ID 1307 | EVALUATING JOB ACCESSIBILITY FOR DIFFERENT TYPES OF TRANSIT ORIENTED DEVELOPMENT AREAS IN BEIJING

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1 INTRODUCTION

Growing levels of urban mobility provide many noticeable benefits, but they also produce negative effects on the environment and society, such as higher energy consumption, CO2 emissions, air pollution, traffic noise, and reduced traffic safety (Bertolini and Le Clercq, 2003; Banister, 2005; Ferreira et al., 2012). In order to find a better balance between the benefits and costs of urban mobility, a shift from mobility-based to accessibility-based transport and land use planning has been advocated (e.g., Cervero, 1996; Levine and Garb, 2002; Bertolini and Le Clercq, 2003; Bertolini et al., 2005; Curtis and Scheurer, 2010; Bos and Lee, 2012; Levine et al., 2012; Papa et al., 2014; Martens, 2016; Levine et al., 2017). Accessibility-based strategies focus more on people’s direct demand for participation in activities (e.g., housing, working/schooling, shopping, visiting people/places, entertainment etc.), in contrast to the focus on derived travel demand that mobility-based strategies mostly focus on. Among several accessibility-based strategies, Transit Oriented Development (TOD) aims to fulfil people’s need to participate in activities by concentrating relatively high-density, mixed-use, cycling- and pedestrian-friendly development in transit station areas (Bertolini and Spit, 1998; Cervero, 1998, 2004; Curtis et al., 2009). Under favourable conditions, TOD can deliver multiple benefits, such as providing access to diverse activities, creating liveable or attractive places, helping renovate the built environment, and mitigating urban sprawl. In order to measure the actual effects, it is particularly crucial to assess accessibility for TOD. This is because many expected impacts of TOD, for example, reduced passenger transport costs (Litman, 2007), reduced CO2, air pollution emissions, and energy consumption (Kimball et al. 2013; Nahlik and Chester, 2014), and increased land/property values (Cervero and Murakami, 2009; Duncan, 2011) – are closely associated with the enhancement of accessibility, as accessibility significantly shapes these impacts by influencing individual travel behaviour (Kockelman, 1997) and business’ decisions (De Bok and Sanders, 2005; De Bok and Van Oort, 2011). Recently, the assessment of accessibility with respect to TOD strategies has generated considerable interest in academic and professional circles (e.g., Papa et al., 2013; Papa and Bertolini, 2015; Qviström, 2015; Palmateer et al., 2016). Studies have also shown large differences in the application of TOD strategies, resulting in different TOD types, even within the same city (Atkinson-Palombo and Kuby, 2011; Kamruzzaman et al., 2014; Vale, 2015; Lyu et al., 2016). This means that deeper insights into the association between different types of TOD areas and accessibility are necessary. To our knowledge, this association has not been empirically measured yet.

The paper aims to address this gap by studying how various TOD types within the same city are related to accessibility. The main focus is accessibility to jobs, because this is closely related to key policy debates about the functioning of the

labour and housing markets, social equity, and personal emancipation (Kawabata and Shen, 2006; Matas et al., 2010; Zhao and Howden-Chapman, 2010; Reggiani et al., 2011). Moreover, access to jobs is one of the main inhabitant demands in cities, requiring adequate responses in transport and land use systems. The study presented in this paper addresses the following research questions: Does TOD deliver higher job accessibility? How does job accessibility differ across different TOD types? By answering these questions, we aim to provide insights that can help develop targeted strategies to improve job accessibility for the entire built-up area or for specific types of urban areas.

Beijing, China was selected as the case study for the following reasons. On the one hand, mobility-based strategies – e.g., road building (increasing road density in Beijing’s urban districts, see Beijing transportation research centre, 2015), vehicle ownership number control (Zhao et al., 2014), and driving restriction (Viard and Fu, 2015) – have shown unable to fundamentally or effectively address Beijing’s major urban problems, such as road congestion, long commuting times, high rates of traffic accidents, air pollution and traffic noise (Li and Tao, 2004; Anas et al., 2009; Beijing transportation research centre, 2015). On the other hand, accessibility-based strategies, in particular TOD strategies, have been proposed (or applied) to address Beijing’s urban problems for many years. In Beijing’s Urban Master Plan 2004–

2020, TOD strategies proposed commute corridors connecting Beijing's central area to the former satellite towns, now part of Beijing's continuous built-up area, and improving accessibility to meet inhabitants' housing and job needs (Beijing Municipal Government, 2003). Since then, TOD has been officially considered as one of the key policy tools to address Beijing's transport problems (Beijing municipal commission of transport, 2012; Beijing municipal commission of transport, 2016). Despite these policy initiatives, an assessment of job accessibility for different types of urban areas is yet to be conducted.

