Measures of Global vs. Local—Research on Accessibility of MTR Stations in Hong Kong

Ziyuan Yin and Charlie Q. L. Xue

ABSTRACT

Considerable quantitative research on space syntax has focused on the interaction between movement and accessibility. In this approach, the accumulation of travelling behaviours can be seen as the result of both cognition and the demands of people within an urban network. Accessibility creates opportunities for facilities and systems, such as a metro system, to generate and transmit human activity. This study on the relationship between patronage and accessibility of the catchment areas of 73 MTR stations in Hong Kong evaluated different methods of analysis. Specifically, it compared accessibility as described by the variables of ‘integration’ or ‘betweenness’ for three dimensions of distance, and it evaluated different statistical methods for representing the accessibility of station’s area as either the sum or the average of the total network around a station. This comparative analysis of the diverse variables of accessibility yielded the unexpected result that the accessibility of exits is more significant than the accessibility of catchment areas, with the latter result having been found in many studies. This finding raises the possibility of a new way of explaining accessibility when studying metro catchment areas: accessibility is the degree to which a station catches the urban structure with all of its exits, and this includes the locations of exits and the site choice for a station.1

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INTRODUCTION

As one of the most crucial factors relating to travel behaviours, accessibility has been widely addressed in transit research. One well-known conceptualisation of accessibility includes ‘the potential opportunities for interaction’ [1]. Although definitions abound, leading to different interpretations, there is considerable consensus that accessibility is what overcomes both physiological and psychological space within an urban network [2, 3]. In a macro-level study of urban structure, Hillier [4] introduced the concept of ‘configuration’ to understand the accessibility of metro stations, and declared that ‘cities are cognitive formations in an even more fundamental sense than they are socio-economic formations’. From this perspective, the urban form reflects social and economic movements, cultural activities and management styles [5, 6], and even the physical formation and urban street configuration affect urban formation [7].

Based on theories of topology and spatial cognition, space syntax allows for a systematic analysis of the relationship between human activity and configuration. The urban structure can be quantitatively described by axial lines and axial maps that ‘provide a simplified signature’ of the urban growth process. Also, the urban impact of local controls on growth is spatially localised, and cities show a surprising degree of universality at the ‘macro’ level [8].

Urban morphology can be formulated by the accumulation of urban elements that are points of identity and recognition [9, 10, 11]. By accelerating human and economic movement, urban configuration implies the accumulation of spatial form and facilities. The ‘movement economy’ can optimise the spatial form and signify the distribution of urban facilities as ‘residential accommodation’, which is concentrated in areas with less by-product movement, while ‘local facilities tend to be in spaces with strong local by-product movement’ [12, 13]. The analysis of urban configuration may explain the generation of spatial agglomeration. The indicator of configuration characteristics may explain and validate the accumulation of BE factors in an MTR catchment area. This approach can help to predict the future developmental intent of an area.

Based on the relationship between urban structure and morphology, a hypothesis may be generated that transit ridership correlates to the structure of a transit station’s catchment area. By surveying all MTR stations in Hong Kong, this study aimed to identify the correlation between metro patronage and the urban structure of the built environment around stations. Here, using new approaches to measure accessibility with Space Syntax, the spatial structure of the catchment areas of 73 MTR stations in Hong Kong was examined. Within these catchment areas, the values for accessibility were calculated as the variables ‘integration’ and ‘choice’ in different dimensions of Space Syntax. Synchronously, all of the data were processed in different ways, with the values of the sums and averages put into the model. This study’s comparative analysis identified the better way to find correlations with metro patronage.
METHODOLOGY

This study collected geographic data from all regions of Hong Kong. The basic map information is the street axial map and the digital map (scale 20000) of Hong Kong\(^2\) and it shows the building outlines, street boundaries, MTR lines, MTR stations and sky bridges. The street network and MTR network were combined through the points of station exits. The ‘depthmap’ produced two groups of data integration, (INT) and normalized choice (NACH), in a radius of 400, 800 and 1200 meters.

Hong Kong’s MTR is known for its financial independence from the government. Besides the light rail operating in the New Territories and the tram on Hong Kong Island, MTR has a total of 84 stations currently in operation. This study focused on the stations located in the urban area that serve the needs of daily commuting. Some stations that are special destinations were excluded from the study, such as the following: Luo Hu, Lok Ma Chau, Asia world-Expo, Airport, Sunny Bay, Disneyland Resort, University, Racecourse, Hong Kong and Kam Sheung Rd station. Ultimately, a total of 73 stations were selected for this case study.

