A Novel Regionalisation Algorithm for Redrawing Cities' Functional Boundary within Mega-city Region

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1. Introduction

The majority of commonly used transport and urban models assumes that flows of people follow a spatial distribution with a distance decay from urban centres to the periphery (Anderson, 2011, Batty and Milton, 2021). Moreover, spatial heterogeneity exists across cities in this distribution due to zoning system, administrative boundaries, transport linkage, jobs and housing balance, and other complicated urban contexts. Because of the limitation of the data and computation, most of the previous studies on flow and urban structures investigated one city only (Zhong et al., 2014). Since the conception of the mega-city regions and the related research topics is getting more important in recent years, some research looked into megacity regions, adding insights into the relationships between cities predominantly using network analysis and emerging mobility data (Zhang et al., 2020). However, the traditional network analysis and most community detection algorithms usually only consider the absolute value of flow volume for dividing the partitions regardless of the spatial factors like travel distance/cost. When detecting the functional boundary between cities, the current methods focus on the strength of local linkages between particular zones but overlook the reasonability for distributing trips in a global sight. Considering the inter-city flow is usually tiny (10% or less) in overall flows, which may fail to support planners and policymakers appropriately. This paper proposed a novel regionalisation algorithm that re-assigned zones' belonging of cities by searching for the best partition with the best goodness of fitting in the modular spatial interaction model (MSIM). This algorithm is not only more sensitive for cross-boundary trips, and this algorithm can reflect the dynamic change of cities' functional boundaries by fitting cross-boundary trips into global trip distribution, providing support for governments and planners to understand the spatial structure in mega city-region.

2. Data and methods

This research takes the cell phone data in a typical metropolitan region (Shenzhen-Dongguan-Huizhou) in China provided by China Unicom. The data contains Origin sub-district ID, Destination sub-district ID, the volume of travel flow and travel time. It detected 8921 flows with 13,588,846 commuters in the SDH area, including both intra-city and inter-city, figure 1 below shows the Distribution of inter-city flows within the SDH area.