The paper is organised into five sections. Following the introduction, in Section 2, we develop a methodology to evaluate job accessibility for any given place in Beijing. Section 3 presents the result of the job accessibility assessment for different types of urban areas. Section 4 discusses some potential policy implications, while Section 5 draws conclusions, reflects on the limits of the study, and provides future research directions.

2 METHODOLOGY

2.1 INTRODUCTION OF THE CONTEXT

2.1.1 DIFFERENT TYPES OF URBAN AREAS IN BEIJING

Beijing Municipality is home to 21.5 million residents, with 86.4% urban population and 1,385.6 km2 urban built-up surface (the main continuous urban areas) in 2014 (Beijing Municipal Statistics Bureau, 2015; Ministry of housing and urban-rural development, 2014). In 2014, the metro (18 lines, 268 stations and 527 km of tracks) served 10 million passengers each workday in 11 of Beijing's 16 districts (Beijing Mass Transit Railway Operation Corporation Limited, 2015; Beijing Infrastructure Investment Corporation Limited, 2015). Our research examines TOD areas around metro stops. Previous studies delineated TOD precincts according to geographical distances from the transit stop. Specifically, most European researchers (e.g., Bertolini, 1999; Reusser et al., 2008; Zemp et al., 2011; Vale, 2015) propose a 700 m Euclidian distance from the transit stop as the TOD precinct boundary, while most American studies use a range of ¼ mile (400 m) to ½ mile (800 m) (e.g., Atkinson-Palombo and Kuby, 2011; Austin et al., 2010; Schlossberg and Brown, 2004). Most TOD radii in European and American case studies are based on a 10-minute walking distance from the station (assuming walking as the main access and egress mode and 10 minutes as an acceptable walking time). In addition, some studies proposed that segments up to 1,500 m (Schütz, 1998) or half a mile (American Public Transportation Association, 2009) can include a secondary catchment area that might profit from the transit connection, substantiated by evidence that some walking trips to a transit node are generated in this secondary catchment area (see García-Palomares et al., 2013; El-Geneidy et al., 2014).

The study area in this paper was set as the entire built-up area of Beijing (the boundary uses Yang et al., 2013), and divided into 1,651 regular grid cells (1 km by 1 km). Given the modifiable areal unit problem (Openshaw, 1984), the choice of grid cells at this spatial scale may influence the results of the analysis. Our choice was made according to two main criteria: the size of the grid cell (1) can sufficiently distinguish between different types of urban areas to be investigated in this paper (compare definitions of area-types below) and (2) is around the average size of the original dataset (the economic census data at community level, also see Section 2.2.2). Moreover, grid cells are comparable spatial units. Next, based on the above-mentioned TOD studies, we identified cells whose centroids are less than 700 m Euclidian distance away from the centroids of metro stations as the TOD cells. Furthermore, we identified cells whose centroids are between 700 m and 1,500 m Euclidian distance from the centroids of metro stations as TOD secondary catchment (SC) cells. Beyond[1],500 m, most studies record only a few walking trips to a transit node, thus we identified cells whose centroids are beyond 1,500 m distance from the centroids of metro stations as non-TOD cells. Based on this methodology, we identified 375 TOD, 548 secondary catchment, and 728 non-TOD grid cells. Furthermore, we also defined six types of TOD cells (TOD_C1 to TOD_C6) and their corresponding secondary catchment cells (SC_C1 to SC_C6) (Figure 1), based on the work of Lyu et al. (2016), who classified 268 metro station areas of Beijing into six types (C1 to C6) by means of a principal-component cluster analysis. Prior the further analysis, a validation of their TOD classification (Lyu et al.,

[1] Here a TOD area refers to a 700-meter buffer from the centroid of a metro station.

2016) was conducted using variance analysis (ANOVA) and Tukey's Honest Significant Differences (HSD) Test (Tukey, 1949). The result shows that their TOD clusters are highly distinguishable from each other.