Due to walking being the most basic way to access a station, this study focused on the built environment relating to pedestrian behaviours around these 73 MTR stations. As a result, two strategies were proposed to evaluate the accessibility of these cases: the first analyses the general situation of all of the catchment areas of stations (circles of a radius of 500 meters, Figure 1); and the second analyses the exits of stations. Accessibilities was examined by a ‘depthmap’\(^3\) in the three dimensions with a radius of 400, 800 and 1200 meters. The accessibility of the 1200-meter area can show the combined movements of pedestrians and mini-buses, while the 400- and 800-meter areas mainly describe walking patterns in the catchment area.

The values of the exits were derived by GIS, which is based on the ‘depthmap’. In the model, all of the exits catch the nearest road with values of INT and NACH in the three distance dimensions, and therefore the values were obtained from the exits and served as their accessibility value (Figure 2). The space syntax data of both the exits and catchment areas, including INT and NACH\(^4\) in the three dimensions, were calculated as the sum and average values, and these data, along with data on the patronage of each station on weekdays (WP) and weekends (EP), were analysed by regression formula in two ways:

- The data of buffer areas, defined by 500 meters Euclidian distance from stations, include average value (AVG) and sum value (SUM) of integration of global (INT), R=400 (IntR400), R=800 (IntR800) and R=1200 (IntR1200)

\(^1\)Obtained from Hong Kong map service, 2012. 
\(^2\)The analytical tool of Space Syntax. 
\(^3\)NACH of catchment areas were analysed with patronage for average (or sum) of choice values and could not properly represent accessibility in a region.
Figure 1. Layout and Location of Exits of Chai Wan (CHW) Station (Red points are exits).

Figure 2. Spatial Analysis of CHW Station Catchment Area.

The data of the exits include the average value (AVG) and the sum value (SUM) of integration (similar to the data of buffer areas) and normalised choice of R=400 (NACH400), R=800 (NACH800) and R=1200 (NACH1200).

DATA ANALYSIS

The primary analysis provides the results for the buffer areas and exits.

Buffer areas

The correlations between patronage (WP, workday; EP weekend) and the INT values of the catchment areas (INT-C, integration of R=n; IntR400-C, integration of R=400m) are listed in Table I and Table II. Besides global integration averages, patronage is significantly correlative with local accessibility values of both averages and sums in the three dimensions of distances, with SUM outperforming all AVG and with IntR800-C being most outstanding variable.
### TABLE III. CORRELATION OF PATRONAGE AND AVERAGE VALUES OF EXITS.

<table>
<thead>
<tr>
<th>AVG</th>
<th>INT-C</th>
<th>IntR400-C</th>
<th>IntR800-C</th>
<th>IntR1200-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>WP</td>
<td>Pearson Correlation Coefficient</td>
<td>.190</td>
<td>.480</td>
<td>.499</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.108</td>
<td>.000</td>
<td>.000</td>
<td>.237</td>
</tr>
<tr>
<td>N</td>
<td>73</td>
<td>73</td>
<td>73</td>
<td>73</td>
</tr>
<tr>
<td>EP</td>
<td>Pearson Correlation Coefficient</td>
<td>.190</td>
<td>.420</td>
<td>.404</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.107</td>
<td>.000</td>
<td>.000</td>
<td>.001</td>
</tr>
<tr>
<td>N</td>
<td>73</td>
<td>73</td>
<td>73</td>
<td>73</td>
</tr>
</tbody>
</table>

**. Correlation is significant at the .01 level (2-tailed). *. Correlation is significant at the .05 level (2-tailed).

### TABLE IV. CORRELATION OF PATRONAGE AND SUM VALUES OF EXITS.

<table>
<thead>
<tr>
<th>SUM</th>
<th>INT-C</th>
<th>IntR400-C</th>
<th>IntR800-C</th>
<th>IntR1200-C</th>
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<tr>
<td>WP</td>
<td>Pearson Correlation Coefficient</td>
<td>.627</td>
<td>.604</td>
<td>.645</td>
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<tr>
<td>Sig. (2-tailed)</td>
<td>.000</td>
<td>.000</td>
<td>.000</td>
<td>.000</td>
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<tr>
<td>N</td>
<td>73</td>
<td>73</td>
<td>73</td>
<td>73</td>
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<tr>
<td>EP</td>
<td>Pearson Correlation Coefficient</td>
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<tr>
<td>Sig. (2-tailed)</td>
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<td>.000</td>
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<tr>
<td>N</td>
<td>73</td>
<td>73</td>
<td>73</td>
<td>73</td>
</tr>
</tbody>
</table>

**. Correlation is significant at the .01 level (2-tailed). *. Correlation is significant at the .05 level (2-tailed).

Note: WP, patronage of weekday; EP, patronage of weekend; Int, integration; NACH, normalized choice;
Exits

Compared with the catchment area, the evaluations of the accessibility of exits provided higher correlation results (Table III and Table IV), especially for the relation between local sums of accessibility and weekday patronage. This result is different from what was found by Chiaradia et al. [14] in two respects, one being that the sum values performed better than average, and the other being that the accessibility of all exits performed well.

