

# Evolving accessibility landscapes: mutations of public transportation networks in China

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## Abstract

Recent years have witnessed an exceptional extension of public transportation networks in People's Republic of China, both at a national scale with the construction of the first HSR railway network of the world, and at local scales with numerous cities developing high coverage subway networks often from scratch. This chapter studies these mutations, both from a quantitative perspective with the study of the evolution of population accessibility landscapes, at a national level and for several cities, and from a qualitative perspective with fieldwork observations. We confirm that rebalancing planning objectives are well achieved in terms of accessibility at both scales, when all planned lines will be achieved but already in a significant manner. We finally hypothesize possible paths for the coupled network-territory systems, given the extent without precedent of such mutations.

**Keywords :** *Transportation networks; Accessibility; HSR; Urban Transit; Pearl River Delta*

## 1 Introduction

Cities and their future form of large urban metropolitan regions are a well-known gordian knot of the sustainable transitions, as they concentrate many apparent paradoxes of concurrent positive and negative externalities, but also more intrinsically as they are the incubator of social change and innovation (Pumain et al., 2009) implying a complex role of their physical structure in processes of decoupling growth with environmental and social negative impacts (Bergeaud et al., 2018). A crucial aspect of the structure of these territorial systems are transportation networks, as activities and flows strongly depend on these at multiple scales (Raimbault, 2018). For example, the development of efficient public transportation systems is crucial to reduce car use, decrease local pollution and global emissions, and enhance geographical equity (Sinha, 2003). Accessibility, in its broader sense including effective but also potential access to different amenities (Bavoux et al., 2005), is a way to quantify the potential impacts of a transportation network on a territory. The evolution of accessibility landscapes following an evolution of a transportation network is thus a relevant entry into these issues.

China, which is concerned by severe air pollution issues and is a significant contributor to global emissions, has in the last decades initiated profound infrastructural changes to develop inter-city rail transport and urban rail transit, expected to have a significant impact for greenhouse gases emission mitigation (Han and Hayashi, 2008), although much remains to be done in terms of total efficiency of the transportation system (Chang et al., 2013).

Jiao et al. (2014) show the role of the HSR network in the national accessibility, with a remarkable uniformization of accessibility values for a large majority of the population.

Hou and Li (2011)

Lyu et al. (2016)

## 2 Evolution of accessibility landscapes

### 2.1 Data and methods

### 2.2 Road accessibility in Pearl River Delta

The notion of megalopolis has been introduced by Gottmann (1961) to designate the emergence of urban agglomerates at a scale that did not exist before. It is at the origin of the concept of *Mega-city Region* (MCR) which was consecrated by Hall and Pain (2006). For the European case, they unveil assemblies of metropolis that are strongly connected regarding mobility flows, connections between companies, which form what they call polycentric *Mega-city Regions* (for example Randstad in Netherlands, the Rhine-Rhur region in Germany). Their characteristics are a certain geographical proximity of centers, a strong integration through flows, and a certain level of polycentrism. It consists in an urban form that did not exist before, which emergence seems linked to globalization processes.

This concept is even more relevant with the recent emergence of new types of urbanization, in particular through the accelerated urbanization in countries with a strong economic growth and undergoing a very rapid mutation such as China Swerts and Denis (2015).

The second case that we develop here enters this category: Pearl River Delta (PRD) is one of the classical illustrations of the structure of a strongly polycentric MCR. Historically initially only composed by Guangzhou, the development of Hong-Kong and the establishment of Special Economic Zones (SEZ) in the context of opening policies by DENG XIAOPING, lead to an extremely rapid development of Shenzhen, and in a less proportion of Zhuhai<sup>1</sup>. Guangdong province in which PRD is fully located has currently the highest regional GDP within China, and the MCR contains a population of around 60 millions (estimations strongly fluctuate depending on the definition of the MCR which is taken, and the inclusion of the floating population). The phenomenon of migrations from rural areas is highly present in the region and a city such as Dongguan has for example based its economy on factories employing these migrant workers.

Ye (2014) analyzes the actions of metropolitan governance at the scale of centers of the MCR, and more particularly how municipalities of Guangzhou and Foshan have progressively increased their cooperation to form an integrated metropolitan area, what can thus strongly influence the development of transportation for example and allowing the construction of a connected network. A strong tension between bottom-up processes, and a state control which is relatively strong in China, which originates from the Central State, to the province government and local government, has allowed the emergence of such a structure. The competition with other cities in the MCR remains strong, and the logic of integration (in the sense of articulation between the different centers, of interactions and of flows between these) of the MCR is only partly guided by the region. The particular nature of SEZ of Shenzhen and Zhuhai, linked to the privileged relations with the Special Administrative Zones of Hong-Kong and Macao, which have returned to the Popular Republic only at the end of the last millenium and keep a certain level of independence in terms of governance, complicates even more the relations between actors within the region. The issue of a correspondence between some levels of governance and urban processes is a tricky one: Liao and Gaudin (2017) interprets the progressive transfers of economic initiatives from the central power to local authorities as a form of a multi-level governance.

