The Comparative Study of TOD in Metro Station Areas of Guangzhou and Shenzhen Using an Extended Node-Place Model

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1. Introduction

Node-place (NP) model is an analytical approach to investigates the status quo of transit-oriented development (TOD) of station areas. Current research mainly expands the model by taking the walking environments around the station areas into consideration, while seldomly improves the model in regard of the compactness of spatial form. Besides, few attentions have been given to applying urban vibrancy as a regional review to improve the model. Finally, node-placed extended model generally uses public data as TOD indexes which make it possible to examine and compare the TOD development between different cities as a benchmark.

This work takes Guangzhou and Shenzhen as the study cases, to investigate how well the stations in Guangzhou and Shenzhen are aligned with transit-oriented development and what's their discrepancies. This work has three key findings: (1) Shenzhen is 20% better in terms of the overall performance of TOD. (2) there are significant discrepancies between the groups of stations within each city in terms of TOD (3) the stations in the same groups within each city showed differentiation and variations in terms of TOD and urban vibrancy.

2. Methodology Overview

Based on the interactions between transportation and land use explained by Bertolini (1996), five types of station areas are identified according to the balance of 'node' and 'place' (Fig. 1). First, 'Balance' stations can be found in the domain along the middle diagonal line, where node and place values are relatively equal. At the upper right corner of the diagonal line are station areas under 'Stress', they have tensions due to both very strong node-place value and may results in conflictions. One the contrary, at the bottom areas along the diagonal line, one finds stations labelled as 'Dependency', as

they are unable to sustain themselves, i.e., they may need government support or dependent upon larger transportation stations. Station areas above the domain of middle diagonal line where station areas have stronger node value are labelled as 'Unsustained Nodes'. Conversely, 'Unsustained Places' below the domain of middle diagonal line represent station areas have stronger place value. Both two are the situations where the development dynamics of node-place can be expected, either positive (upgrading) or negative (downgrading). The situations could also suggest the more targeted planning policy for stations according to different upgrading (downgrading) pathways focusing on different aspects of TOD.

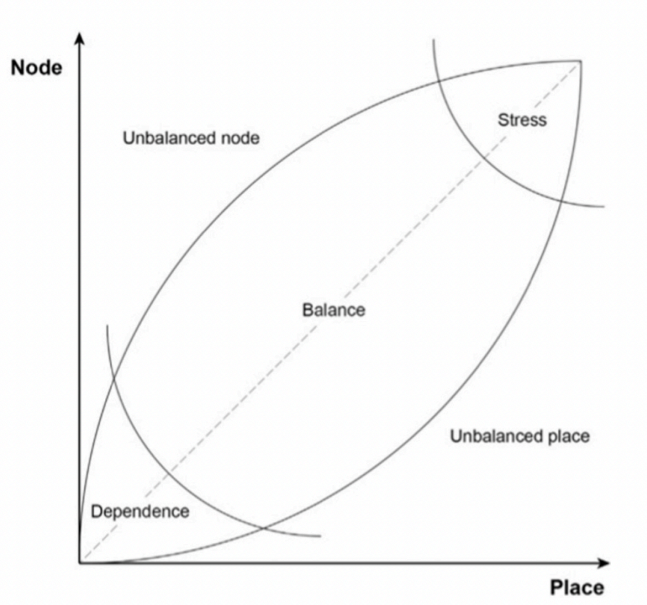

Fig. 1 Node-Place Diagram by Bertolini (1996)

In addition to the two original dimensions: node-place, many studies have added a third dimension, 'design', to current node-place model by interpreting the walkability of metro station areas (Vale, 2015; Lyu, Bertolini and Pfeffer, 2016). Following the same logic, this work expands the design dimension by adding indices focusing on the compactness of spatial form, e.g., average height and areas of buildings, functional distance from public facilities to station. Besides, despite all the advantages, the node-place model is still evaluating the metro station areas at local scale while lacking regional perspectives. To address that issue, Zhang, Marshall and Manley introduce the network criticality to node-place-design model (2019). Since few attentions are given to urban vibrancy in regard of TOD studies, this work introduces the concept of urban vibrancy as a regional review to the node-place-design mode. The indicators are calculated as table x