2.1.2 SELECTION OF GRID CELLS FOR ANALYSIS

We selected 261 TOD cells (classified into six types) and 182 secondary catchment cells (classified into six types) for the analysis. The TOD cells were selected if the centroids of TOD areas1 are located in such cells. Since some distances between the metro stations in Beijing's inner city are less than 700m, a few of the centroids of TOD areas are located in the same grid cells, resulting in a slightly smaller number (261) than number of metro stations (268). The secondary catchment cells were selected when the centroids of secondary catchment areas[1] were located in these cells. However, we only selected 182 secondary catchment (SC) cells for two reasons: (1) a few of the centroids of secondary catchment areas are located in the same grid cells; (2) a few of the centroids of secondary catchment areas are not located in secondary catchment cells[2]. A selected TOD/SC cell was attributed the features (i.e. category C1 to C6 and TOD indicators scores[3]) of its closest[4] metro station area. The locations of the selected cells and the numbers for their categories are presented in Figure 1. We also randomly selected 252 non-TOD cells (see Figure 1) to represent the entire population of non-TOD areas (728), calculated according to Formula 1 (Israel, 1992):

$$S = \frac{\frac{Z^2pq}{e^2}}{1+\frac{\frac{Z^2pq}{e^2}-1}{N}} \qquad (1)$$

S is the sample size; Z2 is the abscissa of the normal curve that cuts off an area α at the tails (1 - α equals the desired confidence level, in this case 1.962 for 95% confidence level); e is the desired level of precision (in this case ±5% precision); p is the estimated proportion of an attribute that is present in the population (we assume p=0.5, i.e. maximum variability); q is 1-p; and N is the entire population (728).

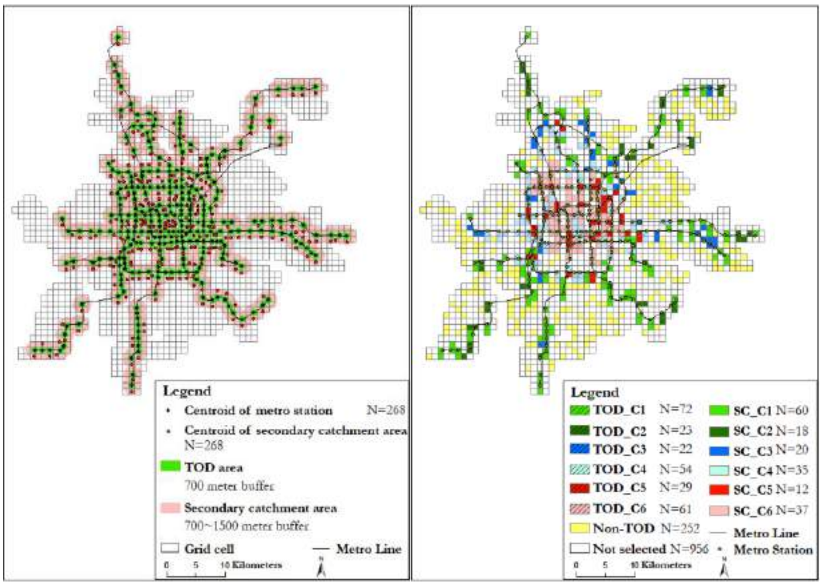

Figure 1 - TOD area and Secondary catchment area buffers (left) and selected cells of different types of urban areas for analysis (right) Based on: Lyu et al., 2016 and selection rules of this paper

[1] Here a secondary catchment area refers to a segment of 700- up to 1,500-meter buffer from the centroid of a metro station. The area has been cut out of the area that proximate TOD areas occupy. Its centroid is generated by the Feature to Point - a tool with an inside generation option in the ArcGIS 10.3.1 desktop platform. The output point was located inside of the polygon as its centre of gravity (centroid).
[2] See Figure 1 for the location of centroids of secondary catchment areas; some of them are located in the cells that have been identified as TOD cell in Section 2.1.1.
[3] See the description in section 2.1.3
[4] The distance is measured from the centroid of cell to the centroid of a metro station area.

2.1.3 TOD CHARACTERISTICS OF DIFFERENT TYPES OF TOD CELLS

Based on the work of Lyu et al. (2016) and the choices made in section 2.1.2, we summarised the TOD characteristics of different types of TOD cells, with 18 TOD indicators (see Table 1) used to cover 'Transit', 'Oriented' and 'Development' characteristics of urban areas. 'Transit' (T) indicators measured transportation features; 'Development' (D) indicators measured urban development features (e.g. land use density or diversity); and 'Oriented' (O) indicators drew attention to the functional and morphological interrelations between 'Transit' and 'Development' characteristics, focusing on relative proximity of residences and economic entities to the transit node and walkable urban design. All original TOD indicators were rescaled into the range of 0 to 1, with higher value means indicating a higher level of 'Transit', 'Oriented', and 'Development' features.

