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Spatial Analysis of the Distribution of Train Station Exits in Central Tokyo
ー 東京都心における駅の出口の分布の空間分析 ー

Motivation

In the course of my research about vulnerability in urban areas I am interested in the analysis of pedestrian traffic flows. Understanding those will help identify areas of high and low traffic volume. This can then be used as an indicator for greater or smaller vulnerability towards disasters. Network analysis methodologies can be used to research the characteristics of the respective pedestrian traffic networks. Examples for such methodologies are Reach, Gravity, and Betweenness measures (Sevtsuk and Mekonnen 2012). In my research I am using the betweenness index to identify more or less populated areas.

Analysis

The goal of this fieldwork was to capture the locations of the station exits using a manual GPS-assisted capturing process. In addition to the spatial location (X and Y coordinates) of each exit some attribute information was also collected, such as the exit name or number and the station complex that this exit belongs to. The total number of exit locations was as high as 540, where 109 exits lead directly into buildings, 9 exits were standalone elevators. The latter two categories were excluded in the upcoming analysis, which therefore was about 422 exit locations. The analysis itself consisted of three parts:

① A comparison of *spatial density maps* of station locations and station exit locations.

② A calculation of the building population (derived using the volumetric estimation approach by Lwin and Murayama (2009) *within certain distance bands* from their closest station centroid and exit location.

③ A comparison of *spatial centrality indices* for all buildings in the study area, calculated based on the station centroids and exit locations.

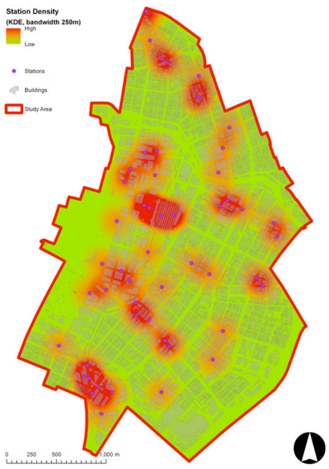

Fig. 1: Density of station centroids.

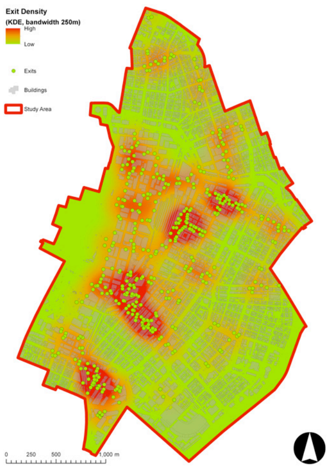

Fig. 2: Density of exit locations.

Results

Since every one of the stations in the study area has more than at least one exit, the number of exit locations would exceed the number of station centroids (54). Since these exits will be spread out within the same area, the density of exit locations has to be higher than that of station centroids. Figures 1 and 2 show the two density maps for the station centroids and exit locations, respectively. They were generated using a kernel density estimation (KDE) with a search radius of 250m. The cell size of the output raster is 10m by 10m.It is obvious how the expected higher density is reflected in the graphic representation. Yet, it also becomes obvious that the density of exit locations varies over the study area. Hence, there are regions with a high density of exits (e.g. around 東京駅, Tōkyō Station), and areas with a low density (e.g. the south-east corner of the study area, around 築地 (Tsukiji)). The density of exits directly affects the perceived quality of service (QoS) for passengers, since a large number of available exits not only heightens the probability of shortening the distance to the closest exit, but also distributes the passenger load onto a greater number of staircases, thereby making them less crowded.

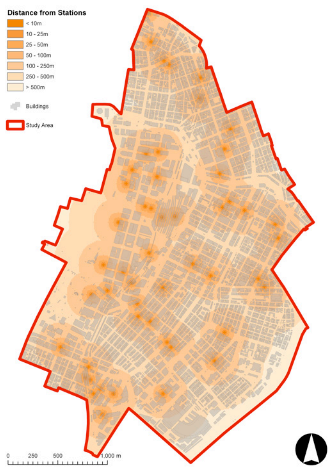

Fig. 3: Distance bands from station centroids.

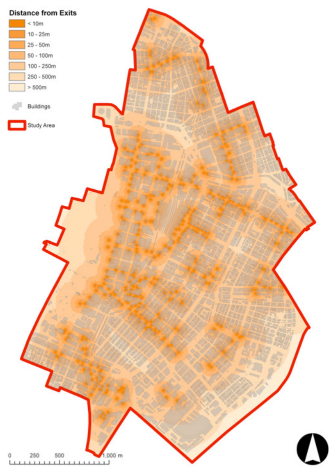

Fig. 4: Distance bands from exit locations.