Indicator description	Calculation
Node index	average of indicators
Number of directions served by metro	x1=Number services offered by station
Time duration per train (Frequency)	x2=average time requency of the day
Number of bus stops	x3=bus stops around the station
Beweeness centrality of network (weighted by distance)	x4= local betweenness centrality weighted by line distances between stations
Closeness centrality of network	x5= local betweenness centrality unweighted
Place index	average of indicators
Number of residents	y1=polulation density assgined from raster grid and residential POIs
Number of workers	y2=number of working establishments POIs
Number of workers in leisure industry	y3=number of leisure POIs
Number of workers in catering and restaurant industry	y4=number of catering and restaurant POIs
Number of workers in administration	y5=number of administration POIs
Number of workers in education	y6=number of education POIs
Number of workers in retail industry	y7=number of retail POIs
Number of workers in hotel industry	y8=number of hotel POIs
Design index	average of indicators
Size of building areas	z1=size of areas of building shapes
Average height of building areas	z2=height of the buildings with station area
Length of predestrian network	z3=length of the road network with pedestrian walk paths
Number of intersections of road network	z4=polulation density assgined from raster grid and residential POIs
Functionality toward station	z5=standard distance[1] calculated by Qgis standard distance plugin
Urban vibrancy	average of indicators
Number of trips originations from station area to whole city	calculated from mobile phone data network
Number of trips detinations to station from whole city	calculated from mobile phone data network
Night time light data	assigned from night light time data of the year

Table 1 The Indicators of TOD Indexes and Urban Vibrancy

3. Results

3.1 node-place-design model for Guangzhou and Shenzhen

Based on the diagram proposed by Bertolini, this work uses hierarchical clustering method to classify the station areas in Guangzhou and Shenzhen under a node-place-design framework. Scaling of indicators and PCA are also adopted to enhance the reliability of clustering analysis.

To directly compare the overall performance, the score is calculated by the ratio of stations with different grade levels (high=3, moderate=2, low=1) in node, place and design dimension. E.g., a station with high grads in node, place and design is assigned with score 9. The results shows that Shenzhen is 20% better in TOD performance (the sum score). However, the basic overall performance didn't gain insights into where the discrepancies between the two cities.

Therefore, the clusters are examined based on the diagram of node-place, as shown in Fig. 2 (a) and Fig. 2 (b). Both cities have a clear "dependency" group (A3, B3), which is low on three dimensions compared to other groups, and a "stressed" group dominating on every dimension (A2, B1). The weaker groups in the two cities all have lower average values in place dimension rather than node and design dimensions, despite there are greater gaps between the better ones and the weaker ones for Guangzhou (A2 compared to A3). In addition, the stations of Shenzhen are more compact than Guangzhou in sub-dimensions scatter plot, indicating that the stations within the same group in Guangzhou have more variations than Shenzhen.

