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Analysis of Multiple Network Accessibilities and Commercial Space Use in Metro Station Areas: An Empirical Case Study of Shanghai, China

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Abstract

Against the background of the rapid development of the Shanghai Metro network, this paper attempts to establish an analytical approach to evaluate the impact of multiple transport network accessibilities on commercial space use in metro station areas. Ten well-developed metro station areas in central Shanghai are selected as samples. Commercial space floor area and visitors in these areas are collected. Using ArcGIS and Spatial Design Network Analysis, the Shanghai Metro network and road network are modeled to compute diversified transport accessibilities. Evidence from land use and commercial space floor area within a 0-to-500-meter buffer zone of stations is consistent with location and land-use theory: commercial land use is concentrated closer to stations. Correlation analysis suggests that hourly visitors to the shopping mall are mainly influenced by metro network accessibility, while retail stores and restaurants are affected by both metro and pedestrian accessibility.

Keywords: Spatial design network analysis, Accessibility, Commercial space use, Metro station area, Shanghai

1. Introduction

It has been commonly accepted that land use and transport planning are closely related to each other through the change in accessibility: the "land-use/transport feedback cycle" (Meyer & Miller, 2001; Wegener & Fuerst, 2004) is often used to illustrate the complex interaction between transport, accessibility, and land use. Understanding the change in accessibility and the co-variation of land uses is key to understand the cycle.

There are many existing studies that provide empirical evidence of the complex relationships between accessibility and land use. For example, Verburg et al. (2004) analyzed the pattern of land-use change in the Netherlands, pointed out that accessibility measures, spatial policies, and neighborhood interactions are important determinants of current land-use changes. Borzacchiello (2010) used distances to city center, railway stations, and urban attractiveness as accessibility indicators in four Dutch cities, and found that the proximity of railway stations and highway exits have a significant influence on the variance of land-use patterns. Zhang et al. (2015) adopted space network analysis to assess the relationship between existing commercial land-use patterns and transport accessibility in Shanghai, finding that commercial land use is strongly distributed on the road network, so as to maximize the micro-to-macro high level of network accessibility advantage. Xiao et al. (2017) looked into a network accessibility-based methodology for appraisal of land use allocation in Wuhan. The study provided empirical evidence of the systematic link between connectivity and land-use class.

Furthermore, in the process of exploring sustainable development, rail transit has been considered by major cities in China as a key player in structuring new urban morphology patterns. Urban rail transit has been built in major cities across mainland China to improve sustainable mobility and reduce negative environmental and social consequences caused by fast-paced motorization. Up to December 2017, 35 cities had constructed subway or light rail transit systems. Therefore, rail transit and its impact on land use have received increasing attention from researchers.

According to urban location theories (Alonso, 1964), transit access determines the worth of land; the closer to the transit station, the higher the bid rent. Therefore, in metro station areas, one should observe a land-use pattern in which more capital-intensive land uses, especially commercial and office, are located closer to the station, and other land uses are located farther away. Previous research

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has found that metro stations have positive effects on nearby commercial properties within walking distance from a transit station; here again, the closer the area is to the station, the stronger is this influence. Nelson's study (1999) of the Metropolitan Atlanta Rapid Transit Authority (MARTA) showed that commercial values are influenced by both transit station proximity and policies that encourage intensive commercial development around transit stations. Cervero & Duncan (2002) studied the effects of proximity to light- and commuter-rail stations on commercial and retail properties in Santa Clara County, California. They highlighted that downtown commercial properties saw greater positive benefits than properties outside the central business district. In an empirical study by Zhuang and Zheng (2007), data are examined for MTR stations in Hong Kong. The result demonstrated that MTR station proximity has significant impacts on commercial land prices, within the first influence radius of 350 meters and the second of 550 meters.

In the mainland China context, Pan & Zhang (2008) investigated the effects of metro station proximity on land use of Shanghai Metro lines 1, 2, and 3, found that 0-to-200-meter buffer zone contains a greater proportion of commercial land use (24%, 18.1%, and 10.7%, respectively) than the 200-to-500-meter buffer zone (16.3%, 15.5%, and 8.9%, respectively) across all three metro lines. However, at that time (July 2007), Shanghai only had a 145-kilometer-long rail transit system in operation. Since the 11th Five-year Plan period (2005 to 2010), Shanghai Metro moved into an accelerated network expansion stage. In the subsequent decade after Pan & Zhang's study (2007 to 2017), the number of stations rose from 148 to 324 – a more than two-fold increase – while the total network length increased from 230 to 633 kilometers. This was an almost three-fold increase based on an already large base figure, making the Shanghai Metro the longest system in the world (Zhang & Chiaradia, 2017). The metro system has radically changed the accessibility and travel pattern of the Shanghai metropolitan area. Therefore, it is necessary to update the land-use changes associated with rail transit up to the present time.