In the frame of transportation within the MCR, there is no specific authority at this scale for the organization of transportation (but indeed entities at the level of the State, of the province and of municipalities), and each municipality manages independently the local network, whereas the connections between cities are ensured by the national train network. This leads to particular situations in which some areas have a very low accessibility, with a very strong heterogeneity locally. Therefore, the southern part of the city of Guangzhou which constitutes a direct access to the sea, is geographically closer to the center of Zhongshan, but a direct link by public transport is difficult to imagine, whereas the area is well linked

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<sup>1</sup>Shenzhen and Zhuhai were among the first Special Economic Zones, created in 1979 to attract foreign investments in these areas with flexible economic rules. The development model of Zhuhai was different of Shenzhen, since heavy industry was forbidden.

Table 1: **Public transportation in Pearl River Delta.** We give populations in 2010 taken from Guangdong Province (2013). Network lengths are taken from the different planning documents for the Guangzhou metro Guangzhou Metro (2016), the Shenzhen metro Shenzhen Planning Bureau (2016) and the Dongguan metro Dongguan Metro (2017), and for the Zhuhai tramway Zhuhai Tramway (2016). Zhongshan is not included since it exploits a BRT system but no heavy infrastructure.

City	Population	Network 2016	Network 2030
Guangzhou - Foshan	18.9 Mio	390km	800km
Shenzhen	10.4Mio	286km	1124km
Dongguan	8.2Mio	38km	195km
Zhuhai (Tramway)	1.6Mio	10km	173km

to the center of Guangzhou by the metro line. A similar situation can be observed at the terminus of line 11 in Shenzhen, for the neighbor district of Dongguan, the latest having a very low accessibility by public transport<sup>2</sup>. This situation could however be transitory, given the infrastructures already being built and the ones planned on a longer term: the Shenzhen metro, which covers today 285km, is planned to reach 30 lines and a length of around 1100km<sup>3</sup> in 2030 as declared by the official plan of the city Shenzhen Planning Bureau (2016). It is clear that these developments mostly follow an existing urban development, a crucial issue is the voluntarism and the capacity to contain urban sprawl and to structure future developments around this new network, in the spirit of a voluntary integration between urbanism and transportation of the type *Transit Oriented Development* that we introduced before. Different final stations will be connected to the Dongguan metro, and new intercity lines will structure the longer range mobility, what will make the Delta a relatively well integrated in terms of public transport in a close temporal horizon. To have an idea of the development of the network in the coming years, the Table 1 gives the size of the planed networks in the different cities for 2030.

### 2.2.1 Impact of the Zhuhai-Hong-Kong-Macao bridge

A major transportation infrastructure project in the region is the bridge-tunnel closing the mouth of the Delta, linking Zhuhai and Macao to Hong-Kong (HZMB). The length of the crossing is 36.5km, what makes it an exceptional infrastructure Hussain et al. (2011). The opening to traffic was delayed of several years and is finally planned for 2018<sup>4</sup>. Zhou (2016) shows that the expected changes in accessibility patterns for the West of the Delta are relatively strong, and these can potentially induce strong bifurcations in the trajectories of cities. The necessity of the project is advocated by the different stakeholders of the project (Guangdong province, Hong-Kong Special Administrative Region, Macao Special Administrative Region) using an argumentation of a strong economic benefit in the frame of opening policies, and also through a social benefit for the West in particular. For example, Zhuhai is positioned as a new pivot between Hong-Kong and the West. The balancing of accessibility, in the sense of a diminution of spatial accessibility inequalities, operates however only for the private car transportation mode, what conducts to question its potential impacts: on the one hand the access to automotive remains reserved to a part of the population only, on the other hand the negative impacts of congestion can rapidly moderate the accessibility gains. These accessibility gains are mapped following the same method as previously, and shown with accessibility  $Z_i$  itself in Fig. 1.

<sup>2</sup>See the map 1 for locations, the map giving also the accessibility with the road network.

<sup>3</sup>For comparison, the Transilien network have a length around 1300km with RER lines included, what could make them comparable, but one must keep in mind that Ile-de-France has a surface of 12000km<sup>2</sup> against 2000km<sup>2</sup> for Shenzhen. This implies for Shenzhen a much higher transport density, corresponding to high urban density areas, such that the plan anticipates 70% of commuting by metro at the horizon 2030.

<sup>4</sup>See the official website at <http://www.hzmb.org/cn/default.asp>.