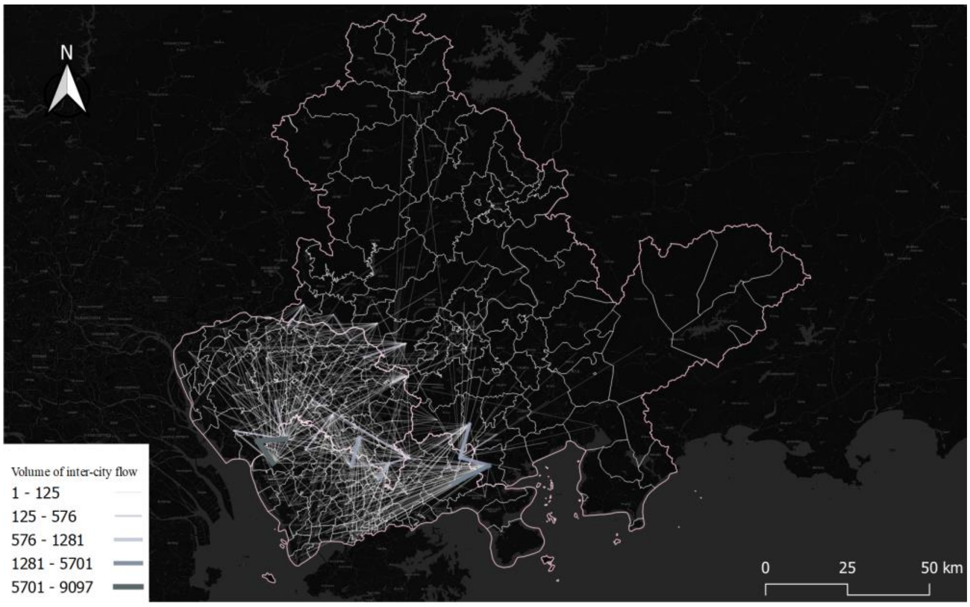

Figure 1 Distribution of inter-city flows within the SDH area

A set of spatial interaction models has been established based on 172 administrative sub-district zones based on the framework of the QUANT model (Batty and Milton, 2021), which is a single constrained gravity model assuming the distribution of trips roughly follows the format of the negative-power function. We found that constrained the administrative boundaries, modifying the spatial interaction model (SIM) by dividing one regional-size 'global model' into several city-level sub-SIM models can significantly improve the goodness of fitting of travel flows by summing of the sub-SIMs. This method is called modular spatial interaction model (MISM). This finding suggests that the travel behaviours of people who belong to the same functional city may yield better performance in fitting the specific distribution of trips. In other words, the goodness of fitting by MISM would be an indicator for assessing the reasonability of functional boundaries of cities. Based on this idea, in contrast to existing administrative city divisions, we draw the boundaries of functional cities by fitting the specific spatial distributions with real human movement flows. Specifically, this algorithm attempts to re-assign the 10% of zones with the highest ratio of inter-city flow and predict the flows by MISM, selecting one re-assigned zone by comparing the fitting results of flows. Then this algorithm adopted the framework of the greedy algorithm, updating boundary with selected zones and repeating the iterating processing above until finding the global best partition with the best goodness of fitting.

We set two scenarios for the case study area: the first scenario is the inter-city flows for each zone is static according to the current administrative boundary during the iteration. This scenario is set based on the situation that current cities' core functional zones can only spill over to zones close to the administrative boundary due to the local authority's current land-use planning and management scope. Moreover, the second scenario is the inter-city flows for each zone is dynamically updating according to the current boundary in iteration processing. It means the changed zones will further influence other unchanged zones as original inner-city flow could become inter-city flow. In this scenario, the cities' core functional zones can spill over freely without the restriction by the current administrative boundary, forecasting the potential functional boundary in the long term.

3. Results and discussion

Figure 2 shows the result of scenario 1 (statistic inter-city flow), indicating the current functional boundary within the SDH area. The functional core of Dongguan city is in the west of its administrative boundary because of its good transport connection with Shenzhen and Guangzhou. Therefore, the only zone in Dongguan that should be re-assigned to Shenzhen is Fenggang, as it has been known as the 'sleep city' for workers in Shenzhen. Moreover, few zones near the Dongguan-Huizhou boundary will be re-allocated to Huizhou from Dongguan because these zones are away from the city centre.

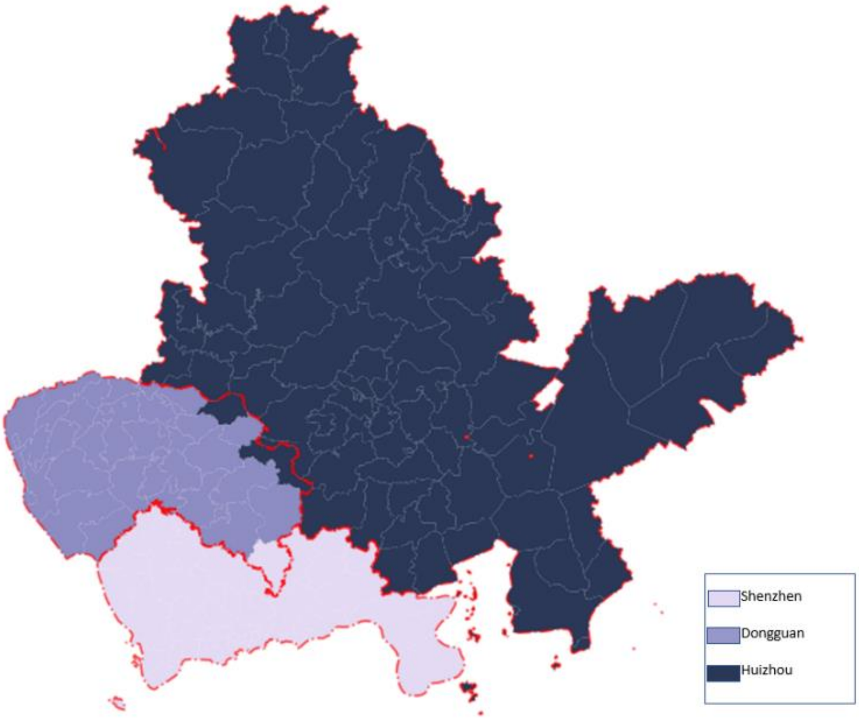

Figure 2 Current functional boundary within SDH area

As for the dynamic inter-city flow scenario, the result (shown in figure 3 below) suggests that the two cities' functional areas will 'invade' the original administrative boundaries starting from the administrative boundaries of Huizhou and Dongguan, respectively.