Despite a growing amount of research on rail-transit accessibility, there is still little research on both the road network and rail transit network. Furthermore, current studies mostly focus on aspects such as land-use patterns and rent at a macro scale; there is a lack of studies on commercial space use in metro station areas at the meso- and micro-scales. In Shanghai case study, this paper focuses on identifying the evidence of multiple network access influencing commercial space use. The remainder of this paper is organized as follows: The second section provides the network accessibility analyses, an overview of the study area, and data collection methodology relevant to the study. The third section describes the relationship of commercial floor area to metro station proximity and network accessibilities. In the fourth section, correlations between commercial visitors and network accessibilities in metro station areas are discussed. Finally, conclusions are drawn from the study results.

2. Data and Methods

2.1. Calculating Network Accessibility Measures

Centrality analysis is often used in Social Network Analysis to calculate accessibility measures of a network (Bavelas, 1950; Freeman, 1977). Two measures of centrality have been widely adopted in recent studies: Closeness centrality and Betweenness centrality (Cutini, 2001; Porta et al., 2006; Newman et al., 2006; Borzachiello et al., 2010; Xiao et al., 2017). "Closeness as mean shortest path" is interpreted as "to-movement" analysis (Pooler, 1995) and "betweenness" as "through-movement" analysis (Shimbel, 1953). In this study, the authors used betweenness centrality as the indicator for evaluating the spatial configuration of networks.

Betweenness is a centrality measure which captures the frequency with each link x fallings on the shortest path between each pair of other links y and z, provided the Euclidean distance from y to z is within network radius R.

$$Betweenness\ (x)=\Sigma_{y\in N}\Sigma_{z\in Ry}W(y)W(z)P(z)OD(y,z,x) \quad (1)$$

where N is the set of all links in the spatial system, Ry is the set of all links within the defined radius of link y, $P(z)$ is the proportion of y falling within the radius from y, and $OD(y, z, x)$ is defined as:

$$OD(y,z,x) = \begin{cases} 1, & if\ x\ is\ on\ the\ shortest\ path\ from\ y\ to\ z \\ 1/2, & x\equiv y\neq z \\ 1/2, & x\equiv z\neq y \\ 1/3, & x\equiv y\equiv z \\ 0, & otherwise \end{cases}$$

The contributions of 1/2 to OD (y, z, x) reflect the end links of geodesics, which are traversed half as often on average, as journeys begin and end in the link center on average. The contributions of 1/3 represent origin self-betweenness.

Following previous empirical studies (Zhang et al., 2015), we adopt Topological betweenness (BtC) to measure the configuration of the Shanghai Metro network. The metro network is modeled by using one link for each line between two stations (topological distance=1) and two short links for each transfer between two lines (topological distance =2) (Chiaradia et al., 2005; Zhang & Chiaradia, 2017). The symbol "n" was used as the analytical radius for computing potential metro flow of the whole network.

Using road/path centerline network, road network-accessibility values were calculated for each street-segment by measuring Angular betweenness (BtA) at the follow-