In order to analyze the difference between station centroids and exit locations I created seven distance bands. Figures 3 and 4 show the spatial distribution of the distance bands from the station centroids and exit locations, respectively. In addition to this visualization of the distances I also calculated the number of people living and/or working within certain distances from the stations and exits. To do this I vectorized the distance raster grid and calculated the statistics for the number of 10m-by-10m raster cells, the number of buildings per distance band, and the actual number of people living and/or working per distance band.

Figure 5 shows a comparison of the calculation results. It shows the change from using exit locations compared to station centroids in percentage growth or shrinking. It is obvious that for all three thematics (raster cells, buildings, population) the amount of hits in the closer distance bands (< 100m) went up, while the amount of hits in the further distance bands (> 100m) went down. The changes were the greatest regarding the estimated population.

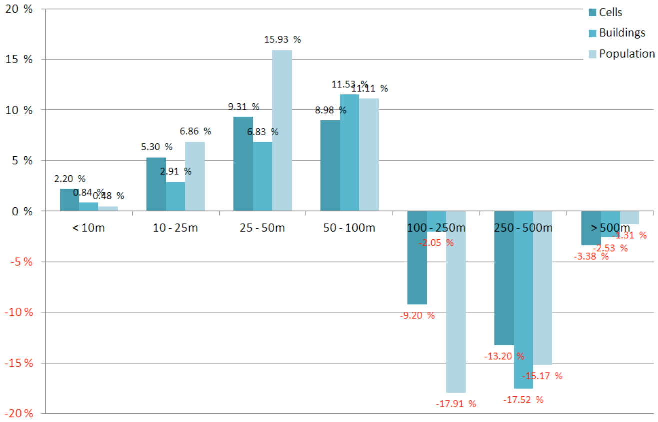

Fig. 5: Differences in the number of raster cells, buildings and estimated population per distance band from station centroids and exit locations.

This result shows the usefulness of using the more realistic exit locations over the station centroids to assess the QoS for passengers, since for most passengers it represents the perceived distance to the closest station. This fact can be easily understood by the data presented in Figure , which shows the percentage of building population per distance band for both station centroids and exit locations in comparison. When regarding the station centroids, more than half of the population (50.94%) is located 100-250m from the closest station, generally more than three quarters (76.56%) are located more than 100m from the closest station. In comparison, more than half (57.81%) of the population in located less than 100m from the closest exit location, almost one third (28.97%) is even closer than 50m.

Lastly I also investigated to which degree the change in input from station centroids to exit locations changes the output result of the betweenness centrality calculation for my study area. The betweenness centrality is an index that calculates how often a certain object (i.e. building) is located along the shortest path between two other objects (i.e. stations and buildings). This allows to identify areas that show high volume of pedestrian traffic as a result of both pedestrian supply (coming from a train station) and demand (walking towards a building). The results of this calculation are shown in figures 6 and 7, using the station centroids and the exit locations, respectively, as origin locations. The outcome of the two calculations is mostly identical, while there are only minor differences. This is mostly due to an existing flaw in the model, which assigns buildings to the incorrect road segments as a result of the unknown positions of building exits.

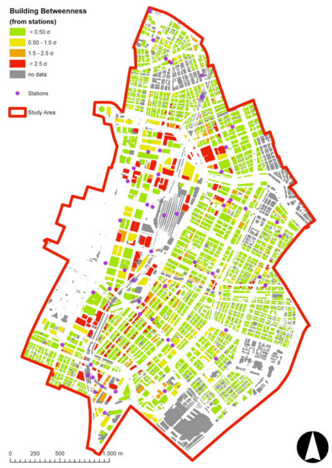

Fig. 6: Betweenness centrality index for station centroids as input locations.

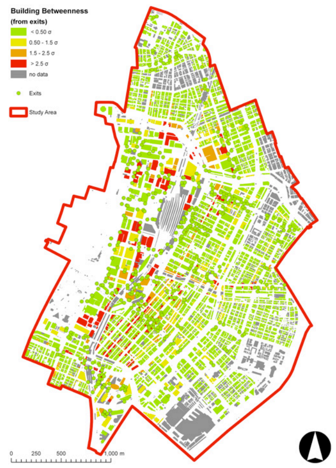

Fig. 7: Betweenness centrality index for exit locations as input locations.

References

Lwin, KoKo, and Yuji Murayama. 2009. "A GIS Approach to Estimation of Building Population for Micro-spatial Analysis." Transactions in GIS 13(4):401–414.

Sevtsuk, Andres, and Michael Mekonnen. 2012. "Urban Network Analysis: A Toolbox for ArcGIS 10." URL: http://cityform.mit.edu/files/UNA_help.pdf