Of the six types of TOD cells, TOD_C2 cells, located in the periphery of the urban area (see Figure 1), show lowest values for the 'T', 'O', and 'D' aspects. TOD_C1 cells also have a peripheral location, but score higher on proximity to jobs and residences, functional density and diversity compared to TOD_C2. TOD_C4 cells are located at the periphery of the core urban districts; their TOD indicator scores are slightly lower than average, but the functional mix is at the highest level. TOD_C3 cells have similar 'T' characteristic to TOD_C4 cells, but higher 'O' dimension values (jobs and housing are located closer to the stations) and higher walking scores. The station areas in TOD_C5 cells and TOD_C6 cells are located at core urban districts and on the inner palm of the metro system. Although both score high on all TOD indicators, there are some notable differences. The 'O' values in TOD_C6 cells are highest among all clusters, suggesting that these areas are the most walkable and have the highest clustering of jobs and housing around stations.

TOD Characteristics	Indicators
Transit	T1 Number of directions served by Metro; T2 Number of directions served by bus; T5 Daily frequency of Metro services; T12 Number of stations within 20 minutes of travel by metro; T15 Travel times to major employment and activity centres by Metro; T19 Car parking capacity
Development	D1 Number of residents; D7 Number of establishments; D9 Number of establishments in retail, accommodation, and catering; D10 Number of establishments in education, health, and culture; D11 Number of establishments in public administration and services; D29 Degree of functional mix
Oriented	O1 Average distance from station to jobs; O2 Average distance from station to residents; O9 Length of paved footpaths per acre; O12 Intersection density; O14 Length of street network; O17 Walking scores

Table 1 - TOD indicators adapted from Lyu et al., 2016

2.2 METHOD OF MEASURING JOB ACCESSIBILITY

2.2.1 DEFINITION OF JOB ACCESSIBILITY

Job accessibility can be captured as the 'potential of job opportunities for interaction' (Hansen, 1959) or the 'ease of reaching workplaces' (Cervero, 1996). Based on these definitions, we define job accessibility as the potential job opportunities that can be reached from a given place, by travelling a certain time by means of a certain transport mode during a certain time period. With respect to travel mode, our focus is on public transport modes (bus, tram, metro, and walking or their combinations) for two reasons. One is that public transport is the main transport mode that TOD strategies build upon to affect job accessibility. The other reason is that public transport is an affordable and frequently used transport mode in Beijing. According to Beijing's annual transport report of 2014, 48% of all trips were made by public transport (Beijing transportation research centre, 2015). We set a travel time of one hour, because the average public transport travel time during peak hours (7:00–8:00 in the morning and 17:00–18:00 in the afternoon) is about one hour (Beijing transportation research centre, 2015). With respect to our specific study context, we thus capture job accessibility as the potential job opportunities that can be reached from a given cell by travelling one hour with public transport.

2.2.2 DATASETS AND MEASUREMENT

In order to calculate job accessibility in a given cell, two main datasets are needed. The first concerns travel times between the centroids of the cells. We retrieved the data by using Google Maps Distance Matrix API (Google Inc., 2016), which returns travel times of the shortest travel route from multiple given places to other multiple places by a given transport mode for a given departure time. We selected 695 cell centroids as trip origins (all the coloured cells in Figure 1), while the trip destinations were all grid cell centroids of the built-up area, namely 1,651 points (thus including all TOD, secondary catchment and non-TOD cells in Beijing). The departure time was set at 7:00 in the morning Beijing local time on Wednesday, 9 November 2016, by using a timestamp code (departure_time='1478646000'). The transport mode was set as 'transit' (Google Inc., 2016), i.e. public transport (bus, tram, metro, and walking or their combinations). The travel time dataset is a table, 695 rows (origins) × 1,651 columns (destinations) and 1,147,445 cells (=695*1651), with total travel times between pairs of origin and destination points. This travel time includes walking time from point of origin to public transit stop, waiting time for transport mode, riding time in public transport, and walking time from transit stop to destination point. If one or several transfers are required, the transfer times are also accounted for by the travel time returned by this API.