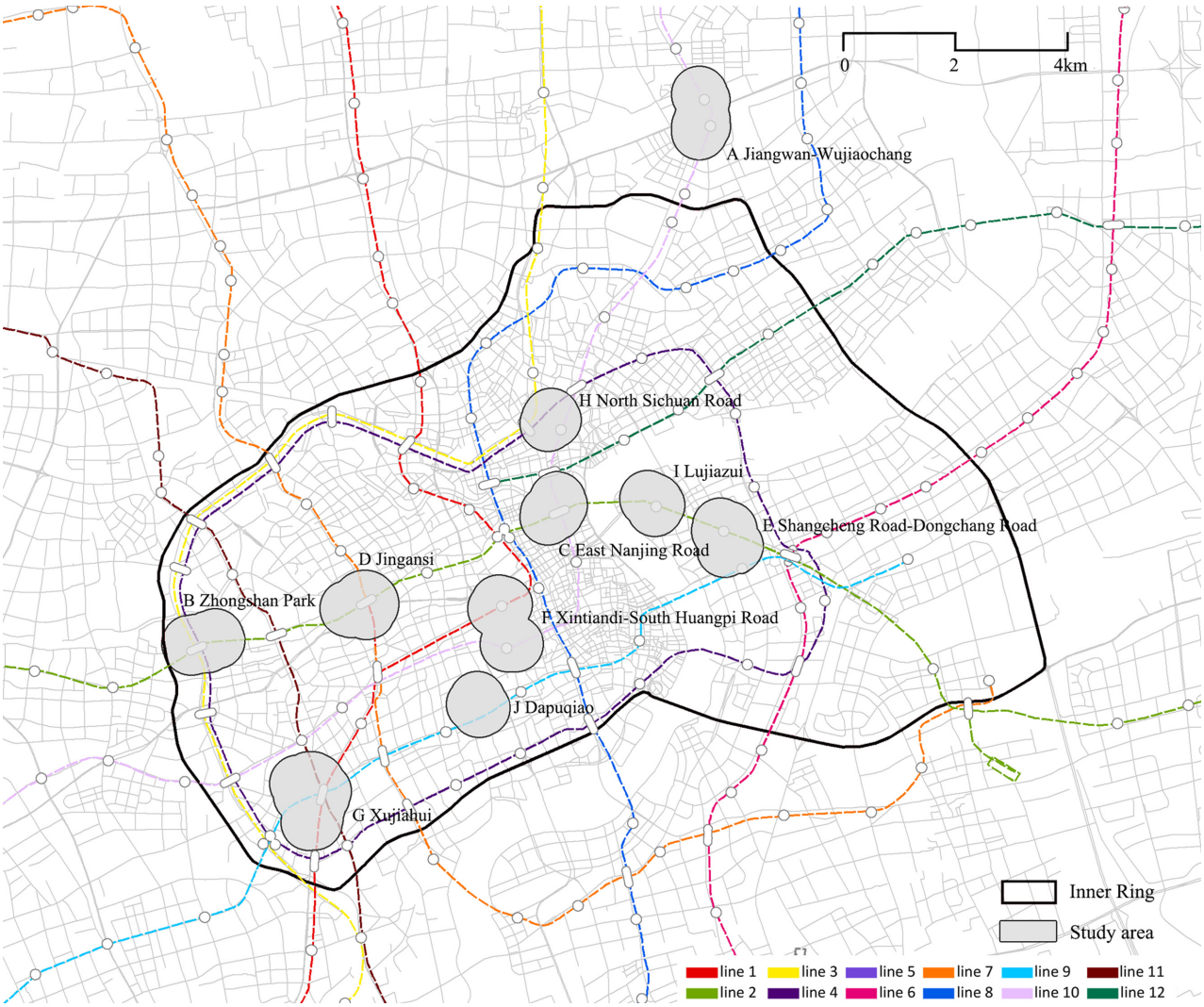


Figure 1. Road network, metro network, and location of 10 metro station areas in Central Shanghai.

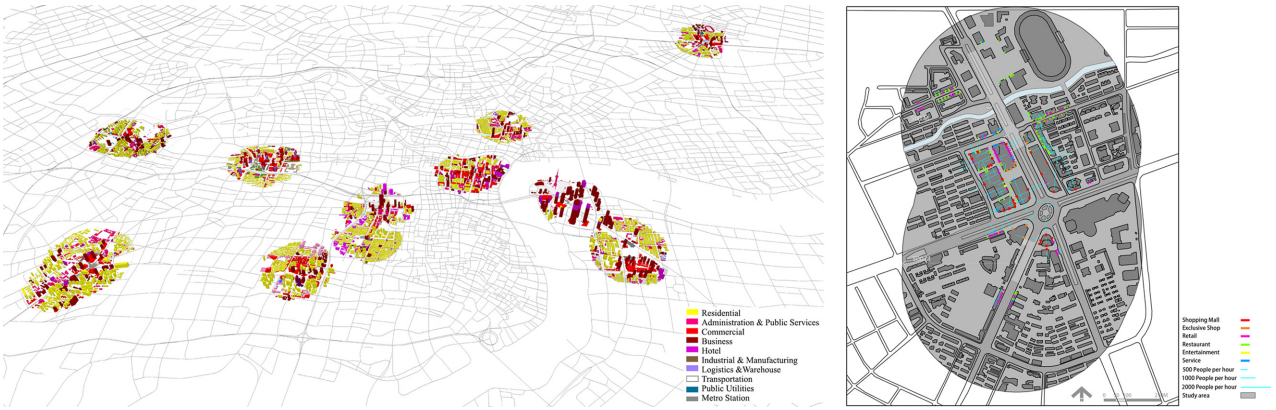


Figure 2. Space use in 10 station areas; (a) space functional location, (b) average hourly commercial visitors in Jiangwan-Wujiaochang station area (Weekend).

ing radii: 500, 2,000, and 5,000 meters. These can be associated with different potential uses of the road network, for example, 500 meters is a comfortable walking distance, 2,000 m is cycling or running distance, and 5,000 m is

car-scale. Spatial Design Network Analysis (Chiaradia et al., 2014; Cooper et al., 2014)[1] (sDNA) in ArcGIS was used to compute and visualize the measures of networks.