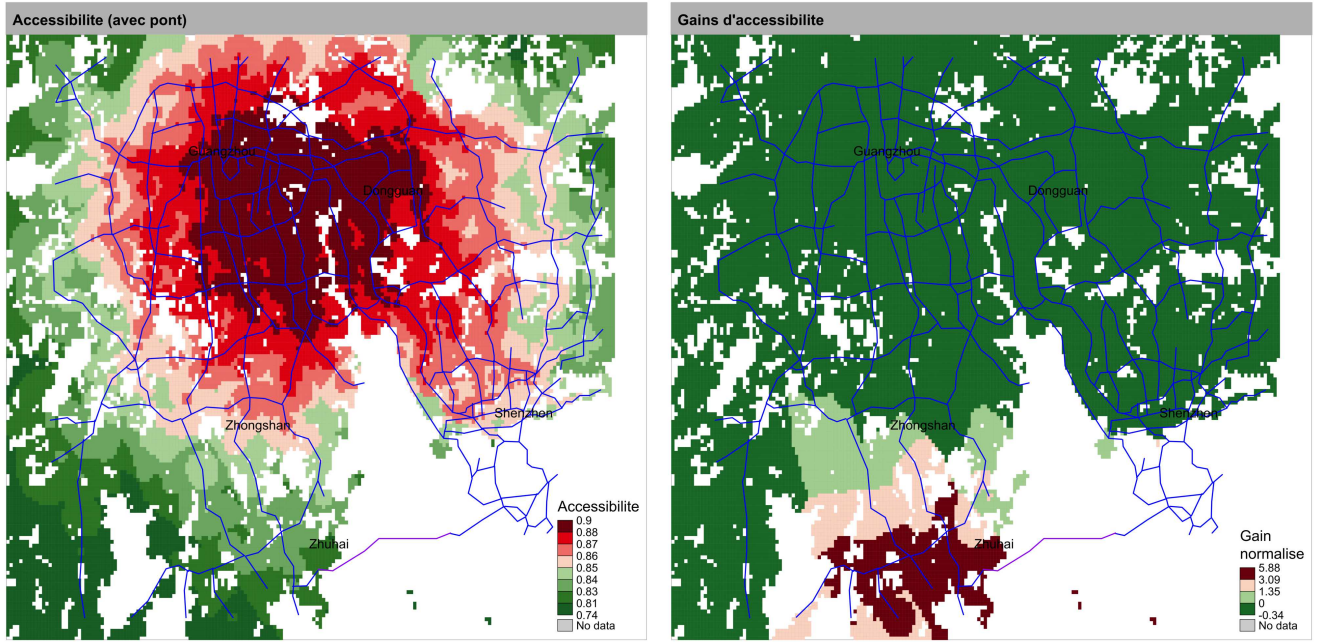


Figure 1: **Accessibility gain induced by the HZMB in Pearl River Delta, for the territory of mainland China.** (*Left*) Accessibility to population  $Z_i$ ; (*Right*) Normalized accessibility gains. The population of Hong-Kong is taken into account in destination points. The highway network (2017) is mapped in blue and the new link of the bridge in purple.

The medium and long term impacts of the bridge are difficult to estimate. Wu et al. (2012) finds patterns similar to the ones we estimate, i.e. a significant benefit for Zhuhai (and Hong-Kong that we did not take into account), and also immediate effects of traffic modification and economic impacts due to the toll or the increase of tourism. They mostly postulate the position of Zhuhai-Macao as a new pivot in the region. Even if it can be directly verified in terms of centrality and accessibility, it is not evident that this new position will influence particularly the socio-economic trajectory of Zhuhai. An increased particular political accompaniment implying an increased collaboration between Hong-Kong, Zhuhai and Macao will be important Zhou (2016). Immediate economic effects are expected, as an increase of Zhuhai residents working in Hong-Kong (Zhuhai inhabitants are the only ones in the region to benefit of a special card allowing them to regularly visit the Special Administrative Areas<sup>5</sup>), but cases showing the contrary, such as investments from Hong-Kong towards the West of the Delta, have no reason to be systematic: the first case extends the already existing dynamic with Macao, the second is mostly to be constructed. Thus, this example is a typical case of our general problematic.

### 2.3 Public transportation accessibility in main cities

## 3 Qualitative fieldwork observations

This section proposes to illustrate the issue of interactions between transportation networks and territories, and more particularly their complexity and the diversity of possible situations already perceptible in a qualitative way (and also subjective in a second time) at the microscopic scale, through concrete fieldwork examples. The geographical subject is Pearl River Delta, in Guangdong province, that we already described before, and more particularly mostly the city of Zhuhai. The objective is to enrich our repertory with concrete situations, to understand if these can be associated to the generic processes we have already

<sup>5</sup>Source: fieldwork on 06/11/2016 with C. Losavio.