The other dataset measures job opportunities in a given grid cell. We used a dataset that contains numbers of employed workers in each community in Beijing (the number of jobs in each work place, Beijing Municipal Statistics Bureau, 2016). The boundary of communities and numbers of employed workers in each community were retrieved from Beijing's web application depicting the third economic census of 2014 (Beijing Municipal Statistics Bureau, 2016; also see Figure 2). In the built-up areas of Beijing, there are 3,045 communities, which have an average surface area of 0.71 km2 and are thus smaller than the area of a grid cell.

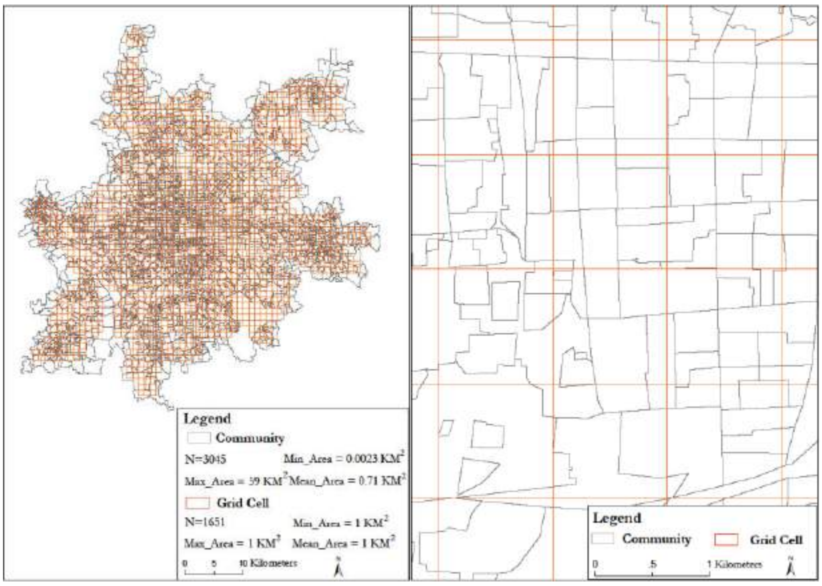

Figure 2 - Communities and grid cells in the built-up areas of Beijing.
Source: Beijing's web application depicting the third economic census of 2014

We selected three categories of jobs to be analysed, based on their relevance to policy intervention. The first is the type of all jobs[1] (no classification) because of its synthetic value. The second is type of jobs categorised by different economic sectors[2], using the Sectorial Classification System GB/T4754-2011 (National Bureau of Statistics of China, 2011), to provide insights into the differentiation of job accessibility across varying economic sectors. Third, we zoomed in on the jobs provided by central government–owned companies, because we assume that intervention in these jobs (e.g. establishing new or relocating existing

[1] It is not a sum based on the different types of jobs but an indicator for its synthetic value, which can be retrieved from the economic census database.

[2] We cannot analyse number of jobs by all different economic sectors because of data feasibility (e.g., the numbers of jobs on the sectors of agriculture, scientific research and polytechnic services, and international organizations are not available).

positions) can be accomplished more easily through direct policy choices (e.g. those suggested in our analysis).

The selected types of jobs for analysis	
All jobs	All-jobs (AJ)
By different economic sectors	Mining quarrying (MQ); Manufacturing (MF); Utilities(supply of water, gas, electric, heat, etc; UT); Construction (CT); Wholesale and retail trades (WR); Transport, storage, and postal services (TP); Accommodation and catering (AC); Information transfer, software and information technology services (IT); Finance (FN); Real estate (RE); Resident, repair and other services (RR); Education (EC); Health care and social work (HS); Culture, sports, and entertainment (CE); Public administration, social insurance, and social organizations (PS)
By capital source	Capital owned by the central government (CG)

Table 2 - Types of jobs selected for analysis

Based on the economic census data and the locations of grid cells, we computed the number of jobs within each grid cell. The processes were conducted in the ArcGIS 10.3.1 desktop platform. First, we calculated job density of each community by means of Equation 2:

$$Job\_Density_{i\_j} = \frac{Numbers-of-employed-workers_{i\_j}}{Areas-of-community_j} \quad (2)$$