2.2. Study Area and Data Collection

Our analysis focuses on Shanghai, the city with the largest and fastest growing metro system in China. The metro station area is defined as 500 meters from each entrance/exit. The surveyed 10 metro station areas are all well-developed stations located in Central Shanghai, as seen in Fig. 2(b).[2] The betweenness centrality of each sample is the average value of links within each station area.

Commercial "space use" in this study includes the amount of commercial gross floor area (GFA) in the 500-meter buffer area, and average hourly commercial visitors in the 300-meter buffer area (Yuan et al., 2017).[3] Red volumes in Fig. 2 show distribution of commercial space in 10 sample areas. Hourly commercial visitor data in station areas were gathered using the "Gate Count" method (Chang & Penn, 1998). We completed 30 minutes of observation for each store in a sample of the Jiangwan-Wujiaochang area, shown in Fig. 2. The observation time was distributed over six different periods for one weekday and one weekend day (weighted 5:2 for weekday vs. weekend to account for average hourly pedestrian flow): 8-10 am, 10-12 am, 12 noon-2 pm, 3-5 pm, 5-7 pm, and 7-9 pm, giving an all-day average commercial visitor data.

3. Road Network, Metro Station, and Commercial Space

3.1. Road Network, Metro Station, and Commercial Land Use

To examine the relationship between road configuration variables and commercial land use, betweenness centrality measures at different radii for two types of road links were investigated (Table 1). Commercial land use is apparently associated with roads with relatively higher betweenness.

This finding is consistent with the previous analysis concerning commercial land use density in relation to betweenness centrality values of roads. There are 14%, 20%, and 21% commercial land uses on the links, with the highest 10% betweenness at different radii: 500, 2,000, and 5,000 meters. More than 50% of commercial land uses are situated along the top 30% links with the highest betweenness value (Zhuang & Zhang, 2016). It means that commercial land use tends to flourish in the areas surrounding roads that provide a greater level of accessibility. At the same time, 7%, 20%, and 29% of metro stations are situated at the links with highest 10% betweenness at different radii (500, 2,000, and 5,000 meters). This is understandable, as most of the metro lines used a cut-and-cover technique of construction, thus they follow the main artery roads, which creates an accessibility multiplier effect for commercial land use around metro stations.

3.2. Commercial Floor Area and Metro Station Proximity

For commercial gross floor area, we classify station areas into three categories, based on the distance from the metro exits: (a) The inner area, 0-100 meters from the exits, (b) The middle area, 100-300 meters from the exits, and (c) The outer area, 300-500 meters from the exits.

Fig. 3(a) shows total floor area ratio in 0-100-meter, 100-300-meter, and 300-500-meter areas. The average FAR of 10 station areas are 2.81, 2.4, and 2.35, for the inner, middle, and outer buffers, respectively. Transit-oriented development (TOD) which requires high-density development around station areas, has been widely adopted in China (Cervero & Day, 2008; Pan & Ren, 2005; Thomas & Deakin, 2008; Pan et al., 2011). Although researchers have pointed out that rapid transit systems like the Shanghai Metro represent the best choice for implementing TOD in China's high-density cities (Cervero, 2011), the current planning policies on FAR (2.5 for residential land use, 4.0 for commercial and office land use) limit the development intensity around station areas.

The proportion of commercial GFA is summarized in Fig. 3(b). A significant downward trend from inner to outer can be observed in most station areas. The average share of commercial space for 10 stations in the inner buffer area is the highest (33%), followed by the middle buffer area (26%); the outer buffer area is the lowest (10%). The most striking difference between inner and

Table 1. Spatial variable measures of two types of road links

	Sample no.	BtA 500	BtA 2000	BtA 5000
Links along Commercial land use	4806	100.92	5913.24	85578.43
Links not along Commercial land use	21435	76.35	2990.95	34630.07

[1] sDNA (Spatial Design Network Analysis) is a plugin for ArcGIS, AutoCAD, and open source GIS (QGIS) it uses the Shapefile (.shp) or .gdb files and link/node standard to analyze the spatial networks design characteristics using centrality measures and other measures such as severance. It provides many control variables. The software is freely available after registration at www.cardiff.ac.uk/sdna/with full specifications.

[2] 10 selected metro stations are: A. Jiangwan -Wujiaochang station; B. Zhongshan Park Station; C. East Nanjing Road Station; D. Jing'an Temple Station; E. Shangcheng Road-Dongchang Road Station; F. Xintiandi-Huangpi Road Station; G. Xujiahui Station; H. North Sichuan Road Station; I. Lujiazui Station; J. Dapuqiao Station

[3] Commercial space data used for this study are part of a database maintained by the Department of Urban Planning at Tongji University. A research team of 13 students started collecting space use, pedestrian flow, and car flow data in March 2014 for 10 station areas.