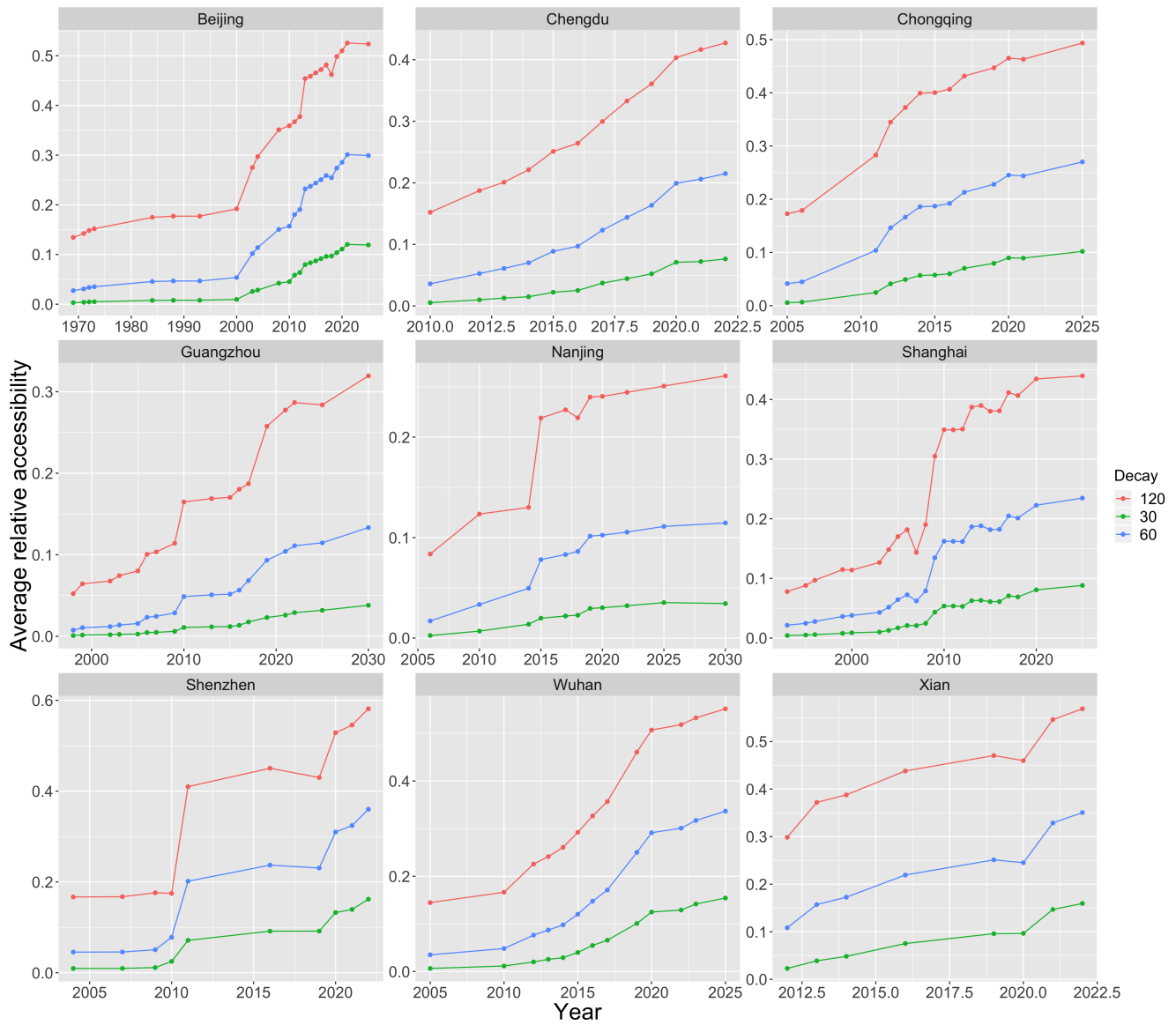


Figure 2: Evolution of the average urban rail transit accessibility for main Chinese cities.