DISCUSSION

Through our analysis of 73 MTR stations in Hong Kong, the results from Space Syntax inform us that the accessibility of stations is significantly related to both weekday and weekend patronage. In these models, the accessibility of stations can be represented by the sum of the reachable degree of all of a station’s exits; similarly, “betweenness” dimensions can be used in this model to provide a reasonable prediction of MTR travel. What is special about this finding is that the accessibility factors of exits outperformed the station catchments; however, how the degree of reachable (INT, integration) and “betweenness” (choice) relate to the urban structure is another important issue that links accessibility with human activity.

According to research using Space Syntax, the urban configuration value has a ‘non-discursive’ relationship with most of the built environment’s characteristics, such as density. The finding on the accessibility of MTR stations can verify the causality between patronage and the built environment. Through its analysis of urban structure around MTR stations, this study identified a relationship between station accessibility and the location of a certain station within the general transit system, instead of predicting actual ridership. Therefore, the configurational model largely interprets accessibility as a pattern of a global transit network, one constructed by the local spatial structure of all stations.

Another issue requiring discussion is the meaning of accessibility in a configurational context. Using the mean values of local integration within a 500-meter buffer, Chiaradia et al. [14] constructed a model combining the underground network and the ground level, finding a correlation of r=0.79 between patronage and the underground of London. The factors leading to the differences between the case studies of Hong Kong and London could include the morphology and algorithm of Space Syntax. Also, both the urban structure and image in Hong Kong are different from those in London, with the former based on a sea and mountain pattern and the latter on a plain and river pattern. Located between mountains and the seas, the land usage in Hong Kong is intense and limited, and its compact urban infrastructure operates with a high level of efficiency, especially in the new towns centralised around MTR stations. There are discontinuous street networks in the outer areas and
around the fringes of the city, which are linked to the central area by MTR and highways. Returning to the two models of the mean integration values of catchments and the sum values of exits, some interesting findings emerge by comparing the residual error of patronage and accessibility variables. In the weekday catchment model, the stations of Mong Kok East Station (MKK) and Prince Edward Station (PRE) are predicted to have much higher ridership than in the exit model; in contrast, the Tsim Sha Tsui (TST) and East Tsim Sha Tsui (ETS) stations, along with the Mong Kok Station (MOK) station, are predicted to have lower ridership in the catchment model, while these three stations more closely fit reality in the exit model. The street networks of the catchment areas around these stations are quite similar and on Kowloon peninsula many industrial buildings were constructed in mid-20th century. After more than 30 years of rapid development, the TST and ETS areas, along with the MOK area, became the most central commercial regions of all of Hong Kong, while there are still many industries and storage facilities in MKK and PRE. Therefore, lower ridership is found for these two stations than for TST, ETS and MOK. This suggests that the catchment model may focus more on basic structure than on the dynamic change inherent in economic activity. Usually a street network is stable during a period of redevelopment whereas the exits are extended with the increasing of passengers, as what happened in the stations of MOK and TST (Figure 3 and Figure 4). Therefore, in Hong Kong the exit model outperforms the catchment model.

Figure 3. Built Environment of ETS, MKK, MOK Station.

Figure 4. Built Environment of TST, PRE Station.
The accessibility of a metro station can be represented in many ways, and superior approaches may focus on the relationship between metro catchment and urban structure. The sum of integration values of all station exits is highly related to the patronage of MTR in Hong Kong and is essential for describing the accessibility of a metro station. This supports that travelling behaviours, influenced by urban structure, can be predicted by Space Syntax.

The use of local integration values in evaluations of metro stations’ accessibility reveals systemic patterns of metro travel behaviour but not exact figures of ridership. The dynamic relation is the link between the underground system and ground level network, and this link helps us to understand the efficiency of a metro system from the viewpoint of urban morphology. Focusing on accessibility and global MTR system, one interesting finding of this study is that local integration is highly related to station patronage. How and to what degree global accessibility affects the relationship between station accessibility and ridership is left for future speculation. One hypothesis may be that certain global factors, combined with local accessibility, affect patronage, thereby suggesting the need to formulate a model of accessibility that combines global and local variables.

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REFERENCES