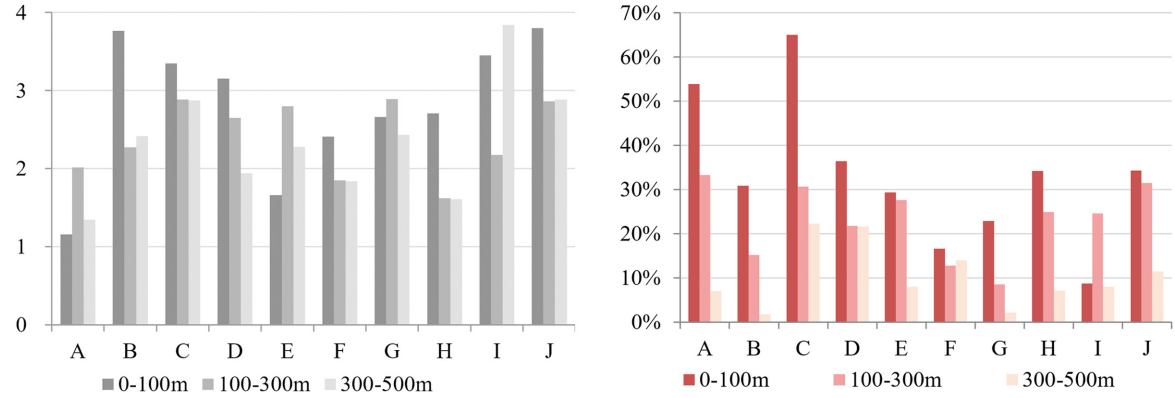


Figure 3. Comparison of space use between 0-100m, and 200-300m buffer zones in 10 station areas; (a) a total space intensity (floor area ratio), (b) the proportion of commercial floor area in total space.

outer areas was noticed in Zhongshan Park station area (B on the chart), where the ratio of commercial proportions in the 0-100 to 300-500-meter area is 17:1. The downward trend is broken in inner areas of both Xintiandi-South Huangpi Road station area (F on the chart) and the Lujiazui station area (I on the chart), due to the high proportion of office space (65% and 91%) in these districts. The data shows consistency with classical urban-location and land-use theory (Alonso, 1964); commercial land use is more sensitive to a change in accessibility than other land uses, which makes the share of commercial space in inner and middle buffer areas higher than in the outer area.

3.3. Commercial Floor Area and Network Accessibilities

A correlation analysis was performed in order to investigate the relationship between commercial space floor area (square meter) and network betweenness measures in 10 metro station areas. As Table 2 shows, in the inner buffer area, commercial floor area is strongly positively correlated with metro network betweenness; the R value is 0.788 (R square=0.61). In the outer buffer area, commercial floor area is influenced by both vehicle and pedestrian accessibility. Relatively weaker positive correlations were observed between commercial floor area and road network accessibilities (R=0.726 for BtA500; R=0.634, for BtA5000).

4. Commercial Visitors in Metro Station Areas

4.1. Commercial Visitors in 10 Sample Areas

Commercial spaces can be grouped into six categories: shopping mall, hypermarket, restaurant, retail store, entertainment, and service. In 10 station areas, a total of 2,436 commercial units were observed; of which 1,097 and 620 were restaurants and retail stores, respectively. As Fig. 4(a) clearly indicates, the numbers of commercial unit are significantly different in 10 station areas. For example, there are more than 350 commercial units in Xintiandi-Huangpi Road (F) and North Sichuan Road Station (H) areas, while there are less than 200 commercial units observed in the East Nanjing Road (C) and Xujiahui Station (G) areas. The Lujiazui area (I) appears to be an exception, with only 35 commercial units in total. The pie chart in Fig. 4(b) indicates the percentage distribution of commercial units. Unsurprisingly, the number of retail stores and restaurant (45% and 25%, respectively) are much higher than that of other categories (service, 17%; shopping mall, 7%; hypermarket, 3%; and entertainment, 2%).

The number of hourly customers in each station was computed by multiplying the average hourly commercial visitors by the number of units for each category. It can be seen from Fig. 5 that about 84% of customers are to shopping malls, retail stores and restaurants, with 36%, 25%, and 22% visiting each, respectively; visitors to hyper-

Table 2. R correlation coefficients between commercial space floor area (square meter) and network betweenness measures in 10 metro station areas

Buffer zone radius (in meters)	Metro Sum BtCn	Road BtA500	Road BtA2000	Road BtA5000
0-500	0.217	0.503	0.249	0.369
0-100	0.788***	0.270	-0.38	0.190
100-300	-0.274	0.034	-0.120	0.031
300-500	0.072	0.726**	0.515	0.634**