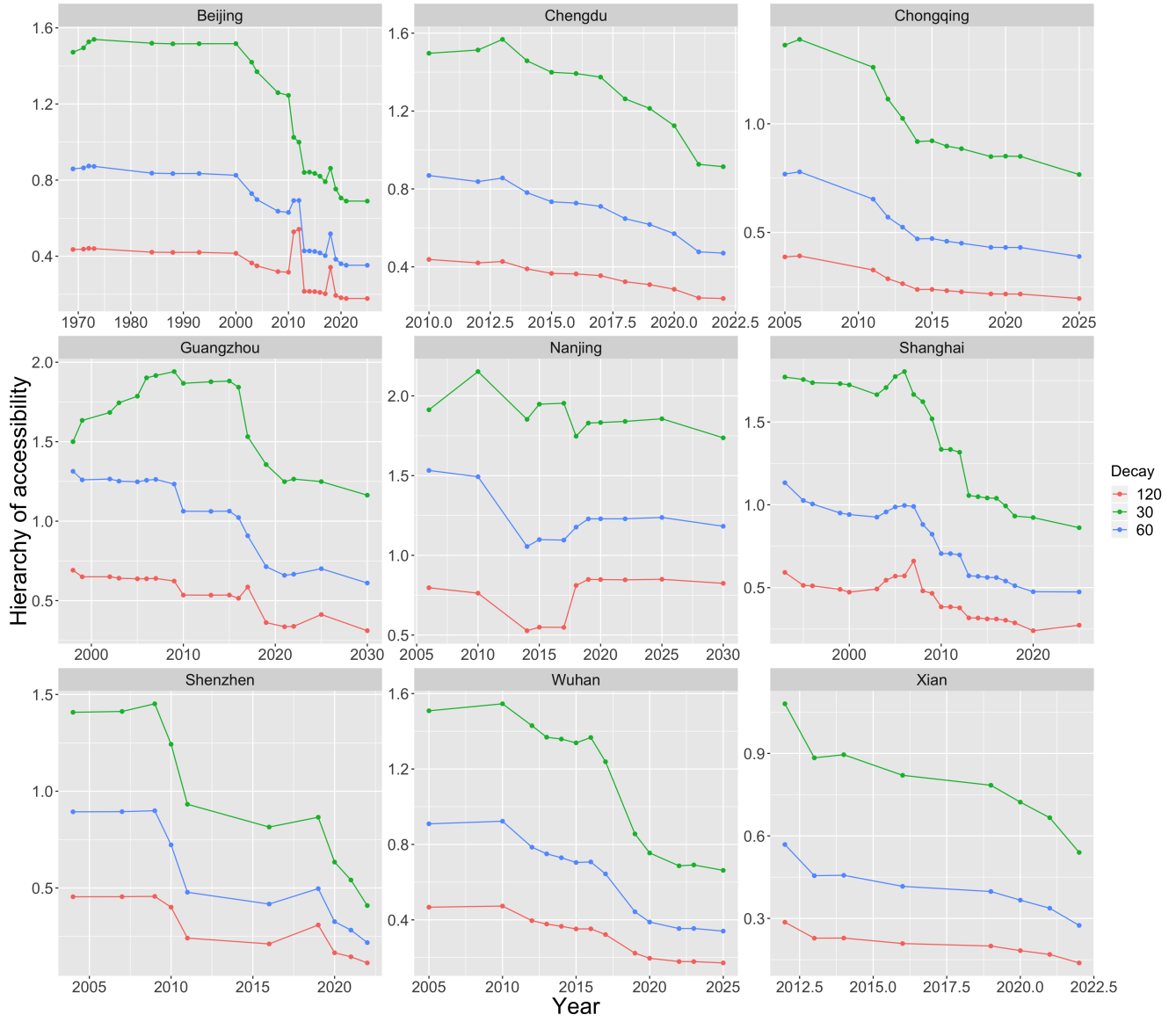


Figure 3: Evolution of the hierarchy of urban rail transit accessibility for main Chinese cities.

exhibited, or if others can be observed at the scales of observation.

We assume the term of *Geographical Fieldwork*, with all knowledge of epistemological debates its use can raise. Indeed, we extract observations from places that were experimented, in the context of a given problematic Retraillé (2010). Our approach will also highlight the role of representations, underlined as a type of fieldwork in itself by Lefort (2012), when we will give a subjective view.

In the frame of the European project Medium which establishes a partnership between European and Chinese universities. The project is entitled “*New pathways for sustainable urban development in China’s medium-sized cities*”. It aims at studying sustainability through an interdisciplinary and multidimensional viewpoint, in the case of rapidly growing urban areas, by concentrating on Chinese medium-sized cities. Three medium-sized Chinese cities were chosen as a case study. The definition of medium-sized cities considered for the project is broader than the official statistical definition of the Chinese government, and covers cities from 1 to 10 millions of inhabitants. More information is available on the website of the project at <http://mediumcities-china.org/>. In this context, Zhuhai was chosen as a case study. When the source is not explicitly given, observations come from fieldwork, for which detailed narrative reports and photographs are available on the open repository of this work at <https://github.com/JusteRaimbault/CityNetwork/tree/master/Data/Fieldwork>.

The format of narrative reports is “on-the-fly” following the recommendations of Goffman (1989) for taking notes in an immersive fieldwork in particular, whereas the voluntary subjective position rejoins Ball (1990) which recalls the importance of reflexivity in order to draw rigorous conclusions from qualitative fieldwork observations of which the researcher is a part in itself. The consideration of the researcher as a *subject* in relation with its object of study does not imply in our case a feedback of the researcher on the system because of its size in the case of a transportation network at the scale of the city, and indeed a conditioning of observations by a subjectivity of which we must detach in the posterior exploitation of the observation material, but which ignoring can only increase the biases.