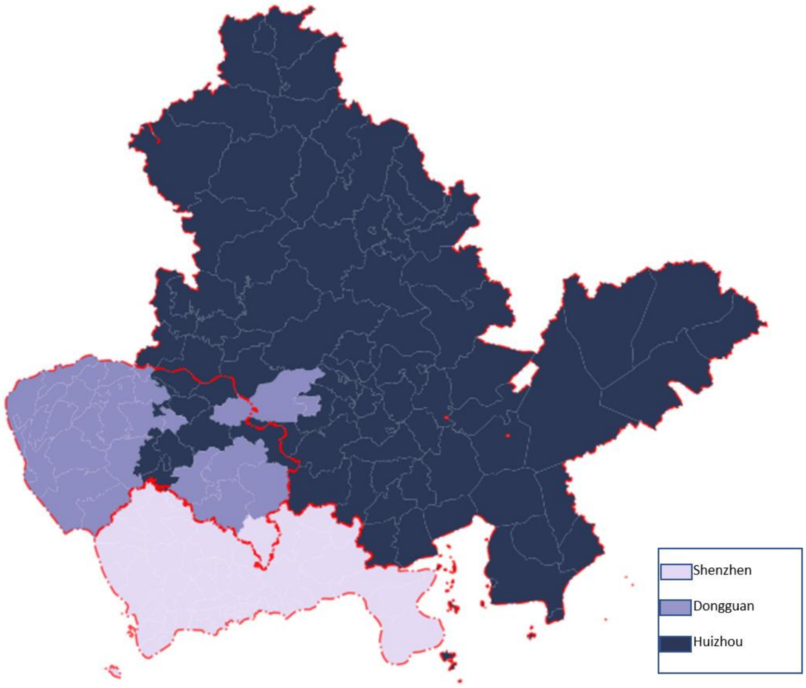

Figure 3 Predicted functional boundary within SDH area in long-term

The re-assigned zones in Dongguan are mainly from the 'East industrial park'. Historically, these zones are the cluster of manufactory industries but lack commuting connection with the city centre. Therefore, when few zones near Dongguan-Huizhou boundaries are re-assigned to Huizhou, these zones will change their belonging following the zones near the boundary. As a result, more functional areas are potentially staggered between Dongguan and Huizhou, which also means there will be more interaction between Dongguan and Huizhou city in the future.

4. Conclusion

Figure 2 shows the result Previous research on spatial interaction models about zoning systems and the modifiable areal unit problem mainly focuses on how spatial resolution affects the SIM. This research answers how different partitions of zones in the same spatial scale could significantly influence the SIM and its meaning in urban studies for redrawing the functional boundary. These empirical-based results can help the governments and planners understand the spatial structure in mega city-region and support their urban integration policy.

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References

ANDERSON, J. E. 2011. The Gravity Model. *Annual Review of Economics,* 3**,** 133-160.

BATTY, M. & MILTON, R. 2021. A new framework for very large-scale urban modelling. *Urban Studies***,** 0042098020982252.

ZHANG, W., FANG, C., ZHOU, L. & ZHU, J. 2020. Measuring megaregional structure in the Pearl River Delta by mobile phone signaling data: A complex network approach. *Cities,* 104**,** 102809.

ZHONG, C., ARISONA, S. M., HUANG, X., BATTY, M. & SCHMITT, G. 2014. Detecting the dynamics of urban structure through spatial network analysis. *International Journal of Geographical Information Science,* 28**,** 2178-2199.