**Correlation is significant at the 0.05 level; ***Correlation is significant at the 0.01 level

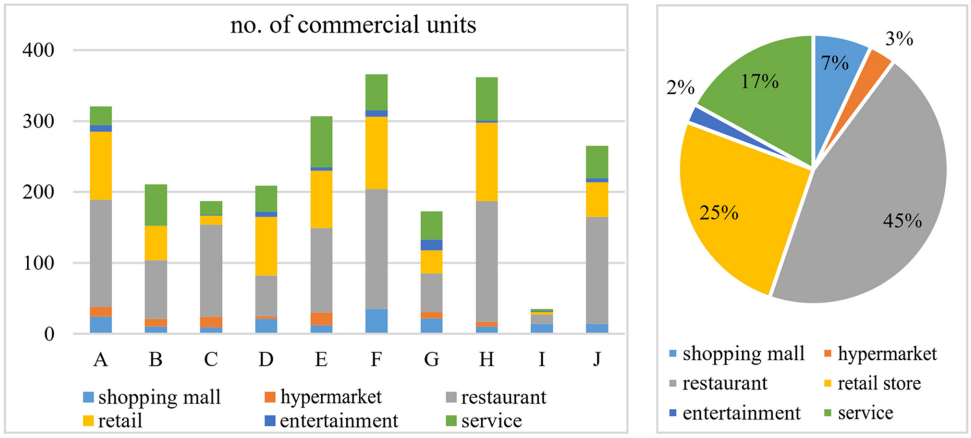


Figure 4. Descriptive statistics of number of commercial units for different categories in 10 station areas.

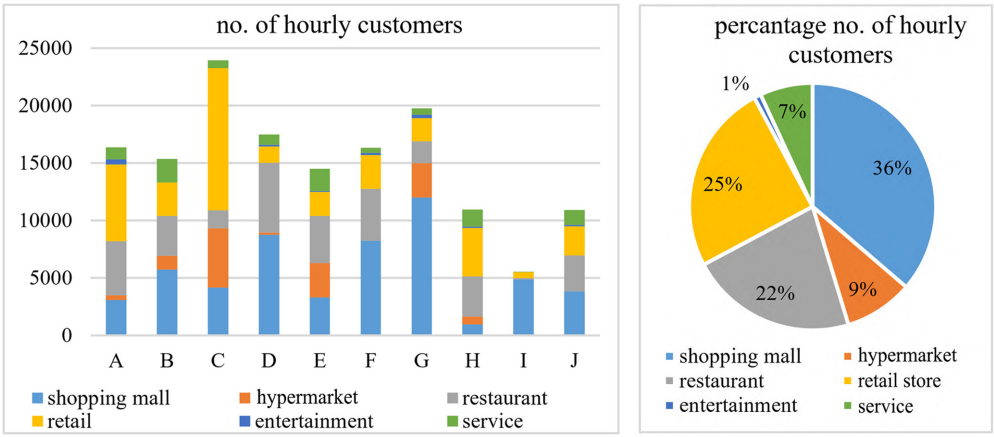


Figure 5. Descriptive statistics of hourly customers for different categories in 10 stations.

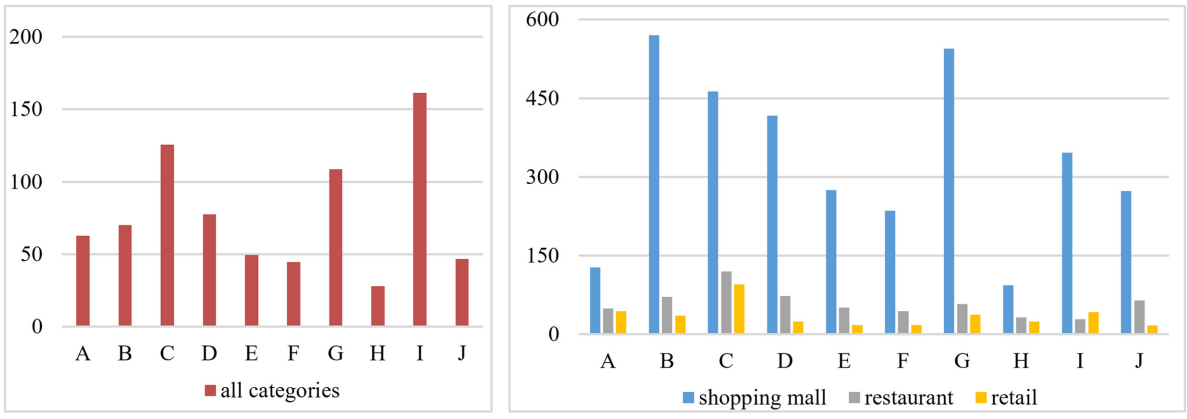


Figure 6. Descriptive statistics of average hourly customers in 10 station areas for; (a) all categories, (b) three major categories.

market and service shops account for 9% and 7% of the total customers, respectively; with the remaining 1% going to entertainment units. The number of shopping malls accounts for only 7% of the total number of retail establishments across the six categories, however, the shopping mall has the highest percentage of customers, which accounts for 36% of the total. This is simply because each shopping mall contains a large number of stores.