### 3.1 Development of a transportation network

The objective of fieldwork is thus to observe the multiple facets and layers of a complex public transport system which is always transforming, its links with observable urban operations, and to what extent these witness of interaction processes between networks and territories. The spatial extent of observations spans on Zhuhai as an illustration of local transportation but also punctually on other regions in China. These observations have their proper logic in comparison to the modeling of transportation networks or data analysis, such as accessibility studies or interaction models between land-use and transportation, that will be done in the following. Indeed, these fail generally in capturing aspects at a large scale, which are often directly linked to the user, and which can become crucial regarding the effective use of the network. For example, multi-modality is profoundly transformed by the use of the network. Multi-modality consists in the combination of different transportation modes: road, train, metropolitan, tramway, bus, peaceful modes, etc., in a mobility pattern. A multimodal transportation system consists in the superposition of modal layers, and these can be more or less well articulated for the production of optimal routes following multiple objectives (cost, time, generalized cost, comfort, etc.) which themselves depend on the user, and of the mobility pattern. It can in practice made efficient through the emergence of self-organized informal transportation modes, or the establishment of new modes such as bike-sharing, what solves the “last-mile problem” (Liu et al., 2012), which seems to be often neglected in the planning of newly developed areas in China. On the contrary, practical details such as tickets reservation or check-in delays at boarding can considerably influence use patterns.

Several trips on the Chinese territory were made to observe the concrete manifestations of the high speed network development. Since 2008, China has established the larger HSR network in the world from scratch, which has a great success and which lines are currently saturated. It answers primary demand patterns in terms of city size, showing that it was planned such that the network answers to territorial dynamics. Its high usage shows the impact of network on mobility, what is a possible precursor of territorial

mutations.

To show to what extent territories can influence the development of network in diverse ways, we can take a particular example, linked to the development of tourism, which corresponds to a particular dimension taken into account in planning. Thus, the line between Guangzhou and Guiyang (North-West axis which is precursor of the future direct link Guangzhou-Chengdu) have witnessed the opening of stations specifically for the development of tourism, such as Yangshuo in Guangxi, which number of visits has then strongly increased. One year after the opening of the station, the main road link with the city is still under construction, showing that the different networks react differently to constraints at different levels. A higher number of trains stops on week-ends - more than one each hour, are are full more than two weeks in advance. New mobility patterns can be induced by this new offer, as illustrate the interview of an inhabitant of Guangzhou done in Yangshuo, which came for a short week-end with her colleagues, in the context of a “team-building” trip financed by her startup in information technology. These new mobility practices are shown in a second interview of an inhabitant of Beijing met at Emeishan, sent by her company in Industrial Design for a short stay in Chengdu for a training in a local subsidiary. The company prefers the high speed train, and it recently increased the mobility practices for its employees.

A similar strategy can be observed concerning the connection of touristic destinations for the line Chengdu-Emeishan. The principal objective of this line is for now to serve the highly frequented touristic destinations of Emeishan and Leshan. However, the missing link between Leshan and Guiyang is already well advanced in its construction and will complete the direct link between Guangzhou and Chengdu. This reveals diachronic and complementary dynamics of network development following properties of territories. This line is a part of the structuring skeleton of the “8+8” recently reformulated by the central government, which corresponds to the general plan for future high speed lines, recently actualized to include 8 North-South parallels and 8 East-West others, completing the 4+4 already realized. The traversed territories expect a lot from it as show LU et al. (2012) for the city of Yibin halfway between Chengdu and Guiyang.

We also observe join mutations of the railway network and of the city. We illustrate thus in Fig. 4 the insertion of the HSR in its territories. Direct effects of the network are linked to the development of totally new districts in the neighborhood of new stations, sometimes in an approach of type “*Transit Oriented Development*” (TOD)<sup>6</sup> - we will come back to it with more details. Furthermore, more subtle indirect effects are suggested by clues such as the promotion of operations through advertisement. It shows the socio-economic expectations regarding the network and the local agents which have to contribute to its success: advertisements claiming the merits of high speed, and the selling of appartements in the associated real estate operations. This dynamic seems to contribute to the construction of a “middle class” and of the role it has to play in the dynamism of territories Rocca (2008)<sup>7</sup>. The insertion of lines in territories seems in some case to be forced, as shows the Yangshuo station which exploits the tourism opportunity offered by the passage of the line in a low populated area but which is very attractive by its landscapes, or the new real estate operations in Zhuhai which are not very accessible because of their price.

Finally, it is important to remark the network development answers simultaneously to different types of territorial contexts. Branches of the new high speed network with a short range, such as the line Guangzhou-Zhuhai, can be seen as being at the intermediary between a long range service and a proximity regional transport, depending on the modularity of serving patterns. This line is thus placed within long range urban interactions (the service Zhuhai-Guiyang being for example ensured) and within interactions in the mega-city region, most of the service being trains to Guangzhou. To this can be added the classical train network which keeps a certain role in territorial interactions: some connections require the use of both networks and of urban transportation, such as the link between Zhuhai and Hong-Kong, experimented through terrestrial transportation modes only. Indeed, following the Hato Typhoon on 23/08/2017, maritime links with the center of Hong-Kong and the international airport has been inter-

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<sup>6</sup>As we defined in ??, this planning paradigm aims at articulating the development of an heavy transportation infrastructure with urbanization, typically through a densification around stations.