$Job\_Density_{i\_j}$ is the job density of the community j on the category i; $Numbers\ of-employed-workers_{i\_j}$ is the number of employed-category-i workers in the community j; $Areas-of-community_j$ is the surface area of community j. Second, we calculated the spatial overlap of 'communities' and 'grid cells' within ArcGIS. This resulted into 9,767 new polygons across the 1,651 grid cells. Third, we re-aggregated the number of jobs within each cell using Equation 3:

$$Job\_Number_{i\_k} = \sum_k Job\_Density_{i\_j\_k} \times Area\_Polygon_{j\_k} \quad (3)$$

3 JOB ACCESSIBILITY IN DIFFERENT URBAN AREAS

3.1 SPATIAL DISTRIBUTION OF JOB ACCESSIBILITY

In order to illustrate the spatial distribution of accessibility of different kinds of job categories of the selected cells, we mapped all job accessibility, manufacturing job accessibility, wholesale/retail/trade job accessibility, and central government–owned-company job accessibility across these cells. The aim is to give the reader an idea about the spatial distribution of job accessibility according to all jobs, to different economic sectors, and to jobs of which the government may more easily determine the location. For the visualisation of the spatial pattern, we used the standard deviation method to classify accessibility values (ArcGIS for Desktop, 2016).

Regardless of the preferred job locations for different economic sectors, Figure 3 shows that the distribution patterns of job accessibility across different job categories are similar. First, it clearly shows a distinction between core and periphery (as defined by Friedmann, 1966). Job accessibility shows a marked decrease when moving from the inner city to the periphery. Second, Figure 3 also shows the influence of the historical distributions of job systems. For instance, job accessibilities in the northern part are generally higher than in the southern part, as the northern part is historically more developed than the southern part (Deng and Srinivasan, 2016). A third pattern is related to differences in TOD features, with job accessibilities in transit nodes and corridors being higher than in areas without transit connection. For example, even in the peripheral areas, job accessibilities are higher along the transit corridors (see light green or yellow coloured cells in the periphery in Figure 3). Potential implications for policy- and strategy-making