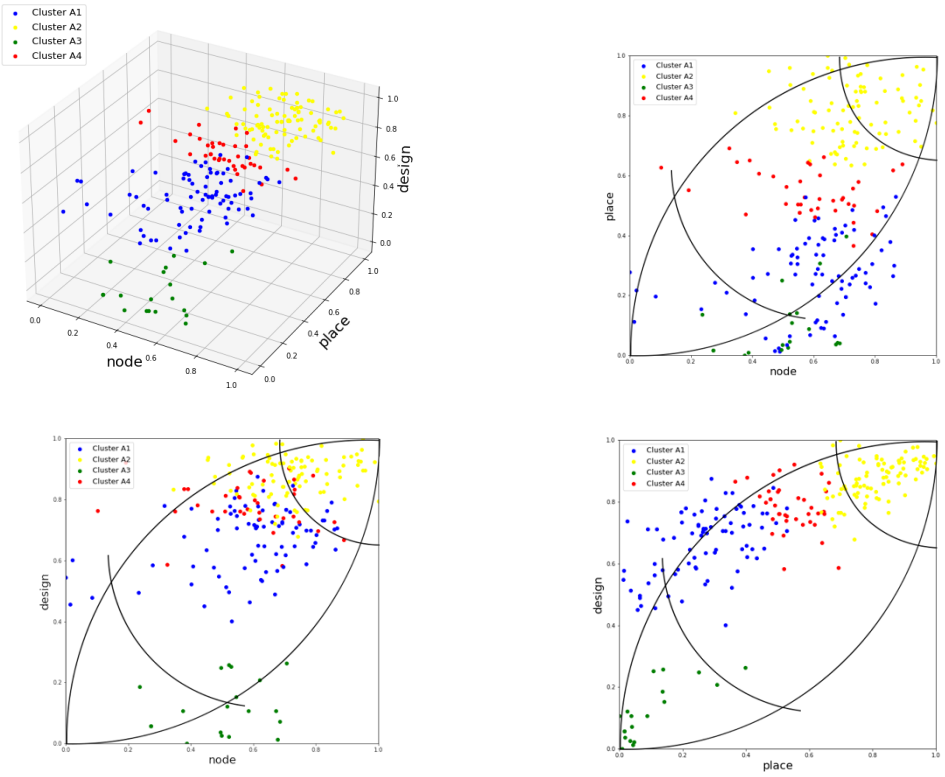

Fig. 2 (a) The Clusters of Stations in Guangzhou in Node-Place-Design Diagram

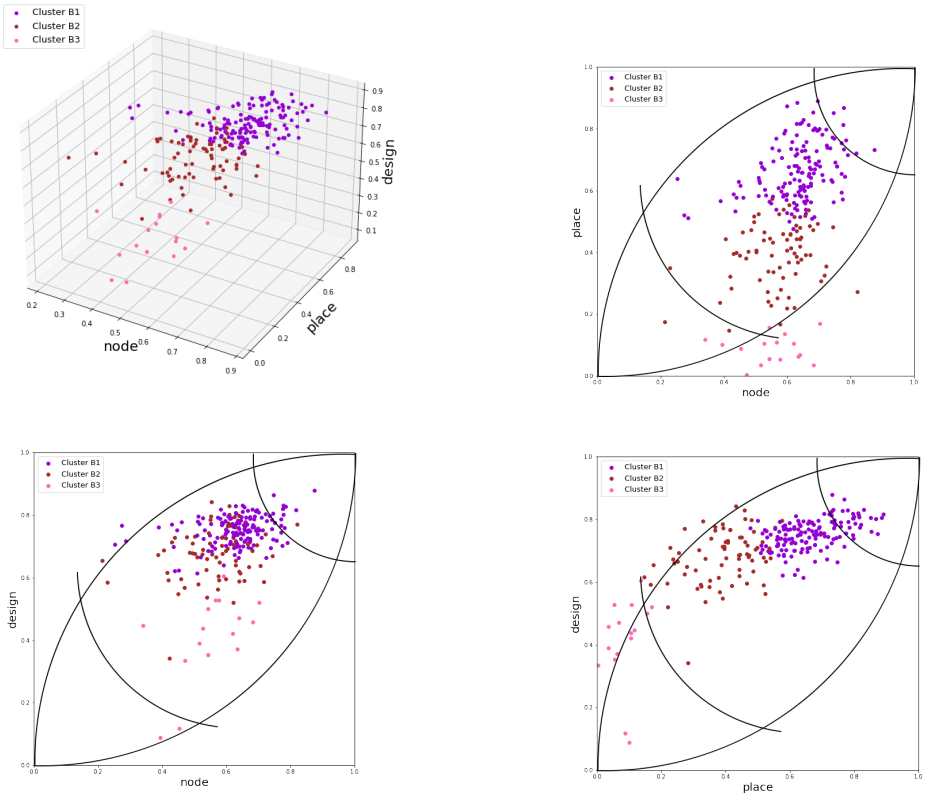

Fig. 2 (b) The Clusters of Stations in Shenzhen in Node-Place-Design Diagram

3.2 node-place-design and urban vibrancy

The urban vibrancy provides us a lens to gain deeper insights into the discrepancies of groups classified by node-place-design model the variations of station within the same group. As shown in Fig. 3 (a) and Fig. 4 (b) , two cites exhibit differently in terms of TOD and urban vibrancy in cluster level and station level.

First, the urban vibrancy exhibits in different structure for Guangzhou and Shenzhen: Guangzhou exhibits a core-periphery structure, while Shenzhen exhibits a polycentric pattern. However, they all follow a same degressive logic from central areas to outskirt of the city.

In addition, combing the cluster results of TOD indexes and urban vibrancy, great correlation c seen in both cities. The station with higher urban vibrancy level is mostly grouped in the best performed TOD clusters of stations. However, Guangzhou showed greater variations within the same group, e.g., in cluster A1, certain stations in cluster A1 with high urban vibrancy level are located at the outskirt of the city. This may suggest theses stations are critical in the outer regions of the city.

