. (2002). "The corridor effects of rail transportation on urban land using." *Urban Mass Transit*, 5:1, 77-81.