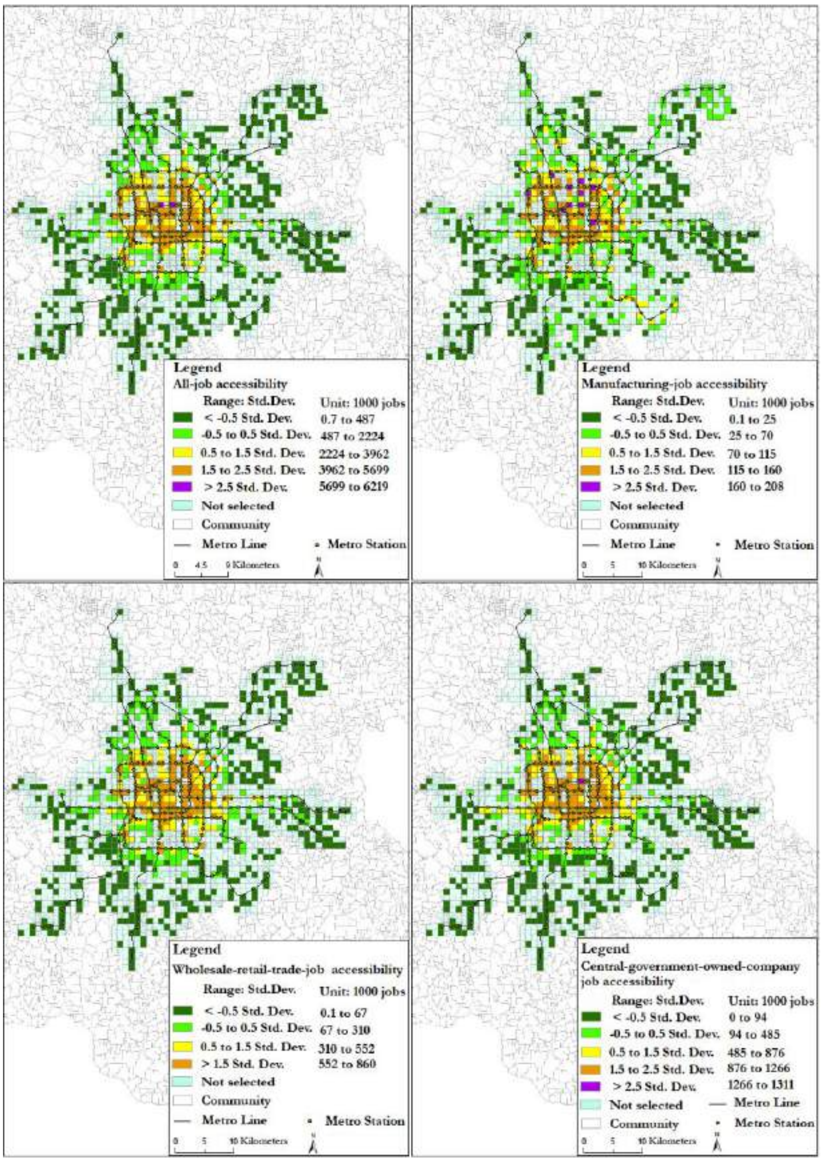

Figure 3 - Job accessibilities of the selected cells for the selected job categories. Source: Job accessibilities calculated, based on Economic Census 2014 and travel times obtained from Google Maps Distance Matrix API

3.2 TESTING SIGINIFICANT DIFFERENCES OF JOB ACCESSIBILITY IN DIFFERENT TYPES OF URBAN AREAS

In order to test whether job accessibility in each type of urban area is significantly different from other areas, we performed Tukey's Honest Significant Differences (HSD) Test (Tukey, 1949) after variance analysis (ANOVA), using the R Stats Package (R Core Team, 2017). Here we take a significance test for the difference in all-job accessibility across types of urban areas as an example. The 161.4 F-value (the ratio of the variance between groups to the variance within groups) in the ANOVA Test indicates that the means of all-job accessibility across different types of urban areas are different; however, it does not show exactly where those differences lie. Tukey's HSD Test provides detailed information about the significance of the difference between different types of urban areas on all-job accessibility. Table 3 shows the difference in all-job accessibility means between two types of urban areas. It also gives the adjusted P-value, indicating the significance of the difference. An adjusted P-value close to 0 means that the means of the two compared groups are significantly different, while an adjusted P-value close to 1 indicates that the means of the two compared groups are almost the same. Comparing, for example, the means of all-job accessibility between TOD cells and secondary catchment cells (TOD_Cell~SC_Cell) shows that the all-job accessibility in the TOD cells is on average higher than in the secondary catchment cells by 917,000 jobs. Their means are significantly different (adjusted P-value 0.00). The compared types in bold in Table 3 indicate that their means are significantly different, suggesting that in some types of urban areas, all-job accessibility is very much different than in the other types of urban areas. However, the result of this test is conservative by nature when applied to unequal sample sizes of compared groups. It means that all-job accessibility across various types of urban areas in Beijing may be much more different than what Table 3 shows.

Comparison between urban areas	Difference in means	Adjusted P-value	Comparison between urban areas	Difference in means	Adjusted P-value
TOD_Cell~SC_Cell	917	0.000	TOD_C2~TOD_C1	-433	0.719
SC_Cell~Non_TOD	1337	0.000	**TOD_C3~TOD_C1**	713	0.059
TOD_Cell~Non_TOD	2253	0.000	**TOD_C4~TOD_C1**	2145	0.000
TOD_C1~SC_C1	225	0.968	**TOD_C5~TOD_C1**	3562	0.000
TOD_C2~SC_C2	199	1.000	**TOD_C6~TOD_C1**	3514	0.000
TOD_C3~SC_C3	685	0.391	**TOD_C3~TOD_C2**	1147	0.001
TOD_C4~SC_C4	860	0.001	**TOD_C4~TOD_C2**	2579	0.000
TOD_C5~SC_C5	1358	0.001	**TOD_C5~TOD_C2**	3996	0.000
TOD_C6~SC_C6	1020	0.000	**TOD_C6~TOD_C2**	3947	0.000
			TOD_C4~TOD_C3	1432	0.000
			TOD_C5~TOD_C3	2849	0.000
			TOD_C6~TOD_C3	2801	0.000
			TOD_C5~TOD_C4	1417	0.000
			TOD_C6~TOD_C4	1369	0.000
			TOD_C6~TOD_C5	-48	1.000

Table 3 - Tukey's HSD Test for all-job accessibilities across six types of TOD cells, six types of secondary catchment (SC) cells, and non-TOD cells. Unit for difference: 1,000 jobs; adjusted p-values range from 0 to 1
Source: All-job accessibility of the selected cells, based on the Economic census 2014

4 POTENTIAL IMPLICATIONS FOR POLICY- AND STRATEGY-MAKING

The evaluation of job accessibility across different types of TOD areas, their corresponding types of secondary catchment areas, and non-TOD areas provides insights for policy- and strategy-making. First, the result that the means of all-job accessibilities in TOD areas are higher than those in secondary catchment and non-TOD areas can motivate urban planners, designers, and policymakers to develop more TOD areas in order to improve all-job accessibility. Second, the result that varying TOD characteristics substantially influences job accessibility suggests that from the perspective of job accessibility some type of urban areas with stronger TOD characteristics should be encouraged over other types, as elaborated below.