3. Discussions

The findings from this work provides policy implications from different scale and perspective. First, the strategic planning for different cities should be made according to the discrepancies between the groups of stations. As strategic planning is vital for a city's long-term prosperity and benefits, it should schedule the priority of development and investments. Groups like cluster A3 in Guangzhou apparently need to be more focus as it is depending on government's support to keep running, how to build a positive feedback of transportation and land-use in a form of compactness design should be given priority than keeping investing in the superior group like cluster A2. e. Furthermore, policymakers should consider the TOD evaluation of stations areas from both local and regional level, by applying regional concept as a strategic dimension in TOD planning. By doing so, it serves as an analytical to identify specific stations that are worth noticing. For example, stations have high urban vibrancy and node value indicating its importance in urban structure, while it is located at the periphery areas of the city. The disruption of these stations' function such as due to delay may cause more sever negative impacts on people who living in these areas. Finally, this work contributes to a more targeted, customized and precise procedure of planning in TOD of metro station areas.

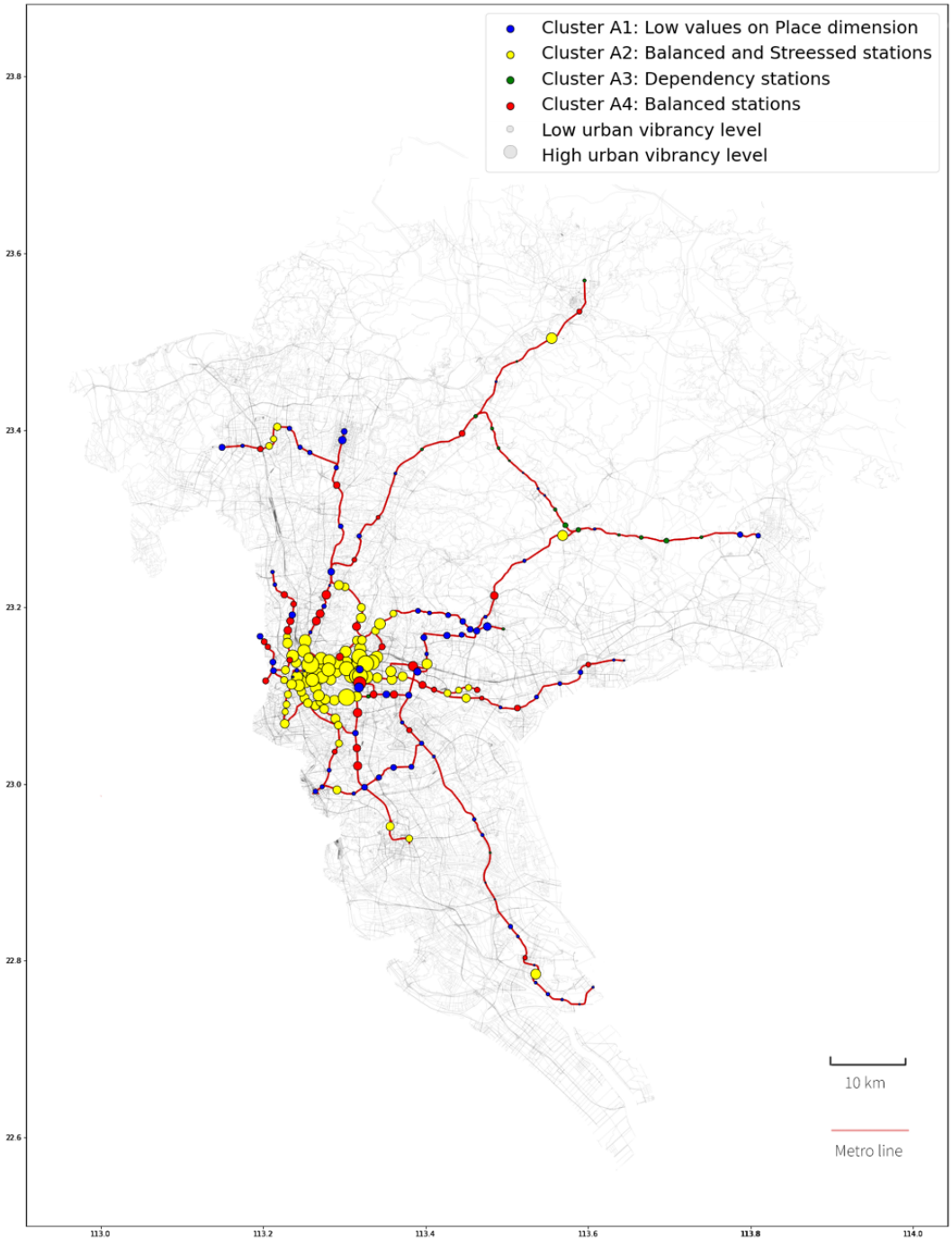

Fig. 3 (a) Spatial Typology of Guanzhou's Stations in TOD and Urban Vibrancy

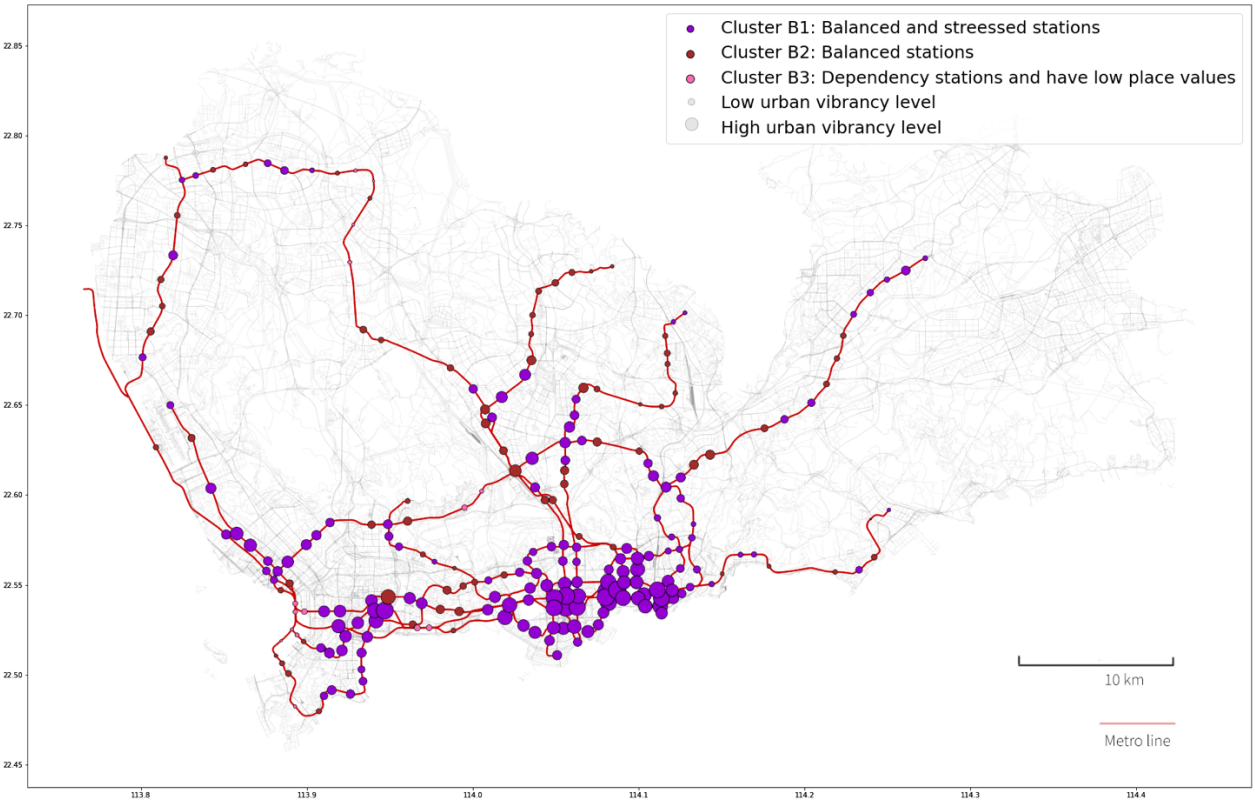

Fig. 4 (b) Spatial Typology of Shenzhen's Stations in TOD and Urban Vibrancy

Acknowledgments

The indicators are sources by open data and calculated by author

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