<sup>7</sup>Construction which is, as JEAN-LOUIS ROCCA emphasizes, as much concrete since it depends on objective realities, as imaginary in the academic and political discourse, which construct the object simultaneously to its study or use.





Figure 4: **Local manifestations of the mutations induced by the new high speed network.** (*Top Left*) High speed station of Tangjia, in Zhuhai city. The monumental advertisement for a real estate operation praises the merits of the proximity to the network, which is also used as an argument for higher prices; (*Top Right*) High speed line in Zhuhai, deserted bus stop and real estate project being realized in a difficultly accessible area: this urban fringe is in direct contact with the rural environment on the other side of the line, and eccentric from the city; (*Bottom Left*) Yangshuo station on the Guangzhou-Guiyang line, which principal function is the development of this touristic destination which bases most of its economy on that field; (*Bottom Right*) Advertisement for high speed in Sichuan, at the station of the international Chengdu airport on the line to Leshan and Emeishan. The train departs from the futurist city to fly over the countryside, recalling the tunnel effect of territories telescoped by high speed.

rupted for a significant part of the delta, and has been reopened for Zhuhai in the beginning of November 2017 only, inspiring a fieldwork trip using terrestrial public transportation.

### 3.2 Implementing TOD: contrasted illustrations

The simultaneous development of the transportation network and the urban environment can be directly observed on the field. The local urban network and real estate development operations are planned closely with the new train network: the Zhuhai tramway, for which a single line is open at the current time and still being tested, is thought to participate in a TOD approach<sup>8</sup> to urban development which aims at favoring the use of public transportation and a city with less cars, such as wanted for example by the Planning Committee of the *High-Tech Zone* in charge of the development around Zhuhai North station. The observation of the surroundings of Tangjia station, also built in the same spirit, reveals a certain atmosphere of desertion and an unpractical organisation can lead to questioning the efficacy of the approach. This also suggests a certain self-fulfilling nature of the project, as suggested by advertisements for new real estate for sale, insisting on the importance of the presence of the railway line. A full narrative encouraging local actors and individuals to be involved around TOD seems to be used by different actors of development.

Other fieldwork observations, such as in the *New Territories* in Hong-Kong, witness of an efficient TOD which fulfils its objective, with a complementarity between heavy rail and local light tramway, and also a high urban density around stations. These observations recall the complexity of urban trajectories coupled to the development of the network, and that we must remain cautious before drawing any general conclusion from particular cases. We summarize in Fig. 5 the comparison between the two TOD cases detailed above, as synthetic schemes of urban structures of each area. In Hong-Kong, urban areas have been conjointly planned with the MTR line (heavy transport) and the multiple light tramway lines Hui and Lam (2005). The infrastructure of light rail and the organisation of missions allow to rapidly connect with the closest station, distributing a highly uniform accessibility for all districts of the territory. On the contrary in Zhuhai, the village of Tangjia is old, even anterior to the rest of Zhuhai, and has developed without any particular articulation with transportation infrastructures. The location of the tramway, which just opened, completes the trajectory of the new railway line, with an objective of reorganizing the North of Zhuhai, and in particular the High-tech Zone which extends from the North railway station (Zhuhai Bei) to Tangjia. Currently, the urban organisation is strongly imprinted with this unsynchronized development, since public transportation accessibility is still relatively low, bus lines being subject to an increasing congestion due to the strong increase in the number of cars. Furthermore, the exploitation of the tramway has been difficult, since the technology used with a third rail in the ground has been imported from Europe and had never been tested in such humidity conditions<sup>9</sup>, what lead to a questioning of the network plan in its entirety.

This fieldwork example thus shows us that (i) under the same designation very different processes exist, and are extremely dependant to geographical, political and economical particularities; and that (ii) the development of a territory which is functional in terms of accessibility necessitates a fine articulation which seems to be the outcome of an integrated planning approach on the long time.

## 4 Discussion

A direction of exploration through modeling consists in considering the problem differently and to try to understand the dynamics of the metropolitan system in an integrated way, i.e. as a territorial system in our sense, in which the strong coupling between territory and network is operated through a proper ontology for governance entities. This approach was partly developed by .

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<sup>8</sup>See preliminary works of planning consulting, such as for example <https://wenku.baidu.com/view/b1526461ff00bed5b8f31d01.html> for the context of the new Xiaozhen district, in the West of Xiangzhou.

<sup>9</sup>Source: personal communication with YINGHAO LI, July 2017.