The internally similar but externally distinct characteristics of TOD types may allow planning professionals to develop a set of targeted strategies to facilitate a transformation of an area from one TOD type into another, which would serve to improve job accessibility for the targeted job category. For example, TOD_C1 areas that have broadly similar locations with TOD_C4 areas (Figure 1) can possibly be planned and designed to facilitate their transformation into TOD_C4 areas (shifts of means of 18 TOD indicators).

With respect to the associations between TOD types and the other types of job accessibility (e.g., manufacturing job accessibility or wholesale/retail/trade job accessibility), we can perform the corresponding Tukey's Honest Significant Differences (HSD) Tests (similarly to the process in section 3.2, the object of test becomes the targeted type of job accessibility). Such HSD Tests also provide insights for policy- and strategy-making in order to improve the targeted type of job accessibility of specific locations.

Furthermore, our work provides insights for actions on the metropolitan level. For instance, the spatial distribution of job accessibilities suggests that Beijing is still a single-centre city with a strong 'core–periphery' opportunity distribution pattern. Based on our work, policymakers can identify potential secondary cores (hubs) of job accessibilities to be strengthened. It seems useful to cultivate these future core urban areas to transform Beijing into a polycentric city, one of main stated planning goals of Beijing's Urban Master Plan 2004–2020.

5 CONCLUSION AND DISCUSSION

This research evaluated job accessibilities across different types of TOD areas, their corresponding types of secondary catchment areas, and non-TOD areas in Beijing. By comparing their job accessibilities, it confirmed that inhabitants of TOD areas enjoy higher all-job accessibilities than those living in secondary catchment or non-TOD areas. We also found that stronger TOD characteristics correlate with higher all-job accessibilities in these locations. This outcome provides insights for developing area-specific and targeted strategies to improve the all-job accessibilities of specific locations. It demonstrates the development of a methodology with future potential application in other geographic contexts, with both analytical and planning support value.

The study's methodology and findings are qualified by several limitations. First, the analysis is limited by the modifiable areal unit problem. It influenced the results on (1) the identification of different types of urban areas, and (2) the job attribution to cells. We took strong efforts to minimise its impact on the final result by using the most disaggregated census data and selecting a meaningful grid cell size for the analysis. Second, with respect to the association between TOD characteristics and job accessibility, we anticipated and confirmed its existence across different types of TOD areas. However, the hypothesised relationship may go in both directions, and it could be a dynamic and long-term relationship, across time or space, as captured by the notion of a transport–land use feedback cycle (Wegener and Fürst, 1999; Bertolini, 2012; and Kasraian et al., 2016). Third, since the results were based on publicly available datasets, namely Google Maps Distance Matrix API and Beijing's economic census of 2014, the level of detail or bias of these datasets also influences the result.

Based on these findings, we postulate the following potential research directions for future efforts. Considering the result that TOD characteristics have a strong effect on job accessibility of urban areas, we think it is worthy to evaluate TOD characteristics for the entire urban area of a city. This approach would entail extending TOD studies to urban areas without transits stops, but with 'T', 'O' and 'D' characteristics (here the 'T' refers to public transport). The next direction is to explore the relationships between specific TOD characteristics and the particular types of job accessibility (e.g., by sector or required skills). It would provide many valuable insights to policymakers for improving the targeted job accessibility in the specific urban areas. Considering the importance of job accessibility for access to the labour market, the third research direction could be to explore the spatial justice of job accessibility across different social groups of inhabitants.

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ID 1322 | COMMUTING PATTERNS AND CAR DEPENDENCY IN URBAN REGIONS

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ABSTRACT: We have analyzed car dependency in urban regions in the Netherlands, focusing on the lack of alternatives for the car in daily commuting. As geographical factors like distance from home to work and accessibility of job locations shape important conditions for potential behavioral change in car use and ownership, we map out the alternatives to the car for commuting in urban environments in the Netherlands, with emphasis on the bicycle and e-bicycle for shorter distances and combined bike-train for longer distances. In 2014, in the three big cities and some medium-sized cities (30% of the Dutch