Table 3. R correlation coefficients between (Ln) average hourly commercial visitors (people per hour) and network betweenness measures of 10 metro station areas

	Metro Sum BtCn	Road BtA500	Road BtA2000	Road BtA5000
all categories	0.625*	0.023	-0.300	-0.293
shopping mall	0.889***	-0.033	-0.324	-0.224
retail store	0.377	0.333	0.190	0.093
restaurant	0.451	0.321	0.142	0.263

*Correlation is significant at the 0.1 level; ***Correlation is significant at the 0.01 level

As the descriptive data of average hourly visitors in Fig. 5 is shown, there is a clear difference between 10 station areas. For instance, the East Nanjing Road (C) and Lujiazui (I) station areas saw the best commercial performance (i.e., the highest average hourly customer value for each shop). Average hourly commercial visitors at North Sichuan Road (H) is the lowest of all 10 sample areas, with 28 persons per hour for each store.

4.2. Correlation Analysis

Based on the above survey data, we compute the correlations between average hourly commercial visitors and network betweenness measures for shopping mall, restaurant, and retail store typologies (Table 3). Extremely strong positive correlation was observed between metro accessibility and the number of shopping mall customers (r= 0.889). In contrast, no statistically significant correlation was present between road accessibility and shopping mall customers. This is due to two reasons. Firstly, for each metro station, the higher the metro network accessibility, the more ridership will be produced (Zhang et al., 2015). Secondly, underground spaces of shopping malls are usually well-connected to metro stations, making metro stations the primary source of customer generation. Furthermore, both metro and pedestrian accessibilities, which are the two main factors of pedestrian distribution in metro station areas, show a moderate influence on retail store and restaurant visitor flows.

5. Conclusions and Recommendations

A significant downward trend from inner to outer buffer areas was observed for the proportion of commercial GFA in Shanghai, which shows consistency with location and land use theory: more capital-intensive land uses locate closer to rail transit stations. However, due to the current planning policies on FAR, the average FAR of the 10 station areas are 2.81, 2.40, and 2.35 for the inner, middle, and outer buffers. The downward trend of development intensity, from inner to outer buffer, is weak. The high correlation between commercial floor area in the inner buffer area and the metro network betweenness measure implies that commercial space is sensitive to metro network accessibility. Correlation analysis between average hourly commercial visitors and network betweenness measures identifies that hourly visitors to the shopping mall are mainly influenced by metro network accessibility, while visits to retail stores and restaurants are affected by both metro and pedestrian accessibilities.

The experiences of rail-intensive cities like Tokyo and Hong Kong make clear that intense development (FAR 8-15) around stations is essential for transit to achieve bi-directional ridership flows (Chen, 2006). Redevelopment of many of the station areas in Shanghai is yet to take place. Technical guidelines for controlled detailed planning of Shanghai, released in 2016, have encouraged intensive development around transit stations: when more than 50% of the land of a certain block is within the buffer area of 300 meters from the rail transit stations, the block is encouraged to use a higher FAR intensity. It can be expected that development of the inner and middle buffer radii of metro station areas will be improved in the near future, and that the interaction between space use and rail transit accessibility will therefore be better.

This study attempts to establish an analytical approach, using multiple network accessibilities, to evaluate their influence on commercial space use, at both the macro and micro levels. Nevertheless, there are several limitations to this study. Firstly, due to the limitation of datasets, the sample size is inadequate for a multiple regression. A larger dataset should be created for a better understanding of the relationship between different network accessibility variables in future research. Additionally, it might be useful to include the bus network to complete the assessment of network accessibilities. Information about the bus network and further analyses are required in order to obtain a full picture of multiple network accessibilities.

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References

Alonso, W. (1964). Location and land use. Cambridge: Harvard University Press.

Bavelas, A. (1950). “Communication patterns in task-oriented groups.” Journal of the Acoustical Society of America, 22(6), pp. 725-730.

Borzacchiello, M. T., Nijkamp, P., and Koomen, E. (2010). "Accessibility and urban development: A grid-based comparative statistical analysis of Dutch cities." Environment and Planning B: Planning and Design, 37(1), pp. 148-169.

Cervero, R. (2011). "Transit-oriented and sustainable development." Urban Transport of China, 9(01), pp. 24-28.