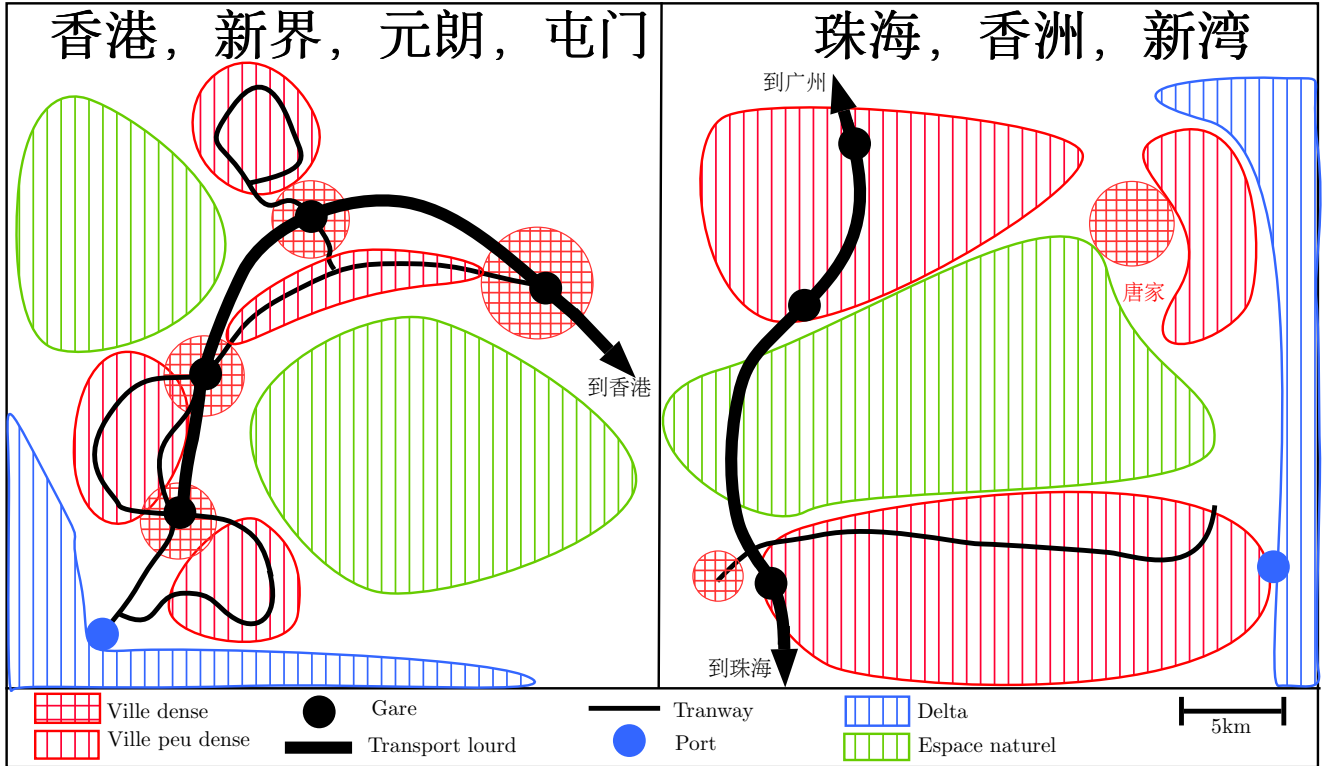


Figure 5: **Comparative analysis of two implementations of TOD in PRD.** At a comparable scale, we synthesize the urban configuration of Yuenlong and Tuenmun, Hong-Kong New Territories, on the left, and of Xinwan, Xiangzhou, Zhuhai on the right, which contains the Zhuhai High-tech zone in its Northern part in particular. The configurations illustrate different dynamics of articulation, and shifted construction temporalities, unveiling thus different realities under the notion of TOD. A first interpretation would be that it is effective if the trajectory of the full territorial system (urban development and transportation network) is modified early in its genesis, whereas a system with a higher level of maturity will have more inertia.

This second shorter study has allowed us to emphasize a fundamentally different governance structure, but the same idea of a considerable transportation project which deeply modifies accessibility patterns. The expectations of actors regarding territorial mutations potentially induced are comparable in the sense that a high expectation is put in the project.

We have studied here two cases of metropolitan development and infrastructure projects in their frame. The possibility of transfer of urban models (such as TOD), in the sense of the applicability of generic frameworks to different geographical contexts, is generally difficult. The synthesis of empirical conclusions obtained from very diverse case studies is also difficult.

The East-Asian particularity has already been shown for the economic structure, and how it can not be interpreted in a simple way by a separation of microscopic and macroscopic processes as some quick and ideologically oriented readings may have done, such as the approach of the World Bank Amsden (1994). The comparability of urban systems is an open question at the core of issues for the Evolutive Urban Theory. It is linked to the ergodic character of these systems: the ergodicity assumption postulates that the trajectory of a city in time captures the set of possible urban states, and also that different cities are different manifestations of the same stochastic process at different periods. In that case, an ensemble of cities would allow to understand their temporal trajectories. It is intuitively not the case, and urban systems would rather be non-ergodic Pumain (2012). Empirically, this non-correspondence between global statistics and individual dynamics of cities is shown for traffic data by ?. Thus we will have to remain cautious for the generalization of conclusions, as much as empirical as theoretical, or obtained through modeling.

## Conclusion

## Acknowledgements

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