Cervero, R. and Duncan, M. (2002). "Transit's value-added effects: Light and commuter rail services and commercial land values." Transportation Research Record: Journal of the Transportation Research Board, Issue 1805, pp. 8-15.

Chang, D. and Penn, A. (1998). "Integrated multilevel circulation in dense urban areas: The effect of multiple interacting constraints on the use of complex urban areas." Environment and Planning B: Planning and Design, 25(4), pp. 507-538.

Chen, W. (2006). "The discussion of rational exploitation strength in the plot around the metro station: Starting with the detailed plan of rail transport in second phase in Shenzhen." Modern Urban Research, Issue 8, pp. 48-50.

Chiaradia, A., Crispin, C., and Webster, C. (2014). sDNA a software for spatial design network analysis. [Online] Available at: www.cardiff.ac.uk/sdna/ [Accessed 27 Nov. 2018].

Chiaradia, A., Moreau, E., and Raford, N. (2005). Configurational exploration of public transport movement networks: A case study, the London Underground. Delft, Techno Press, London, pp. 541-552.

Cooper, C., Chiaradia, A., and Webster, C. (2014). Spatial Design Network Analysis(+). [Online] Available at: www.cardiff.ac.uk/sdna/ [Accessed 27 Nov. 2018].

Cutini, V. (2001). "Centrality and land use: three case studies on the configurational hypothesis." Cybergeo: European Journal of Geography [On line], Systèmes, Modélisation, Géostatistiques, Volume 188.

Freeman, L. C. (1977). "A set of measures of centrality based on betweenness." Sociometry, 40(1), pp. 35-41.

Meyer, M. and Miller, E. (2001). Urban Transportation Planning: A Decision-Oriented Approach. Boston: McGraw-Hill.

Nelson, A. C. (1999). "Transit stations and commercial property values: A case study with policy and land-use implications." Journal of Public Transportation, 2(3), p. 4.

Newman, M., Barabasi, A.-L., and Watts, D. J. (2006). The structure and dynamics of networks. Princeton and Oxford: Princeton University Press.

Pan, H. and Zhang, M. (2008). "Rail transit impacts on land use: Evidence from Shanghai, China." Transportation Research Record: Journal of the Transportation Research Board, Issue 2048, pp. 16-25.

Pooler, J. A. (1995). "The use of spatial separation in the measurement of transportation accessibility." Transport Research A: Policy and Practice, 29(6), pp. 421-427.

Porta, S., Crucitti, P., and Latora, V. (2006). "The network analysis of urban streets: A dual approch." Physica A: Statistical Mechanics and its Applications, 369(2), pp. 853-866.

Shimbel, A. (1953). "Structural parameters of communication networks." The Bulletin of Mathematical Biophysics, 15 (4), pp. 501-507.

Verburg, P. H., van Eck, J. R. R., de Nijs, T. C. D. M. J., and Schot, P. (2004). "Determinants of land-use change patterns in the Netherlands." Environment and Planning B: Planning and Design, 31(1), pp. 125-150.

Wegener, M., and Fuerst, F. (2004). "Land-Use Transport Interaction: State of the Art." [Online] Available at: http://ssrn.com/abstract=1434678 [Accessed 01 May 2015].

Xiao, Y. et al. (2017). "Street network accessibility-based methodology for appraisal of land use master plans: An empirical case study of Wuhan, China." Land Use Policy, Issue 69, pp. 193-203.

Yuan, M. and Zhuang, Y. (2015). "Analysis of metro station commercial space and its planning." Planners, 31(6), pp. 91-96.

Yuan, M., Zhuang, Y., and Zhu, X. (2017). "Performance evaluation and influence factors on commercial space of rail transit station area: Case studies of 10 samples in core area of Shanghai." Shanghai Urban Planning Review, Issue 6, pp. 116-121.

Zhang, L., Alain, C., and Zhuang, Y. (2015). "A Configurational accessibility study of road and metro network in Shanghai, China." In: Q. Pan & J. Cao, eds. Recent Developments in Chinese Urban Planning - Selected Papers from the 8th International Association for China Planning Conference, Guangzhou, China, June 21-22, 2014. English & Chinese Ed. Cham: Springer International Publishing, pp. 219-245.

Zhang, L. and Chiaradia, A. (2017). "How to design the metro network for maximal accessibility potential? A comparative analysis of Shanghai." Proc. 24th ISUF International Conference, Valencia, Spain.

Zhuang, Y. and Zhang, L. (2016). Station-City Synergy: Transport Accessibility & Spatial usage in Metro Station Areas. Shanghai: Tongji Press.

Zhuang, Y. and Zheng, X. (2007). "Impact of subway stations on commercial land prices." China Land Science, 21(4), pp. 38-43.